Essays on Exchange Rates and Debt in International Economies

By

Pak Yeung Wu

A DISSERTATION SUBMITTED IN PARTIAL FULFILLMENT OF THE

REQUIREMENTS FOR THE DEGREE OF

DOCTOR OF PHILOSOPHY

(ECONOMICS)

at the

UNIVERSITY OF WISCONSIN – MADISON

2020

Date of final oral examination: April 16, 2020

The dissertation is approved by the following members of the Final Oral Committee:

Charles M. Engel (co-chair), Professor, Economics

Kenneth D. West (co-chair), Professor, Economics

Menzie D. Chinn, Professor, Public Affairs and Economics

Dmitry Mukhin, Assistant Professor, Economics

Abstract

This dissertation consists of three separate but interconnected essays on exchange rates and debt in international economies.

The first chapter studies sovereign debt pricing in the presence of foreign-currency (FC) denominated corporate debt. We find that foreign currency corporate external debt empirically explains sovereign credit spreads in emerging countries, even after controlling for sovereign debt and global factors. Decomposing sovereign credit spreads into their default premium (default probability) and risk premium components, we find that a 1% increase in FC corporate external debt is associated with a 5 basis point increase in the sovereign risk premium but a small and insignificant change in the sovereign default premium. We incorporate a productive corporate sector and risk-averse foreign lenders into a quantitative sovereign default model. An increase in FC corporate external debt has three effects on tax revenue, and thus sovereign spreads. It increases the mean of tax revenue due to higher investment, increases the variance of tax revenue due to higher exposure to exchange rate risk, and changes the covariance of sovereign defaults and the state of foreign lenders due to the safe currency property of FC. The first two effects counteract each other and help explain the insignificant change in the sovereign default premium, while the third effect results in a higher sovereign risk premium. Corporates do not internalize their effect on sovereign debt pricing, leaving room for policy improvement.

The second chapter studies exchange rate determination. We find strong empirical evidence that economic fundamentals can well account for nominal exchange rate movements. The important innovation is that we include the liquidity yield on government bonds as an

explanatory variable. We find impressive evidence that changes in the liquidity yield are significant in explaining exchange rate changes for all the G10 countries. Moreover, after controlling for liquidity yields, traditional determinants of exchange rates – adjustment toward purchasing power parity and monetary shocks – are also found to be economically and statistically significant. We show how these relationships arise out of a canonical two-country New Keynesian model with liquidity returns. Additionally, we find a role for sovereign default risk and currency swap market frictions.

The third chapter studies the implications of a change in debt currency denomination in emerging market corporate sector. Several emerging markets have graduated from the “original sin” and are able to borrow abroad in their local currency. This paper provides a two-country model-based evaluation of how the shift from foreign currency to local currency debt doesn’t eliminate the original sin concern, which morphs into an "original sin redux” (Carsten and Shin 2019). As long as EMs still rely on foreign intermediated funding, the currency mismatch problem merely shifts to the balance sheet of financially constrained global lenders, and exchange rate movements affect their capacity to lend. We find that a large domestic investor base can cushion the impact of external shocks, and foreign exchange intervention targeted at improving the balance sheet of the financial sector proves to be a useful addition to the policy kit of central banks.

Acknowledgements

This dissertation would never have been possible without the advice and support of my advisors, other mentors, family, and friends.

I owe a debt of gratitude to my advisors, Charles Engel and Ken West, for their mentorship. I greatly appreciate their offer of opportunities to allow me to learn from their wisdom, scholarship, and professionalism. They act like my mom and dad in research, who have given me hard times to improve myself but also encouraged me during difficult times. I am indebted to Menzie Chinn, who have followed my research continuously, and substantially sharpened my dissertation. Being around them has not only taught me loads about economics but also about the profession.

I am grateful to many faculty members with whom I've had the opportunity to interact repeatedly. Dean Corbae, Kim Ruhl, Dima Mukhin, Rishabh Kirpalani haven given me valuable comments and helped shaping my way of thinking about economics and the profession. Erwan Quintin and Ivan Shaliastovich for their helpful comments and seminar opportunities. Ken Hendricks for guidance throughout the job market. Special thanks go to Juan Carlos Hatchondo, who introduced me the sovereign debt literature and offered me his valuable time that goes beyond his duty.

I would like to thank all the course instructors, who equipped me with the fundamental knowledge and technique to write this dissertation. I thank Enghin Atalay, Kamran Bilir, Steven Durlauf, Kenichi Fukushima, Bruce Hansen, Jack Porter, Lones Smith, Bill Sandholm, Noah Williams, Randy Wright, for their excellent teaching. I also thank Chairman Ananth Seshadri, Kimberly Grocholski, Becca George, Julie Anderson, Susana Landsverk, Vicki Fugate and Molly Laboda, who put continuous effort in building a functional department.

A big part of my Ph.D. journey involves interacting with and learning from my fellow classmates. I would like to thank everyone in my cohort, and Pavel Brendler, Eirik Brandsas, Francesco Celentano, Mark Colas, Kyle Dempsey, Wontae Han, Rosemary Kaiser, Junhyong Kim, Kanit Kuevibulvanich, Ohyun Kwon, Annie Lee, Dohyeon Lee, Saiah Lee, Chenxin Liu, Phai Phongthiengtham, Mark Rempel, Sandra Spirovska, Adam Spencer, Saerang Song, Ikuo Takei, Joanna Venator, Woan Fonng Wong, Anson Zhou. Special thanks go to Zehao Li, Shoya Ishimaru, Chang Liu and Vince Su, who saved me academically and personally in different occasions. I also thank four economists from Hong Kong, Julian Chan, Ron Chan, Michael Choi and Eric Wong, who offered me help at different stages of my post-graduate study.

The dissertation benefited from comments and interaction with many researchers. For chapter 1, I appreciate useful comments from Manuel Amador, Yan Bai, Javier Bianchi, Hal Cole, David Cook, Mick Devereux, Jim Hamilton, Tim Kehoe, Guido Lorenzoni, Ken Rogoff, Ilhyock Shim, Hyun Song Shin, Giorgio Valente, Jing Cynthia Wu, Jason Wu, and Jing Zhang. For chapter 2, we thank useful comments from Luca Dedola, Harris Dellas, Pierre-Olivier Gourinchas, Dmitry Mukhin, Maury Obstfeld, Alessandro Rebucci, Andy Rose, and Hyun Song Shin. For chapter 3, we thank Ryan Banerjee, Michael Chui, Mathias Drehmann, Giovanni Lombardo, and James Yetman for useful comments.

Financial support from the Economics Department Summer Fellowship, Ko and Ying Shih Fellowship, Walker Family Fellowship are greatly acknowledged. I also thank the International Monetary Fund, Hong Kong Institute of Monetary Research and the Bank for International Settlements for the fellowship and internship opportunities to broaden my horizon in policy research. I thank my supervisors in these institutions, Rabah Arezki, Hongyi Chen, Boris Hofmann, Akito Matsumoto, Nikhil Patel and Giorgio Valente. Computational and staff support from the Center for High Throughput Computing and Social Science Computing Cooperative are greatly appreciated.

Lastly, and most importantly, I dedicate all my success to my family. The tough Ph.D. journey would not be possible without their unconditional love and support.

List of Figures

List of Tables

Contents

Chapter 1

Corporate Balance Sheets and Sovereign Risk Premia

1.1 Introduction

In recent years, there has been a dramatic surge of corporate foreign currency-denominated (FC) external debt in emerging countries.[1] According to the Bank for International Settlements (BIS) data, the size of external corporate debt in developing countries went up from 2.7 trillion USD equivalent in the first quarter of 2008 to 4.7 trillion USD equivalent in the fourth quarter of 2016. FC comprises a dominant share (over 90%) of this debt. Figure shows a time-series plot of the FC corporate external debt to GDP ratio in several emerging countries.[2] In all cases, the ratio doubled in less than 10 years since 2008. This data shows that the increasingly leveraged corporate sectors in emerging countries are still highly dollarized when they seek funding from the rest of the world.

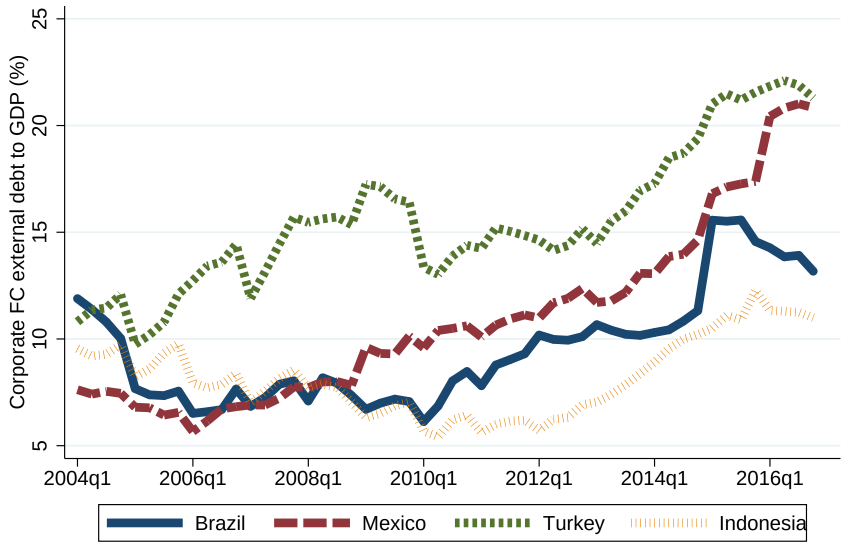
The rise of FC corporate external debt in many emerging countries raises concerns for policymakers,[3] who worry about increasing macroeconomic vulnerabilities. This paper studies

[1] Throughout the paper, corporates include both financial and non-financial corporates. External debt refers to both bonds and loans held by the rest of the world. McCauley et al. (2015), Chui et al. (2016) and Hardy and Saffie (2019) find that this surge in FC debt is mainly driven by non-financial corporates.

[2] The pattern is, in general, true for a larger set of emerging countries. We show only a few for exposition purposes.

[3] See for example, Borio (2018), Lagarde (2016), IMF Global Financial Stability Report (2015).

Figure 1.1.1: Increasing foreign currency corporate external debt to GDP in emerging countries (%)



Source: Author's calculation based on BIS statistics and Bloomberg.

the implications of foreign currency-denominated corporate external debt for emerging countries' sovereign credit spreads. Sovereign credit spreads are important for two reasons. First, it is a biometer of a country's macroeconomic conditions. Second, it is the funding cost of the sovereign. We argue that the corporates' increasing reliance on FC external debt does not necessarily increase sovereign default risk, but has a positive impact on the sovereign risk premium and therefore increases sovereign spreads. This argument consists of two main components. First, we empirically document the relationship between FC corporate external debt, sovereign default risk, and the sovereign risk premium. Second, we build a quantitative sovereign default model that features a productive corporate sector with corporate debt and risk-averse lenders to account for the empirical findings.

Our key empirical findings are that there is a positive correlation between FC corporate external debt and sovereign credit spreads, and this positive relationship is mostly driven by the risk premium but not the default premium. We decompose the sovereign credit default swaps

(CDS), a common measure of sovereign credit spreads,[4] into their default premium and risk premium components, following the affine term structure approach developed by Longstaff et al. (2011) and the credit rating approach developed by Remolona et al. (2008).[5] Figure uses Brazil as an example to visualize the empirical findings. The left panel shows a scatter plot of the 5-year USD-denominated sovereign CDS versus the FC corporate external debt to GDP in Brazil, using quarterly data from 2004Q1 to 2016Q4. The panel displays a clear positive correlation between corporate debt and Brazilian sovereign CDS. In the middle panel, we decompose the CDS spreads into their default premium and risk premium components using the credit rating approach. Interestingly, FC corporate debt to GDP is positively correlated with the sovereign risk premium and (weakly) negatively correlated with the sovereign default premium. In the right panel, we plot the decomposed sovereign CDS spreads versus FC sovereign external debt to GDP. Both components are positively correlated with FC sovereign external debt to GDP. These figures show that the relationship between sovereign credit spreads and corporate debt is not same as that of sovereign debt.

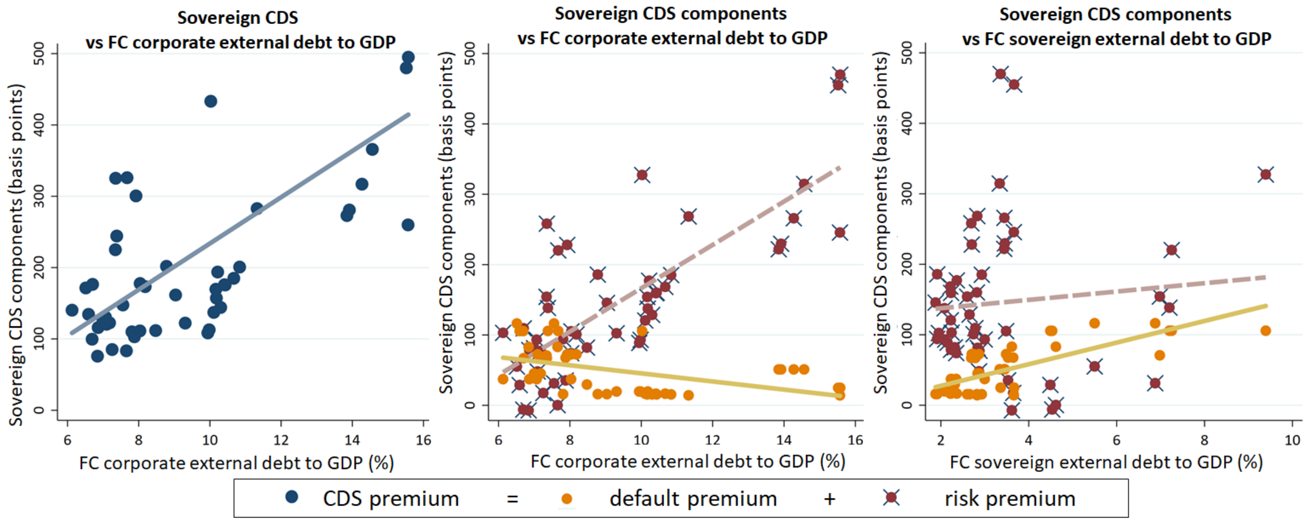
In the next section, we document these relationships of FC corporate external debt and sovereign credit spreads systematically. Using a panel regression analysis for 17 emerging economies, we find a robust pattern that a one percent increase in FC corporate external debt to GDP is significantly associated with a sizable five basis point increase in the sovereign risk premium.[6] However, a one percent increase in FC corporate external debt to GDP is not significantly associated with movements in the sovereign default premium. Contrastingly, an

[4]We use 5-year USD-denominated sovereign CDS spreads as the measure of sovereign credit spreads, which is commonly used in the literature. The cash-flow of shorting a risky coupon sovereign bond and investing in a coupon risk-free bond, generate exactly the same cashflow as buying a CDS contract. In the absence of market friction and arbitrage, the premium of a CDS should be equal to the yield difference of the two bonds. See Appendix A.1 for an illustration.

[5]The default premium component could be understood as the spread that compensates a lender in an actuarially fair sense; therefore it compensates the expected default probability. The risk premium component is the additional spread needed to compensate a risk-averse lender or a constrained investor. We discuss the methods in more detail in subsection 1.2.1 and Appendix A.2.

[6]As a reference, the average CDS spreads of the sample countries are 155 basis points.

Figure 1.1.2: Brazilian 5Y USD-denominated sovereign CDS and FC debt to GDP



increase in FC sovereign external debt to GDP is associated with a significant increase in both sovereign default premium and risk premium. These stylized facts show that FC corporate external debt explains sovereign credit spreads, and the underlying sovereign spread components explained by corporate debt are not the same as sovereign debt. We also use exogenous event date analysis to establish that the FC corporate external debt is an important determinant of sovereign spreads.

To account for these empirical findings, we introduce a productive corporate sector with dynamic corporate debt and investment decisions and risk-averse foreign lenders into the canonical small open-economy sovereign default model (Eaton and Gersovitz (1981), Aguiar and Gopinath (2006) and Arellano (2008)). Both the sovereign and corporate sectors can borrow externally from risk-averse foreign investors. The model has three key components. First, firms optimally choose investment and corporate debt. Second, the sovereign relies on taxation of corporate profits as a source of income. Third, corporate revenue is denominated in local currency (LC) but debts are denominated in FC; thus corporates are subject to exchange rate risk and currency mismatch issue.

To understand the key mechanisms of the model, consider a scenario in which an exogenous reduction in the world risk-free interest rate occurs.[7] The low risk-free rate incentivizes firms to borrow more in order to invest, leading to an increase in the corporate debt level and next period capital. These results have three different effects on the sovereign default risk. First, holding the exchange rate constant, the increase in capital leads to more production and a higher expected corporate tax revenue, resulting in a reduction in the sovereign default probability. This is the "investment effect" of corporate debt. Second, the increase in FC debt exposes corporate profits more to exchange rate risk and increases the variance of tax revenue, raising the sovereign default probability. This is the "exchange rate effect" of corporate debt. In the model, the investment and exchange rate effects counteract each other, resulting in FC corporate debt having an insignificant effect on the sovereign default probability, as documented by the panel regression. Finally, the increase in FC debt changes the state where sovereign default tends to happen. Specifically, an appreciation of FC results in lower tax revenue and a higher chance of sovereign default. Since FC tends to appreciate in foreign lenders' bad times,[8] sovereign defaults tend to occur more often when foreign lenders value repayment more. This "state switching effect" of corporate debt changes the covariance of sovereign defaults and how foreign lenders discount repayment in different states. This explains the positive relationship of FC corporate debt and sovereign risk premium in the data. In a simple sense, the corporate behavior alters the distribution of tax revenue (mean, variance, and covariance with lenders' pricing kernel) and therefore sovereign default decisions.[9]

We calibrate a quantitative version of the model to match moments in pre-2008 data from Mexico, as the pre-2008 period exhibited a high world risk-free interest rate. Then, we mimic

[7] Papers by Bruno and Shin (2017) and Bräuning and Ivashina (2019) show empirical support that the low world interest rate is an important factor for the increase in both bonds and loans to emerging markets.

[8] This is often known as a behavior for a reserve currency. See Caballero et al. (2016) and Maggiori (2017).

[9] This extends Arellano (2008)'s model, where the sovereign receives stochastic endowments to repay the debt. In this paper, the sovereign repays the debt with stochastic tax revenue, in which the time-varying probability distribution is determined by the corporate sector behavior.

the post-2008 period as a change from a high world risk-free rate regime to a low world risk-free rate regime, and evaluate the model performance by comparing the untargeted post-2008 moments. The model accounts well for the corporate and sovereign debt moments in the post-2008 period of Mexico such as quantitatively matching 80% of the increase in FC corporate external debt to GDP and the increase sovereign risk premium.

The policy implication of the model is that an externality arises as the corporate sector fails to internalize the effect of their borrowing decisions on sovereign debt pricing. We analyze the optimal trade-off from the private and social planner perspectives. Compared to the decentralized solution, the social planner solution has on average a 1.5 percentage point lower corporate debt to GDP, a 0.5 percentage point higher sovereign debt to GDP, and a 10 basis point lower sovereign risk premium. This suggests policies such as a tax to reduce FC corporate external debt.

Related Literature. The paper contributes to three strands of the literature on open macro emerging economies. First, it relates to work on empirical sovereign debt pricing. Extensive studies by Borri and Verdelhan (2011), Broner et al. (2013), Aguiar et al. (2016), and Tourre (2017) have shown that sovereign credit spreads are consistently larger than what would be implied by historical default probabilities. Two notable papers by Longstaff et al. (2011) and Remolona et al. (2008) develop methods to systematically separate the default premium and risk premium components from CDS spreads. They find a large risk premium component and it is mainly driven by global factors. This paper contributes to the literature by providing novel empirical evidence that FC corporate external debt to GDP, a domestic variable, is a robust predictor of the sovereign risk premium component.

Second, this paper bridges two popular literatures of open macro emerging economies that study public and private capital flows separately. We bring the dynamic corporate debt and investment consideration in corporate currency mismatch models (Aghion et al. (2001) and Céspedes et al. (2004)) into quantitative sovereign default models (Aguiar and Gopinath (2006) and Arellano (2008)).[10] We contribute to a growing literature that studies spillovers from sovereign risk to the private sector, including Arellano et al. (2017), Bocola (2016), Sosa-Padilla (2018), and Perez (2015), by exploring spillovers occurring in the reverse direction (from the corporate sector to the sovereign) and develops a model that is consistent with the new empirical findings. Asonuma (2016) and Na et al. (2018) explore exchange rates and sovereign defaults. While Na et al. (2018) focuses on exchange rate devaluation as an optimal response to sovereign default, we instead focus on exchange rate triggered default and also the presence of corporate debt. This paper is most similar to Du and Schreger (2017), which studies how currency mismatch in the corporate sector could alter the sovereign incentive of inflating away the local currency sovereign debt. We share the idea of having a currency mismatched corporate sector in a sovereign default setting with Du and Schreger (2017). We decompose the sovereign spreads into the two different components and find the new empirical findings of an increase in the sovereign risk premium but no change in default premium when corporate debt increases. To account for the new findings, we additionally allow for dynamic optimal choices on corporate investment and debt to fully study the corporate sector effect on sovereign debt pricing.

Finally, the paper develops relevant insights for capital control policy in emerging countries. Following Korinek (2010) and Bianchi (2011), one way to rationalize capital control policy is to consider a collateral constraint on borrowing. Individual agents fail to internalize the pecuniary externality that arises when they sell their assets, thereby lowering the value of collateral for other agents. This leads to room for policy improvement when the constraint could

[10] Bai and Zhang (2012), Park (2017) and Gordon and Guerron-Quintana (2018) are sovereign default models with public investment. None of these models has a private sector.

be potentially be binding in some future states. Kim and Zhang (2012) and Wright (2006) also study externalities in a sovereign default setting where individuals decide how much to borrow and the sovereign decides whether to default or not. This paper provides an alternative way of rationalizing capital control regulation: individual firms fail to internalize their aggregate effect on tax revenue. Since foreign lenders price the sovereign bond by evaluating the sovereign's repayment ability, this generates an externality on the sovereign. The externality in this setting calls for capital control policy at all times, rather than only when the constraint is potentially binding.

Layout. In section 1.2, we discuss in detail the empirical setup, key empirical findings and supplementary regressions that support the model. Section 1.3 provides the setup of the theoretical model. Section 1.4 presents the quantitative results and inspects the model mechanism. Section 1.5 discusses the social planner solution. Section 1.6 concludes.

1.2 Empirical evidence of corporate balance sheet spillovers

This section presents empirical results regarding the interaction between corporate debt and sovereign credit spreads. Subsection 1.2.1 describes the construction of variables of interest and the data sources used. Subsection 1.2.2 presents baseline regression results showing that an increase in FC corporate debt is associated with an increase in sovereign risk premium but not sovereign default risk. Subsection 1.2.3 then proceeds with additional empirical support that will guide underlying mechanisms of the model.

1.2.1 Construction of variables

Sovereign spreads and sovereign CDS premia reflect the funding costs of a country's sovereign.[11] Therefore, throughout this analysis, sovereign CDS premia are taken as a measure for sovereign

[11] In the absence of market friction and arbitrage, the premium of a CDS should be equal to the coupon rate difference of shorting a sovereign bond and a risk-free bond, both trading at their face values. See Appendix A.1 for an illustration.

funding costs. We prefer the CDS spread to the actual bond yield for this measurement, due to the CDS market being typically more liquid than the underlying bond market of emerging countries. Additionally, unlike underlying fixed-rate bonds, CDS spreads are not directly subject to interest rate risk. Finally, because CDS are standardized and quoted in constant maturities, they can be more easily compared across countries with no need to conduct any yield curve interpolation to obtain the cost of funding for constant maturities.

Extensive studies consistently show that sovereign spreads and CDS premia are much larger than actuarially fair prices, or prices that would compensate for historically observed credit default probabilities.[12] Therefore, the default probabilities only account for a fraction of the sovereign CDS premia. Due to this empirical phenomenon, this paper adopts two widely used methods from the finance literature to separate the sovereign CDS premia into their default premium and risk premium components. The default premium component is the component directly associated with the default probability of a sovereign borrower and is often understood as the hypothetical CDS premium if the investor were risk-neutral. In contrast, the risk premium component is measured as the difference between the observed CDS premium and the default premium component, and it is understood as the additional premium charged because of investors' risk aversion or the presence of other frictions.[13]

To separate CDS premia into these two components, we applied two methods from the finance literature: (1) a decomposition based on credit rating and (2) a decomposition based on an affine term structure model.[14] We briefly describe the methods here and refer readers to Appendix A.2 for technical details. The first method for separating CDS premia into their separate components relies on credit ratings, assigned by rating agencies to sovereign issuers,

[12] See for example: Remolona et al. (2008), Longstaff et al. (2011), Borri and Verdelhan (2011), Aguiar et al. (2016) and Tourre (2017).

[13] For example, lenders could be limited by some lending capacity constraints.

[14] These are the most commonly used approaches for credit spread decomposition in the finance literature. See Manzo and Veronesi (2016) for a discussion.

to infer expected default probabilities. The approach is developed by Remolona et al. (2008). We view the credit rating process as a function mapping a large set of time t information into expected default frequencies. Rating reports provide default probabilities associated with each rating.[15] We use the assigned default probability to compute the corresponding default premium by assuming a constant default probability until maturity.[16] This method imposes almost no restriction on the separation. Papers relying on credit ratings to measure default probabilities include Borri and Verdelhan (2011) and Tourre (2017). The second method relies on the term structure of sovereign CDS spreads to infer the expected default probability implied by the market and follows the affine pricing model made specific to the sovereign CDS market by Pan and Singleton (2008). The affine pricing model assumes the arrival rate of credit event follows a log-normal process and the market price of risk is affine in the arrival rate. The pricing model is consistent with a no-arbitrage condition. Leveraging the panel structure of CDS term structure data, we use the maximum likelihood estimation to estimate the arrival rates of credit events and lenders' stochastic discount factor. Papers by Longstaff et al. (2011) and Hébert and Schreger (2017) also apply this method to estimate the default probability.

For each of the two methods, we obtain estimates of the default premium for each sample country individually. Default probabilities and default premia are updated every time period (with each period taken to be a quarter). For each estimate of the default premium, we compute the risk premium as follows:

[15] Throughtout this paper, we use Moody's credit rating as the primary crediting rating source.

[16] One might worry that credit ratings are only updated infrequently and therefore limit the variation of the default premium. We improve the variation in two dimensions. First, even if there is no change in rating, the default probability could vary as new rating reports could change the default probability for the same rating. We update the rating corresponded default probability as soon as the new reports are released. Second, we also interpolate (cubic spline) the rating bins by using the outlook/watch-list information. The empirical findings are not sensitive to these refinements.

$$\text{Sovereign CDS}_{i,t}^{\text{Risk premium}} = \text{Sovereign CDS}_{i,t} - \text{Sovereign CDS}_{i,t}^{\text{Default premium}} \tag{1.1}$$

For the corporate and sovereign debt data, no publicly available dataset exists that provides external debt statistic measures by sector (sovereign vs. corporate) and by currency at a quarterly frequency. We follow the data cleaning procedure developed in Du and Schreger (2017) to construct these variables.[17] The basic principle involves using BIS data as the baseline and filling in the gaps by combining various national data sources and aggregating transaction-level data to the country level from commercial databases.

Bloomberg is the primary source for CDS data, with the end-of-quarter observations being used here. Debt levels are obtained from BIS International Debt Securities, BIS Locational Banking Statistics, Bloomberg, and Arslanalp and Tsuda (2014). Other economic variables are obtained from FRED and IMF datasets, and detailed data source information is provided in the appendix. Data from the first quarter of 2004 to the fourth quarter of 2016 comprise the main sample period and, unless otherwise specified, the 17 emerging market countries in the sample are Brazil, Chile, China, Colombia, Croatia, Hungary, India, Indonesia, South Korea, Malaysia, Mexico, the Philippines, Poland, Russia, South Africa, Thailand, and Turkey.[18]

1.2.2 Baseline regression analysis

We now turn to the investigation of the link between FC corporate debt and sovereign credit spreads and their components. For any observed CDS spread at time t, we decompose the CDS spread into two components as in eq (1.1). We then estimate the following panel fixed effect regressions:

$$\begin{aligned} \text{Sovereign CDS}_{i,t} = \quad & \alpha_i + \beta_1 \left(\frac{\text{FC Corp debt}}{\text{GDP}}\right)_{i,t-1} + \beta_2 \left(\frac{\text{FC Sovereign debt}}{\text{GDP}}\right)_{i,t-1} \\ & + \beta_3 \left(\frac{\text{LC Sovereign debt}}{\text{GDP}}\right)_{i,t-1} + \mu GC_t + \varepsilon_{i,t} \end{aligned} \tag{1.2}$$

[17] See Appendix A.2 for the details.

[18] The start date of sample and country choice are limited by availability of CDS data.

$$\text{Sovereign CDS}^{\text{Default premium}}_{i,t} = \eta_i + \gamma_1(\frac{\text{FC Corp debt}}{\text{GDP}})_{i,t-1} + \gamma_2(\frac{\text{FC Sovereign debt}}{\text{GDP}})_{i,t-1} + \gamma_3(\frac{\text{LC Sovereign debt}}{\text{GDP}})_{i,t-1} + \omega GC_t + \nu_{i,t} \quad (1.3)$$

$$\text{Sovereign CDS}^{\text{Risk premium}}_{i,t} = \chi_i + \delta_1(\frac{\text{FC Corp debt}}{\text{GDP}})_{i,t-1} + \delta_2(\frac{\text{FC Sovereign debt}}{\text{GDP}})_{i,t-1} + \delta_3(\frac{\text{LC Sovereign debt}}{\text{GDP}})_{i,t-1} + \theta GC_t + u_{i,t} \quad (1.4)$$

where α_i, η_i, χ_i are country fixed effects. Sovereign $\text{CDS}_{i,t}$ denotes the 5-year USD-denominated sovereign CDS for country i at time t.[19] $\frac{\text{FC Corp debt}}{\text{GDP}}$, $\frac{\text{FC Sovereign debt}}{\text{GDP}}$, and $\frac{\text{LC Sovereign debt}}{\text{GDP}}$ are the FC corporate debt, FC sovereign debt, and LC sovereign debt in country i, normalized by the GDP and all converted to same currency. GC_t denotes a vector of global control variables, including the VIX index, the BBB-Treasury spread, the 10-Year Treasury yield, the TED spread, and the US Federal Funds Rate. Note that these variables are not country i-specific. $\varepsilon_{i,t}, \nu_{i,t}, u_{i,t}$ denote the regression residuals.[20] The regression specification is inspired by Du and Schreger (2017), which employed the same set of regressors.

Table 1.2.1 reports the coefficient estimates for eq (1.2, 1.3, 1.4). The debt to GDP variables enter the regression in percentage term and the CDS quotes enter the regression in basis points. Therefore, the regression estimate of β_1 can be interpreted as indicating that a one percent increase in corporate debt to GDP is associated with a β_1 basis point increase in sovereign CDS premium. As a reference, the average CDS spreads over the sample countries are 155 basis points.

We first compare our result with Du and Schreger (2017) (reproduced in column (1a)). Column (1b) of Table 1.2.1 shows that a one percent increase in FC corporate debt to GDP is significantly associated with 5.66 basis points increase in 5-year USD-denominated sovereign CDS

[19] 5-year maturity is the most heavily traded maturity in the market and the most commonly used measure in the literature.

[20] One might worry about the error terms $\nu_{i,t}$ and $u_{i,t}$ are correlated. Since the independent variables are the same in the two regressions, seemingly unrelated regression and standard OLS deliver equivalent estimates.

spreads. Similarly, a one percent increase in FC sovereign debt to GDP is significantly associated with 11.12 basis points increase in 5-year USD-denominated sovereign CDS spreads. While Du and Schreger (2017) use local currency sovereign spreads as the dependent variable,[21] the estimated effect we find here is consistent with what Du and Schreger (2017) reported.

To focus now on the sub-components of CDS spreads, columns (2a) and (2b) report the coefficient estimates of eq (1.3) using term structure and credit rating based decompositions respectively, while columns (3a) and (3b) report the coefficient estimates of eq (1.4). Columns (2a) and (2b) show that a one percent increase in FC sovereign debt to GDP is associated with a 2-3 basis point increase in the sovereign default premium. Columns (3a) and (3b), show that FC sovereign debt to GDP is also positively and significantly associated with the sovereign risk premium. These regresion estimates are consistent with predictions from sovereign default models, reaffirming that the regression findings on sovereign debt are consistent with the literature.

Main empirical findings:

More interestingly, column (2a) and column (2b) show that an increase in FC corporate debt to GDP has a small and insignificant effect on the sovereign CDS default premium. Regardless of the method of decomposition, the results indicate an insignificant relationship between FC corporate debt to GDP and the sovereign CDS default premium, a sharp contrast to the effect of FC sovereign debt to GDP to the default premium. This also notably contrasts with column (1b), which shows that the FC corporate debt to GDP has a significant correlation with the sovereign CDS.

Column (3) focuses on sovereign CDS risk premium spreads and shows that, regardless of

[21] Local currency credit spreads are defined as the difference between an emerging country's local currency bond yield and an US-Treasury bond yield that is converted to the emerging country's currency by using FX swaps to eliminate exchange rate risk.

Table 1.2.1: Association between FC corporate debt to GDP and components of CDS premium

	Local currency sovereign spreads (bps)	Sovereign CDS premium (bps)	Sovereign CDS default premium (bps)		Sovereign CDS risk premium (bps)	
			Term	Rating	Term	Rating
(%)	(1a)	(1b)	(2a)	(2b)	(3a)	(3b)
$\frac{\text{FC Corporate debt}}{\text{GDP}}$	5.34***	5.66***	0.43	-0.24	5.23***	5.90***
	(1.13)	(1.20)	(0.28)	(0.26)	(1.03)	(1.17)
$\frac{\text{FC Sovereign debt}}{\text{GDP}}$	9.53*	11.12***	2.41***	2.50***	8.71***	8.62***
	(5.08)	(2.31)	(0.50)	(0.57)	(1.91)	(1.97)
$\frac{\text{LC Sovereign debt}}{\text{GDP}}$	6.78***	2.27	0.70	0.53	1.57	1.74
	(2.00)	(2.01)	(0.51)	(0.56)	(1.73)	(1.66)
Observations	355	761	761	761	761	761
R^2 adjusted	0.69	0.64	0.72	0.65	0.60	0.62
Period	2005Q1-2012Q4	2004Q1-2016Q4				
Countries	13	17				
Global Controls	Yes	Yes				
Country FE	Yes	Yes				

Notes: Standard errors in parentheses are heteroskedasticity autocorrelation spatial correlation robust standard errors (Driscoll and Kraay (1998)) with a 4-quarter lag. * p<0.1, ** p<0.05, *** p<0.01. All the spread measure of the independent variables are 5-year tenor. Column (1a) is from Du and Schreger (2017). The CDS are USD-denominated. Decomposition in column (2a) and column (3a) uses the affine term structure model by Longstaff et al. (2011). Decomposition in column (2a) and column (3a) applies the credit rating method by Remolona et al. (2008)..

the decomposition method, a one percent increase in FC corporate debt to GDP is significant and is associated with an increase of 5-6 basis points in the risk premium component. In fact, the adjusted R^2 decreases by twelve percentage points if we exclude FC corporate debt to GDP as an explanatory variable. The results show that almost all correlation of FC corporate debt to GDP with sovereign CDS spreads comes from co-movement with risk premium.[22] We find this intriguing, as many papers in the empirical sovereign debt pricing literature have documented a large risk premium component in international asset prices and find that the risk premium is largely driven by global factors such as the VIX Index, US stock market returns, or monetary policy in advanced economies (among many others, see Longstaff et al. (2011) or Rey (2015)). The fact that FC corporate debt to GDP, a local factor, is also significant in explaining risk premium after controlling for all the global controls (GC_t) is important for understanding the mechanism and policy analysis. The positive and significant correlation of FC corporate debt to GDP and sovereign risk premium spreads indicates a potential spillover from the corporate sector to the sovereign sector.

In summary, the empirical results show that an increase in FC corporate debt to GDP is significantly associated with an increase in the sovereign risk premium and a small and insignificant change of the sovereign default premium. Both the insignificance for the default premium and significance for the risk premium are interesting findings that the model section attempts to explain. Appendix A.4 provides robustness checks that control for additional factors motivated by the existing literature (including GDP growth, trade balance to GDP, reserve to GDP, country specific commodity price index and domestic credit to GDP). The main findings of this section are robust to various specifications.

[22] Coefficients in column (2a) and column (3a) adds up to column (1b), up to rounding errors. So as column (2b) and column (3b).

1.2.2.1 CDS spreads response on extreme dates conditional on FC corporate debt

We now turn the analysis to an extreme value event study approach.[23] We show that the sovereign CDS spreads change on the event dates depends on the FC corporate external debt to GDP. Specifically, we identify event dates when the daily change of the VIX Index is at the top 1% of the sample distribution (a daily VIX change of 22%).[24] We think of a dramatic change of VIX as a sudden increase in investor risk appetite, which is exogenous to emerging countries. The interest is in seeing how the CDS spreads change on these event dates conditional on existing debt; we do this by estimating the following daily panel local linear projections (Jordà (2005)):

$$\begin{aligned}\Delta_h \text{Sovereign CDS}_{i,t} = \quad & \alpha_{i,h} + \gamma_{1,h}(\tfrac{\text{FC Corp debt}}{\text{GDP}})_{i,t-1q} + \gamma_{2,h}(\tfrac{\text{FC Sovereign debt}}{\text{GDP}})_{i,t-1q} \\ & + \gamma_{3,h}(\tfrac{\text{LC Sovereign debt}}{\text{GDP}})_{i,t-1q} + \omega_h FE_t + \nu_{i,t+h}\end{aligned} \tag{1.5}$$

where $\Delta_h \text{Sovereign CDS}_{i,t} \equiv \text{Sovereign CDS}_{i,t+h} - \text{Sovereign CDS}_{i,t-2}$ is the difference in CDS spreads between $t-2$ and h^{th}-day after the event date t. FE_t are time fixed effects. The right-hand-side variables are values of the latest quarter prior to the event date ($t-1q$).

We identify 47 event dates over the sample period. We plot the coefficient estimates $\gamma_{1,h}, \gamma_{2,h}, \gamma_{3,h}$ for $h = 0$ to $h = 10$ (two business weeks) in Figure 1.2.1. The top panel illustrates that the $\gamma_{1,h}$ are consistently positive and significant, with the average estimate being 0.77 basis points, indicating that when investor risk aversion increases, a higher pre-existing FC corporate debt causes an increase in sovereign CDS spreads. The middle panel gives the estimates of $\gamma_{2,h}$. FC sovereign debt also has a significant positive effect on sovereign CDS spreads, the average estimate is 0.67 basis points. Finally, the bottom panel plots coefficient estimates of $\gamma_{3,h}$. Consistent with the regression reported in Table 1.2.1, the estimated coefficients are not significant for all h. This provides evidence that the foreign currency nature of the debt is important for

[23] See Forbes (2012) for a recent example that uses the same approach.

[24] For example, these dates include Lehman collapse, US being downgraded by S&P and Brexit referendum.

the underlying mechanism.

Overall, we find that a country with a higher $\frac{\text{FC Corp debt}}{\text{GDP}}$ suffers from a larger sovereign CDS increase when investor risk aversion increases.[25] We interpret this as evidence of FC corporate debt is a pricing factor for sovereign CDS. Investors ask for more compensation to take sovereign risk when $\frac{\text{FC Corp debt}}{\text{GDP}}$ is higher.

1.2.3 Supportive empirical evidence

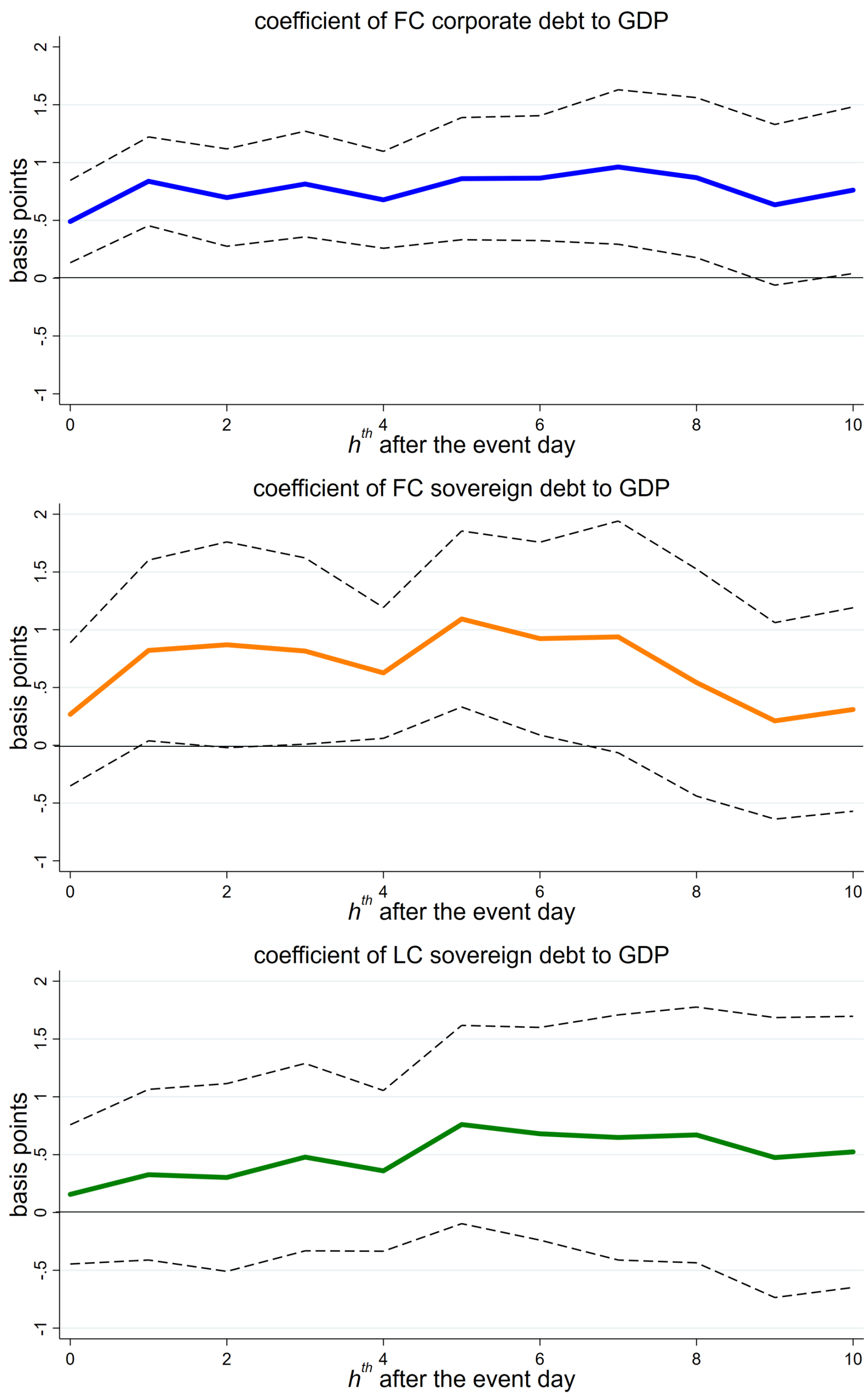
In this subsection, we provide empirical evidence that guides the model direction. In particular, we first provide empirical evidence that emerging market sovereigns rely heavily on tax revenue. Secondly, we show that FC corporate debt could affect tax revenue when the exchange rate fluctuates, and therefore affects the default decision of a sovereign.

1.2.3.1 Tax revenue structure in emerging countries

Emerging market sovereigns rely on tax revenue as an important source of income. Figure 1.2.2 shows the 2004-2014 average of tax revenue to fiscal revenue ratio for the sample countries. We obtain the data from the IMF World Revenue Longitudinal Dataset (IMF WRL), which ends in 2014. Compared to the developed economies, emerging markets have a higher share of fiscal revenue that is attributable to tax revenue. The sample country average of tax revenue to total fiscal revenue ratio is 73%, which is 13% higher than the G7 average of 60%. The high reliance on tax revenue suggests fluctuation in tax revenues could affect the sovereign's debt repayment ability.

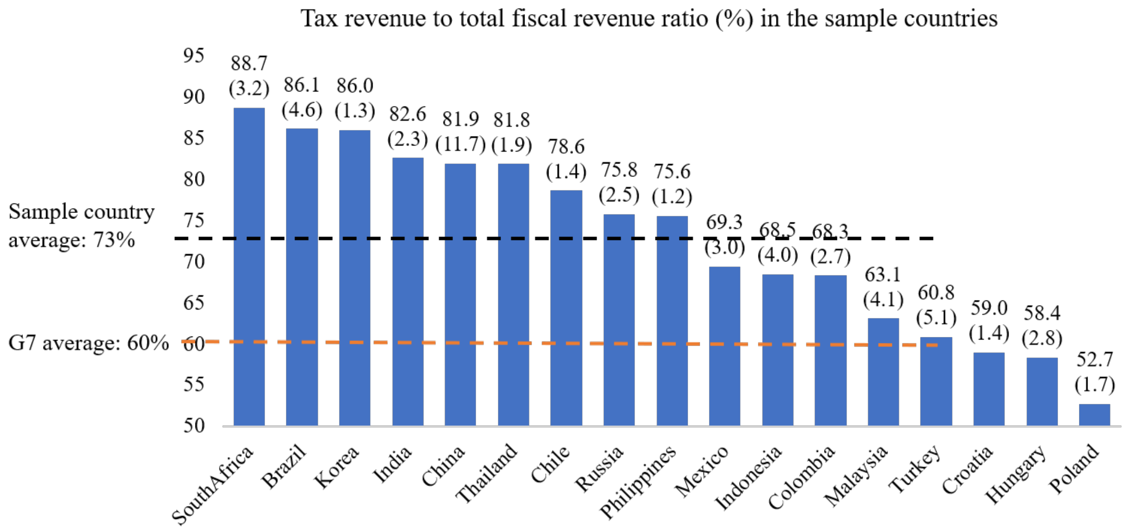
[25] In Appendix A.5, we show a scatterplot of $\frac{\text{FC Corp debt}}{\text{GDP}}$ and Δ_2Sovereign $\text{CDS}_{i,t}$ on the Brexit referendum to visualize the positive relationship.

Figure 1.2.1: Local projection estimates of sovereign CDS change on debt to GDP (equation (1.5))



Notes: Dash lines are 95% confidence interval based on robust standard errors.

Figure 1.2.2: Tax revenue to total fiscal revenue ratio (%) in the sample countries



Notes: This table reports the average tax revenue to total fiscal revenue from 2004-2014; standard deviation in parentheses. Data source: Author's calculations of the IMF World Revenue Longitudinal dataset.

1.2.3.2 Corporate debt, exchange rate and tax revenue in emerging countries

Motivated by the literature that studies the trade channel and financial channel of exchange rates,[26] we provide evidence that FC corporate debt and exchange rates could affect tax revenue. We focus on two definitions of tax revenue: the revenue from corporate profit tax and total tax revenue.[27] FC corporate debt and exchange rate movements could have a direct impact on corporate profits. Since corporate performance also affects the rest of the economy and therefore other tax sources such as trade tax, production tax and even labor income tax, we also examine the impact on total tax revenue.

We perform the following panel fixed effect regression to examine the relation between USD

[26]For recent examples, see Kim et al. (2015), Kearns and Patel (2016), and Hofmann et al. (2017).

[27]Emerging countries tend to have a higher share of corporate income tax than advanced economies. For example, Mexico and Chile are characterized by the OECD as "substantially higher revenues from taxes on corporate income & gains". Summary statistics of corporate tax share is reported in the Appendix A.6appendix.

corporate debt and tax revenue in emerging countries:[28]

$$\Delta\%(\text{tax revenue})_{i,t} = \alpha_i + \beta_1 \Delta S_{t-1} + \beta_2 (\tfrac{\text{USD Corp debt}}{\text{GDP}})_{i,t-1} \Delta S_{t-1} + \beta_3 (\tfrac{\text{USD Corp debt}}{\text{GDP}})_{i,t-1} + \delta_1 \text{GDPgrowth}_{i,t-1} + \delta_2 \text{FE}_t + \varepsilon_{i,t} \tag{1.6}$$

where FE_t is the time fixed effect, and ΔS_t is the percentage change of bilateral local currency per USD exchange rate. The data frequency is annual.

The trade and financial channels of exchange rates posit that if trade-related exchange rates depreciate, this aids export expansion and therefore increases corporate profits. However, if the financial exchange rate depreciates, the financial burden of firms increases and leads to a reduction in corporate profits. In this regression, the unconditional change in the exchange rate could capture the trade channel, therefore, we expect a positive β_1. The exchange rate interaction with USD corporate debt to GDP captures the extent to which an increase in corporate USD debt changes the impact of the exchange rate to tax revenue. We hypothesize that a larger debt to GDP strengthens the financial channel, and thus expect a negative value of β_2. Table 1.2.2 displays the regression estimates of eq (1.6), with the first two columns showing the year-on-year change of exchange rates on the RHS. To ease the concern about the endogeneity of exchange rates and tax revenue, in columns 3 and 4 we instrument the exchange rate change by exchange rate shocks that are identified through high frequency identification on the Federal Reserve FOMC meeting dates.[29] The estimates of β_1 and β_2 have the expected signs. In all cases, the estimates of β_2 are significant and negative, and they show that the reduction of a country's tax revenue caused by a depreciation of its currency is more dramatic

[28] Rather than looking at FC corporate debt as in the earlier section, we focus on USD corporate debt so that the relevant exchange rate is simply the bilateral dollar-local currency exchange rate. To the extent that USD is the dominant currency in financing, which is what we observed in the data. $\frac{\text{USD Corp debt}}{\text{GDP}}$ and $\frac{\text{FC Corp debt}}{\text{GDP}}$ capture very similar variations. Moreover, we can instrument the exchange rate change by external US shocks that are identified through high-frequency identification.

[29] The high frequency identified shocks look at the one-day US-local currency exchange rate change during the FOMC meeting dates. This is known in the macroeconomics literature as the FOMC shocks. See for example, Kuttner (2001) and Gertler and Karadi (2015).

when its corporate sector has high USD corporate debt. To interpret these estimates, a coefficient of -0.033 indicates that if the corporate USD debt to GDP is 10% and the local currency depreciates by 1%, then the corporate tax revenue is changed by 10 x 1 x (-0.033) = -0.33% on average.[30]

In summary, emerging market sovereigns rely heavily on tax revenue, especially corporate tax revenue, as a source of income. The tax revenue fluctuates with exchange rates, and a local currency depreciation lowers tax revenue especially when the corporate sector has high FC debt. The connections between sovereign and corporations through tax revenue will serve as the main linkage in the model.

1.3 An endogenous sovereign default model with a corporate sector

In this section, we build a small open economy sovereign default model with a corporate sector and risk-averse foreign lenders. We use this model to explain the empirical evidence we find in the baseline regression that FC corporate debt has a significant effect on the sovereign risk premium but an insignificant effect on the sovereign default premium. We first lay out the infinite-horizon dynamic stochastic model, then we reformulate it into a recursive model and define the equilibrium.

1.3.1 A infinite-horizon dynamic stochastic model

1.3.1.1 Environment:

Time is discrete and indexed by $t \in \{0, 1, ...\}$. There are three types of agent. Two types of agents live indefinitely in the small open economy: entrepreneurs, who represent the corporate sector in the data, and a sovereign. The last agent type consists of foreign lenders who live

[30] As a reference, the mean change for Korea is 6% and for Brazil is 12%. Summary statistics are provided in Appendix A.3.

Table 1.2.2: Regression of tax revenue change on corporate debt and exchange rates (eq (1.6))

	YoY change of measures of tax revenue OLS: change of exchange rates		YoY change of measures of tax revenue IV: change of exchange rates instrumented by FOMC shocks	
	(1)	(2)	(3)	(4)
ΔS_{t-1}	0.416*	0.186**	0.869	0.066
	(0.224)	(0.076)	(0.548)	(0.210)
$(\frac{\text{USD Corp debt}}{\text{GDP}})_{i,t-1} \times \Delta S_{t-1}$	-0.033**	-0.018***	-0.057**	-0.025**
	(0.014)	(0.005)	(0.028)	(0.012)
$(\frac{\text{USD Corp debt}}{\text{GDP}})_{i,t-1}$	0.249	-0.079	0.182	0.006
	(0.359)	(0.174)	(0.393)	(0.162)
GDP growth	1.073***	0.311**	0.945**	0.088
	(0.303)	(0.105)	(0.458)	(0.224)
Observations	199	218	199	218
R^2 adjusted	0.27	0.48	0.18	0.45
Period	2004-2014	2004-2014	2004-2014	2004-2014
Countries	17	17	17	17
Country/Time FE	Yes	Yes	Yes	Yes

Notes: The dependent variable of Column (1) and (3) is the year-on-year change of corporate tax revenue. The dependent variable of Column (2) and (4) is year-on-year change of total tax revenue. Standard errors in parentheses are heteroskedasticity autocorrelation spatial correlation robust (Driscoll and Kraay (1998)) standard errors with a 3-year lag.* p<0.1, ** p<0.05, *** p<0.01.

outside the small open economy.

Exogenous processes. The small open economy experiences three persistent exogenous processes: productivity (z_t), government default disutility cost (V_t), and exchange rate (S_t). The government default disutility cost is a utility cost that the sovereign bears when defaults occur.[31]

The productivity process follows:

$$\log(z_t) = \mu_z + \rho_z \log(z_{t-1}) + \varepsilon_{z,t},$$

with $|\rho_z| < 1$ and $\varepsilon_{z,t} \sim N(0, \sigma_z^2)$.

The shock to default cost serves as a shock that drives sovereign default that is independent from the rest of the world condition. The default disutiltiy cost process follows:

$$V_t = \mu_V + \rho_V V_{t-1} + \varepsilon_{V,t},$$

with $|\rho_V| < 1$ and $\varepsilon_{V,t} \sim N(0, \sigma_V^2)$.

The exchange rate changes the effective borrowing cost of corporate and sovereign debt, and is related to the conditions of the rest of the world. The exchange rate (S_t) is defined as local currency per foreign currency (peso per dollar). An increase in (S_t) represents a depreciation of the local currency. The exchange rate process follows:[32]

$$\log(S_t) = \mu_S + \rho_S \log(S_{t-1}) + \varepsilon_{S,t},$$

[31] See below on the discussion of modeling default cost.

[32] In the model, we take the domestic final goods as the numeraire. We denote the price of the final goods in local currency as P_t; the price of the final goods in foreign currency is P_t^*. If law of one price holds, then $S_t P_t^* = P_t = 1$. Therefore $S_t = \frac{1}{P_t^*}$, which is reasonable to assume to be exogenous to the small open economy.

with $|\rho_S| < 1$ and $\varepsilon_{S,t} \sim N(0, \sigma_S^2)$.

Entrepreneur sector:

Preferences. A unit continuum of representative risk-averse entrepreneurs, each indexed by i, live in the small open economy.[33] The entrepreneurs value present discounted consumption goods (c) and government spending (G). They have the following preference:

$$U_t = E_t \sum_{j=t}^{\infty} \beta^{j-t} u(c_j, G_j), \tag{1.1}$$

where β is the discount factor. The utility function $u : \mathbb{R}_+ \to \mathbb{R}$ is strictly increasing and strictly concave.

Production Technology. The entrepreneurs are endowed with production technology that produces final goods (y_t) with capital (k_t). The production technology is:

$$y_t = z_t k_t^{\alpha}$$

Budget constraint. The entrepreneur has access to a one-period FC external bond market and can accumulate capital. They face the following budget constraint:

$$c_t + k_{t+1} \leq (1-\tau)[z_t k_t^{\alpha} - (\Delta S_t) b_t]) - S_t b_t + S_t q_t b_{t+1} + (1-\delta) k_t \tag{1.2}$$

Here b_t denotes the amount of corporate bond in foreign currency maturing at time t; τ is a constant tax rate;[34] $\Delta S_t = \log(S_t) - \log(S_{t-1})$; δ is the capital depreciation rate; and q_t is the corporate bond price in foreign currency. The entrepreneurs spend their income on consumption (c_t), capital accumulation (k_{t+1}), and repayment of debt (b_t, on the RHS). The tax structure, which is consistent with accounting standards, taxes production revenue (1st term in the square brackets) minus exchange rate gains and losses (2nd term). The sources

[33] When stating the entrepreneur problem, the i subscript is suppressed when it is not necessary.

[34] Optimal taxation in sovereign default model is an interesting research question but is not the focus of this paper. The constant tax rate parsimoniously captures the fact that tax rate is usually not able to be changed quickly for institutional and political reasons.

of income for entrepreneurs are the after-tax profit earned this period (the term in square brackets), bond proceeds from new bond issuance ($S_t q_t b_{t+1}$), and undepreciated capital ($(1-\delta)k_t$). The budget constraint converts all terms to local currency. The numeraire is the final goods.[35]

Default. As the major focus of the paper is sovereign default, we model the default of the entrepreneur in a simple way.[36] We assume a utility cost of default (ε) which follows an iid across time logistic distribution with a mean of μ_ε and a scale of σ_ε.[37] Each period, after the shocks and production, the entrepreneur chooses either to repay their debt or default on it. If he/she chooses to default on the debt, they walk away from all debts with zero recovery ($b_t = 0$) and tax obligation, and suffer the cost of default (ε). The period budget constraint in the default state is:

$$c_t + k_{t+1} \leq z_t k_t^\alpha + S_t q_t b_{t+1} + (1-\delta)k_t \tag{1.3}$$

Sovereign sector:

Preferences. The sovereign is benevolent, so it has the same preference as the entrepreneurs:

$$U_t = E_t \sum_{j=t}^{\infty} \beta^{j-t} u(c_j, G_j), \tag{1.4}$$

[35]The budget constraint allows for exchange rate pass-through to output (final goods) prices, it is then normalized by the final goods prices. Therefore, the exchange rate effect in the model is the net of export and balance sheet effect. Numerous empirical papers has documented strong balance sheet effect and non-tradable non-exporting firms issuing FC debt, resulting in a net currency mismatch (For example, see Kim et al. (2015) and Du and Schreger (2017)).

[36] Entrepreneur default is not necessary for the tax revenue channel, which is the main mechanism in the model, to operate. The possibility of entrepreneur default allows the model to have two realistic features: corporate debt is defaultable and sovereign spreads and corporate spreads are positively correlated. See Bevilaqua et al. (2019) and Kaas et al. (2016) for recent evidence on the positive correlation.

[37]This cost is commonly used in the discrete choice econometrics literature (McFadden (1973)) and recently used in sovereign default literature. For example, see Arellano et al. (2018). One could think of this as a non-monetary effort cost the entrepreneurs incur to abscond from the debt.

Budget constraint. The sovereign has access to a one-period FC external bond market.[38] When the sovereign is not in the default state, the sovereign is subject to the following period-by-period budget constraint:

$$G_t + S_t B_t \leq TR_t + S_t Q_t B_{t+1} + L \tag{1.5}$$

Here B_t denotes the amount of sovereign bond in foreign currency maturing at time t. The sovereign finances government spending (G_t) and bond repayment ($S_t B_t$) with tax revenue (TR_t), new bond issuance ($S_t Q_t B_{t+1}$), and a constant endowment L. The constant endowment is meant to capture the part of sovereign resources in the data that are not contributed to by corporate activities.

Tax revenue. The tax revenue formulation is important for understanding the spillover from corporate to sovereign. Total tax revenue is an aggregation across all entrepreneurs:

$$TR_t \equiv \tau[\int_0^1 (1 - d_{i,t})(z_t k_{i,t}^{\alpha} - \Delta S_t b_{i,t}) \mathrm{d}i] = \tau(1 - \bar{d_t})(z_t \overline{k_t}^{\alpha} - \Delta S_t \overline{b_t}) \tag{1.6}$$

where $\overline{k_t} \equiv (\int_0^1 k_{i,t}^{\alpha} \mathrm{d}i)^{1/\alpha}$, $\overline{b_t} \equiv \int_0^1 b_{i,t} \mathrm{d}i$ and $\overline{d_t} \equiv \int_0^1 d_{i,t} \mathrm{d}i$. d_t is the entrepreneur default indicator, which is equal to one if defaults happen and zero otherwise.

The terms $\overline{k_t}$ and $\overline{b_t}$ denote aggregate capital and corporate debt in the economy, which are independent from individual entrepreneur i's actions. When each individual entrepreneur chooses capital and bond to maximize their lifetime utility, they do not take into account their individual effect on total tax revenue.[39] Therefore, individual entrepreneurs do not account for their effect on the sovereign provision of government spending and sovereign debt prices.

Default. When the government defaults, we assume it does so on all the debt obligations. This standard assumption in the literature is consistent with the historical behavior of defaulting governments. As in most previous studies, we also assume zero recovery of the debt in default.

[38] As standard in the literature, the discount rate (β) in the small open economy is assumed to be lower than the risk free rate. Therefore the sovereign always want to borrow to front-load G_t. Borrowing is used also for smoothing G_t across periods.

[39] Mathematically, from a private point of view, $\frac{\partial \bar{k}_{t+1}}{\partial k_{t+1}} = \frac{\partial \bar{b}_{t+1}}{\partial b_{t+1}} = 0$.

We follow Arellano et al. (2017) in modeling the cost of default. Each period, after the shocks, the sovereign chooses to repay or default on the debt. In the period that the sovereign chooses to default, it suffers a one-time disutility cost (V_t), which is stochastic and known at time t before the default decision is made. The cost (V_t) can be thought of as a cost derived from a change of government office, reputation, sanctions, etc. The time variation of this cost can be understood as the change in the enforcement commitment of the government. Modeling default cost in this way, rather than through income/productivity loss, allows for the possibility that default could happen in good as well as bad productivity states.[40] The default utility cost approach also facilitates analytical discussion in the next section and computation in the quantitative section. A few recent sovereign default papers introduce this approach to modeling sovereign default cost, including Aguiar and Amador (2013), Arellano et al. (2017), Arellano et al. (2018), and Bianchi et al. (2018). The period budget constraint in the default state is:

$$G_t \leq TR_t + S_t Q_t B_{t+1} + L \tag{1.7}$$

Foreign lenders pricing:

Risk-averse foreign lenders provide funding to both the sovereign and entrepreneurs. They price both sovereign and corporate bonds competitively according to their stochastic discount factor ($m_{t,t+1}$ or SDF). Since investors are outside of the small open economy, we need to specify the lenders' pricing behavior. We adopt a reduced form approach as in Arellano and Ramanarayanan (2012) and Bianchi et al. (2018) to specify the SDF. While Arellano and Ramanarayanan (2012) and Bianchi et al. (2018) assume the shock to the income of the small open economy is included in the SDF formulation,[41] we assume the shock to the exchange

[40] Sovereigns do not only default in bad times. Tomz and Wright (2007) document that there are one-third of the sovereign defaults happen when the country's GDP is above the trend.

[41] In their formulation, $m_{t,t+1} = e^{(-r-\kappa_t \varepsilon_{t+1} - 0.5\kappa_t^2 \sigma_\varepsilon^2)}$, where κ_t is the time-varying price of risk, ε_{t+1} is the shock to endowment and σ_ε^2 is the variance of the endowment shock.

rate is included instead:

$$m_{t,t+1} = e^{(-r+\gamma\varepsilon_{S,t+1}-0.5\gamma^2\sigma_S^2)} \tag{1.8}$$

Here ε_S is the shock to the exchange rate, and σ_S^2 is the variance of exchange rate shocks. $\gamma \geq 0$ is the market price of risk, a parameter that governs the size of the risk premium.[42] The reduced form SDF says the investors value payoffs more when the foreign currency appreciates.[43]

Sovereign and corporate bond prices must satisfy the following asset pricing conditions:

$$q_t = E_t\left[m_{t,t+1}(1-d_{t+1})\right] \tag{1.9}$$

$$Q_t = E_t\left[m_{t,t+1}(1-D_{t+1})\right] \tag{1.10}$$

where d_t and D_t are the entrepreneur default and sovereign default indicator respectively. These indicators are equal to one if defaults happen and zero otherwise.

Discussion of model assumptions:

Before moving forward, we discuss three assumptions we have made in the model.

First, we assume that both entrepreneurs and the sovereign borrow solely in foreign currency. The assumption that no borrowing in local currency is mainly for computational reasons, as it results in one less dimension to consider. Otherwise, we need to keep track of two state variables. This assumption is reasonable for the corporate sector, as almost all external corporate debt is denominated in FC for emerging countries.[44] Our focus on the spillover from

[42] γ is a parameter that captures both the risk aversion of investor and the correlation of SDF and exchange rate shock. For example, even if investors are risk averse but the correlation is zero, then γ will be zero.

[43] For example, it is reasonable to think the marginal asset pricer is an emerging market specialized bond fund or lender, an appreciation of the dollar leads to in general bad performance of the investment portfolio (potentially due to currency mismatch), making the investors value more the cashflow in these states. See the discussion below on the assumption of this particular relationship. See also Appendix A.7 and A.8 for the empirical support.

[44] The is true across time. See the Appendix in Du and Schreger (2017) for the data evidence.

corporates to the sovereign controls for the level of the sovereign debt and the currency mix, as was done in the baseline regression. Therefore, the mechanism should work independently of the sovereign currency composition.[45]

Second, we assume that the exchange rate and lender SDF are correlated such that the lender SDF is high when FC appreciates. In many small open economy models with a risk-averse investor, the rest of the world variables, such as lender SDF, are exogenous. Therefore, we need to make assumptions on how these exogenous variables behave.[46] We assume the lender SDF is linked to the exchange rate of the small open economy rather than being directly linked to the endowment process of the small open economy. The particular correlation in mind could be generated from some banking/asset manager constraints such as the Value-at-Risk constraint in Bruno and Shin (2017) or the abscond constraint in Morelli et al. (2019). Caballero et al. (2016), Maggiori (2017) think of this as a safety property of reserve currency: a currency that appreciates in bad times (i.e., high lender SDF).[47] Maggiori (2013) provides empirical evidence for this relationship ($cov(m_{t,t+1}, \Delta S_{t+1}) > 0$) for USD against a basket of currency, and terms this relationship the "USD Safety Premium." In Appendix A.7, we document the positive USD Safety Premium for each of our sample currencies.

Third, we assume sovereign default has no effect on the entrepreneur sector besides the disutility cost. We make this assumption mainly for emphasizing the spillover from entrepreneur to sovereign, but it also helps improve the tractability of the model. We emphasize the spillover from entrepreneur to sovereign, as the private sector does not take account into its aggregate effect. On the other hand, a benevolent sovereign internalizes its spillover to private sector, if

[45] Engel and Park (2018), Ottonello and Perez (2018), and Du et al. (2016) provide more analysis on optimal sovereign debt currency composition.

[46] A notable exception is Lizarazo (2013), which directly models the foreign investor portfolio problem.

[47] This correlation is consistent with many views in the exchange rate determination literature such as disaster risk (Burnside et al. (2011), Farhi and Gabaix (2016)), countercyclical risk compensation (Lustig et al. (2014)), liquidity motive (Engel and Wu (2018), Jiang et al. (2018)) , and big country size of the lender country (Hassan (2013)).

there is any.[48]

1.3.1.2 Recursive problem and equilibrium

We now describe the recursive optimization problems of the sovereign and entrepreneurs, and define the equilibrium. As is standard in the sovereign default literature, we focus on Markov perfect equilibrium. That is, we assume that in each period the agents' decisions depend only on payoff-relevant state variables.

At the beginning of each period, the four exogenous shocks (z, ε, S, V) are realized. We also need S_{-1} for tax revenue accounting. We condense the exogenous shock notation to $X \equiv (z, \varepsilon, S_{-1}, S, V)$. Given these variables, the entrepreneurs repay their debt, pay taxes, and choose how much to consume, invest, and borrow. Simultaneously, the sovereign chooses its default decision on the existing debt, issuance amount of the new debt, and the amount of government spending to provide.

Recursive entrepreneur problem:

We denote the option value of default for the entrepreneur as $W^E(k, b; X)$ and the value of repaying for the entrepreneur as $U^E(k, b, d; X)$. d is a default indicator and is equal to one if entrepreneur defaults and zero otherwise. Given exogenous state variables (z, S, S_{-1}), endogenous state variables (k, b, d), and bond price schedule $q(k', b', X)$, the entrepreneur solves the following problems each period:

$$W^E(k,b;X) = \max_{d=\{0,1\}} \{(1-d)U^E(k,b,0;X) + (d)[U^E(k,0,1;X) - \varepsilon]\} \tag{1.11}$$

$$\begin{gathered} U^E(k,b,d;X) = \max_{c>0, k'\geq 0, b'} u(c,G) + \beta E_{X'|X} W^E(k',b';X') \\ \text{subject to} \\ c + k' \leq [1-\tau(1-d)][zk^\alpha - (\Delta S)b] - Sb + Sq(k',b',X)b' + (1-\delta)k \end{gathered} \tag{1.12}$$

[48] Two simple extensions of this model with sovereign default has an effect on TFP or entrepreneur cost of default will complete the feedback loop.

Recursive sovereign problem:

We denote the option value of default for the government as $W^G(B,k,b,d;X)$ and the value of repaying for the government as $V^G(B,k,b,d;X)$. Given exogenous state variables $(z,\varepsilon,S_{-1},S,V)$, endogenous state variables (B,k,b,d), bond price schedule $Q(B',k',b';X)$, and tax revenue schedule $TR(k,b,d;X)$, the sovereign solves the following problems each period:

$$W^G(B,k,b,d;X) = \max_{D=\{0,1\}} \{(1-D)V^G(B,k,b,d;X) + (D)[V^G(0,k,b,d;X) - V]\} \ , \quad (1.13)$$

where D is a default indicator and is equal to one if default occurs and zero otherwise.

The value of repaying of the government, V^G, is given by:

$$\begin{gathered} V^G(B,k,b,d;X) = \max_{G>0,B'} \{u(c,G) + \beta E_{X'|X} W^G(k',b';X')\} \ , \\ \text{subject to} \\ G + SB \leq TR(k,b,d;X) + SQ(B',k',b',X)B' + L. \end{gathered} \quad (1.14)$$

where $TR(k,b,d;X) = (1-d)\tau[z\bar{k}^{\alpha} - \Delta S\bar{b}]$.

Foreign lenders' bond price schedule:

The equilibrium bond prices are consistent with lender asset pricing conditions:

$$q(k',b';X) = E\left[m'(S')(1-d'(k',b';X')\right] \quad (1.15)$$

$$Q(B',k',b';X) = E\left[m'(S')(1-D'(B',k',b';X')\right] \quad (1.16)$$

Recursive equilibrium definition

The recursive Markov equilibrium consists of two main blocks: the sovereign block and the entrepreneur block.

The entrepreneur block consists of policy functions for entrepreneur default, $d(k,b;X)$, capital accumulation, $k'(k,b,d;X)$, corporate borrowing, $b'(k,b,d;X)$, entrepreneur consumption,

$c(k,b,d;X)$, value functions $W^E(k,b;X)$, $U^E(k,b,d;X)$, and bond price schedule $q(k',b';X)$. The policy and value functions solve the entrepreneur problem in eq (1.11, 1.12) and the bond price satisfies pricing equation (1.15). These policy functions result in a tax revenue function $TR(k,b,d;X)$ for the sovereign block.

The sovereign block has policy functions for default, $D(B,k,b,d;X)$, sovereign borrowing, $B'(B,k,b,d;X)$, provision of government goods $G(B,k,b,d;X)$, value function $W^G(B,k,b,d;X)$ and $V^G(B,k,b,d;X)$, and bond price schedule $Q(B',k',b';X)$. The policy and value functions solve the sovereign's problem in eq (1.13, 1.14), and the bond price satisfies pricing equation (1.16).

In the model, we can think of the spread between the sovereign bond and risk-free bond as $Q^{RiskFree} - Q$. We can directly decompose the sovereign spread into the default premium and risk premium:

$$\begin{aligned} Q^{RiskFree} - Q &= E[m'] - E[m'(1-D')] \\ &= E[m'] - E[m']E(1-D') - cov(m', 1-D') \\ &= \underbrace{E(m')E(D')}_{\equiv Q^{DP}} + \underbrace{-cov(m', 1-D')}_{\equiv Q^{RP}} \\ &\equiv \text{default premium} + \text{risk premium} \end{aligned} \tag{1.17}$$

1.4 Quantitative Analysis

In this section, we first discuss the calibration strategy in subsection 1.4.1.[49] We calibrate the model to target the pre-2008 moments. In subsection 1.4.2, we present some graphs from the policy function that illustrate the model mechanism. We evaluate the model performance in subsection 1.4.3 by comparing the untargeted model simulated moments with an unexpected reduction in the risk-free rate, which mimics the low world risk-free rate environment in the

[49] The model is solved by value function iteration. Details of the numerical computation are described in Appendix A.9.

post-2008 period.

1.4.1 Calibration

We calibrate the model to Mexico, a standard emerging country in the sovereign default literature, using a model frequency of one year. We calibrate the model to target pre-2008 moments. The pre-2008 period is associated with a high risk-free interest rate of 2.5% (which is the 2003-2008 average of the real 5-year US Treasury rate).

Functional form. We assume a constant relative risk aversion (CRRA) utility function in which the entrepreneurs derive utility from consumption goods and government goods separately. The period utility function is:

$$u(c,G) = \frac{(c)^{1-\sigma}-1}{1-\sigma} + \frac{(G)^{1-\sigma}-1}{1-\sigma}$$

where σ is the coefficient of risk aversion.

Parameter values. We first choose a subset of parameters values that can be directly pinned down from the data or that have standard values from the literature. We then choose the second subset of parameter values so that model simulations match key aspects of the data. We estimate the TFP process using 1950-2014 data from Penn World Table where quadratic detrending is applied.[50] This results in an estimation of ρ_Z of 0.93 and σ_Z of 0.02. We set the corporate tax rate to be 28%, as observed in Mexico. We estimate the exchange rate process using 2003Q1-2017Q4 data,[51] which results in an estimate of ρ_S of 0.95 and σ_S of 0.06. We choose capital share (α) to be 0.33 and capital depreciation rate (δ) to be 0.05. The persistence of sovereign default disutilty (ρ_V) is chosen to be 0.5, following Arellano et al. (2017).

[50] We use a longer series than our empirical sample period, as we only have annual data for TFP.

[51] The exchange rate we estimate is the nominal exchange rate divided by Mexico's consumer price index, which reflects that the exchange rate is normalized by the final goods price in the model. The estimates are very close if we use tradable goods price index.

Table 1.4.1: Calibration

Symbols	Description	Values	Notes
Parameters from the data			
τ	Corporate tax rate	28%	Mexico data
ρ_Z	Persistence of TFP shock	0.93	AR(1), Mexico data
σ_Z	s.d. of TFP shock	0.02	AR(1), Mexico data
ρ_S	Persistence of exchange rate shock	0.95	AR(1), Mexico data
σ_S	s.d. of exchange rate shock	0.06	AR(1), Mexico data
r	risk free rate	2.5%	2003-2007 5Y US Treasury average
Parameters from the literature			
α	Capital share	0.33	standard literature value
δ	Capital depreciation	0.05	standard literature value
σ	CRRA coefficient	2	standard literature value
β	Discount factor of the SOE	0.95	standard literature value
ρ_V	Persistence of sovereign default cost	0.5	Arellano et al. (2017)
Parameters from moment matching			
μ_ε	Mean entrepreneur default cost	1.3	mean FC corporate debt to GDP (7.6%)
σ_ε	Scale of logistic distribution	0.22	mean corporate default probability (1.8%)
μ_V	Mean sovereign default cost	0.5	mean FC sovereign debt to GDP (4.2%)
σ_V	s.d. sovereign default cost	0.12	mean sovereign default premium (37bps)
L	Value of constant endowment	0.35	share of exchange rate sensitive fiscal revenue (60%)
γ	Lender SDF parameter	41	mean sovereign risk premium (57bps)

We choose the rest of the parameters by simulated method of moments, targeting six key pre-2008 moments of interest. These moments are 1) mean corporate default probability (1.8%), 2) mean corporate debt to GDP (7.6%), 3) mean sovereign default premium (37 bps), 4) mean sovereign risk premium (57 bps), 5) mean sovereign debt to GDP (4.2%), and 6) mean share of fiscal revenue that is exchange rate sensitive (60%).[52] We choose six parameters $(\mu_\varepsilon, \sigma_\varepsilon, \mu_V, \sigma_V, L, \gamma)$ to match these six moments. Although the parameters are calibrated jointly, we can give a heuristic description of how the empirical moments inform specific parameters. First, the corporate default probability is useful for inferring the firm default cost (σ_ε). We infer μ_ε from the corporate debt to GDP ratio. The sovereign debt to GDP and sovereign default premium jointly gauge the parameter values of μ_V and σ_V. L is highly related to the equilibrium long run share of exchange rate sensitive fiscal revenue. Finally, we infer the risk premium parameter γ from the size of the sovereign risk premium. Table 1.4.1 reports the parameter values.

Table 1.4.2 reports long-run moments in the data versus those in the model simulations. The targeted moments section (Panel (A)) shows that the simulated data matches the calibration target well. The risk-free interest rate is 2.5% in this case. The mean output in this economy is 1.8.

1.4.2 Model mechanism

We first examine how the sovereign bond price changes when entrepreneurs' decisions change.[53]

[52] We conduct regressions of eq (1.6) for each subcomponent of tax revenue in Mexico. If the coefficient on the interaction term is significant, we count these as the exchange rate sensitive and as the data counterpart of the model tax revenue.

[53] The figures are generated from the calibrated model. The calibration strategy is discussed below.

Table 1.4.2: Model generated moments and the targeting data moments

	Panel (A) Pre-2008 period Targeted moments	
	Data (Mexico)	Model
Corporate Sector		
corporate FC debt to GDP	7.6%	7.6%
corporate default rate*	1.8%	1.8%
Sovereign Sector		
sovereign FC debt to GDP	4.2%	4.3%
sovereign default premium	37 basis points	37 basis points
sovereign risk premium	57 basis points	56 basis points

Notes: Panel (A) is simulated with the parameters reported in Table 1.4.1 (with 2.5% risk-free rate). Moments are computed by generating 600 simulation samples of 400 periods each and discarding the first 300 periods. Default and the year after default are excluded. *Due to the lack of country-specific data, we use the Latin America corporate default rate reported by M&G investments.

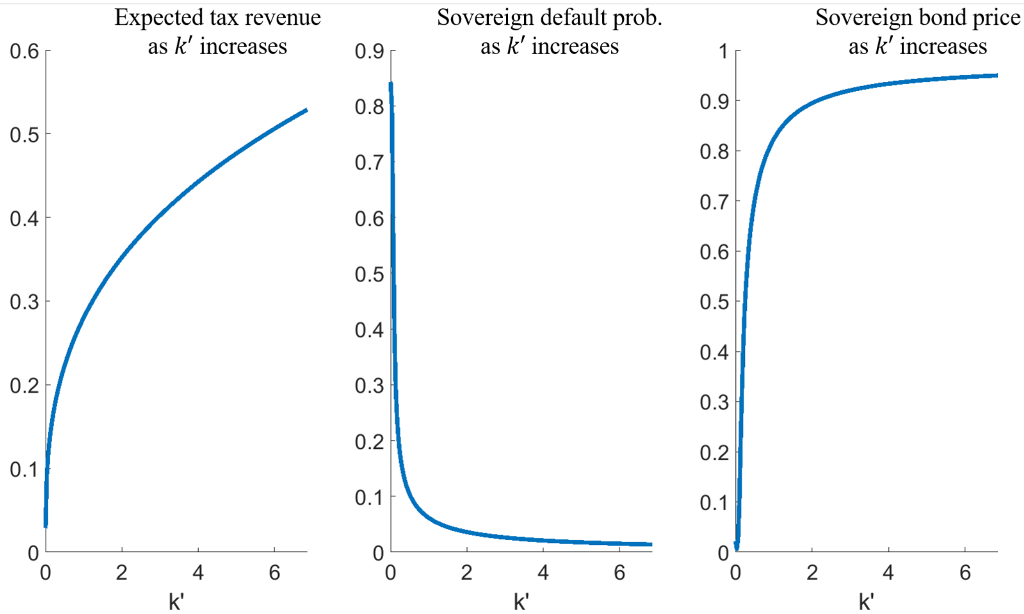
Figure 1.4.1 demonstrates how the sovereign bond price varies with next period capital, k', holding all other variables, including sovereign debt, at a constant level.[54] In the left panel, we plot the expected tax revenue against k'. We see that as k' increases, the sovereign expects to obtain more tax revenue. This is because the expected future production increases. As we show in the middle panel, this increase in expected tax revenue is associated with a decrease in the sovereign default probability because the sovereign is more likely to repay with a higher tax revenue. Finally, in the right panel, we see that as k' increases, the sovereign bond price increases and eventually reaches the risk-free rate region. Overall, the increase in k' increases expected tax revenue, which supports sovereign bond repayment, lowers the sovereign default probability, and thus supports the sovereign bond price.

Figure 1.4.2 displays how the sovereign bond price varies with bond issuance, b'. Recall that the tax revenue is $\tau[z\bar{k}^{\alpha} - \Delta S\bar{b}]$. Because the exogenous variables are held at the mean level in this illustration, $E(\Delta S) = 0$, an increase in b' does not change the expected tax revenue in the next period. However, a change in b' still has an effect on sovereign bond price. In the left panel, we plot the variance of tax revenue against b'. Since the exchange rate is stochastic, an increase in b' increases the volatility of tax revenue next period. As we show in the middle panel, an increase in b' leads to an increase in the sovereign default probability. This is because the increase in volatility increases the probability of getting very low tax revenues in the next period (greater left tail risk), and therefore leads to a higher default probability. In the right panel, the increase in the volatility of tax revenue and sovereign default probability translate to lower sovereign bond price as b' increases.

Besides its effect on the default probability, an increase in b' also has an effect on the risk premium. Figure 1.4.3 shows how the sovereign bond risk premium varies with b'. The left panel plots the covariance of tax revenue and the SDF against b'. The covariance becomes

[54] Exogenous variables are held at their mean level. Endogenous state variables are held at the mean level of the simulated data.

Figure 1.4.1: Effect of a change in next period capital k'



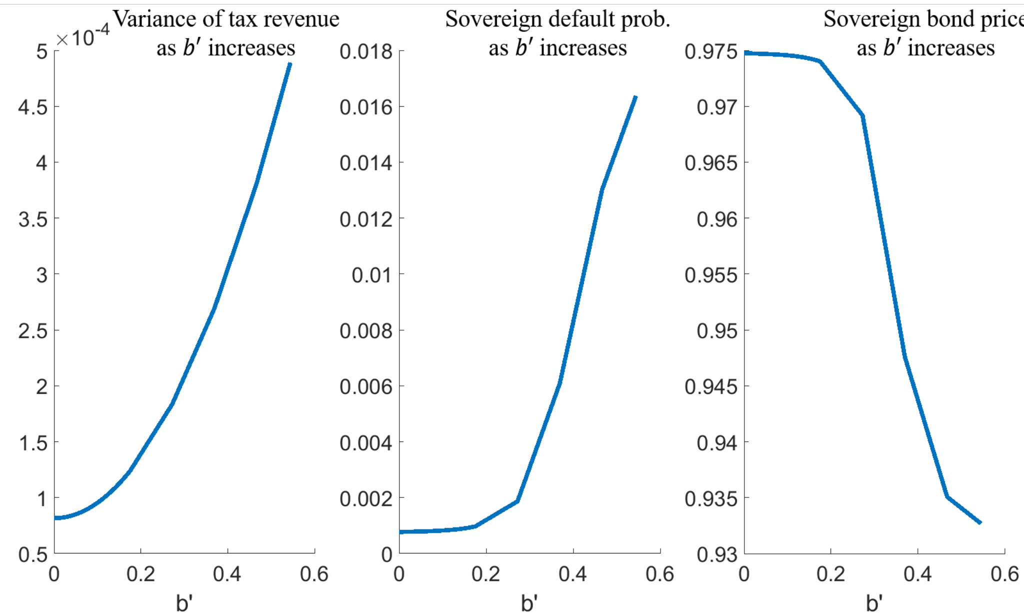
Notes: The figures plot the expected tax revenue, sovereign default probability, and sovereign bond price as next period capital k' varies. The state variables are held at their mean level and the other choice variables are held at their simulated mean level.

more negative as b' increases. Since the debt is denominated in FC, a FC appreciation reduces the profit of the entrepreneur, which leads to lower tax revenues. The higher b' amplifies the tax revenue contraction for the same unit of FC appreciation. SDF increases when FC appreciates, therefore the covariance of the SDF and tax revenue becomes more negative. This affects the sovereign risk premium as tax revenues shrink more and default is more likely at the states when foreign lenders have a high valuation on cash-flow. The higher b' increases the sovereign risk premium.

Iso-default probability

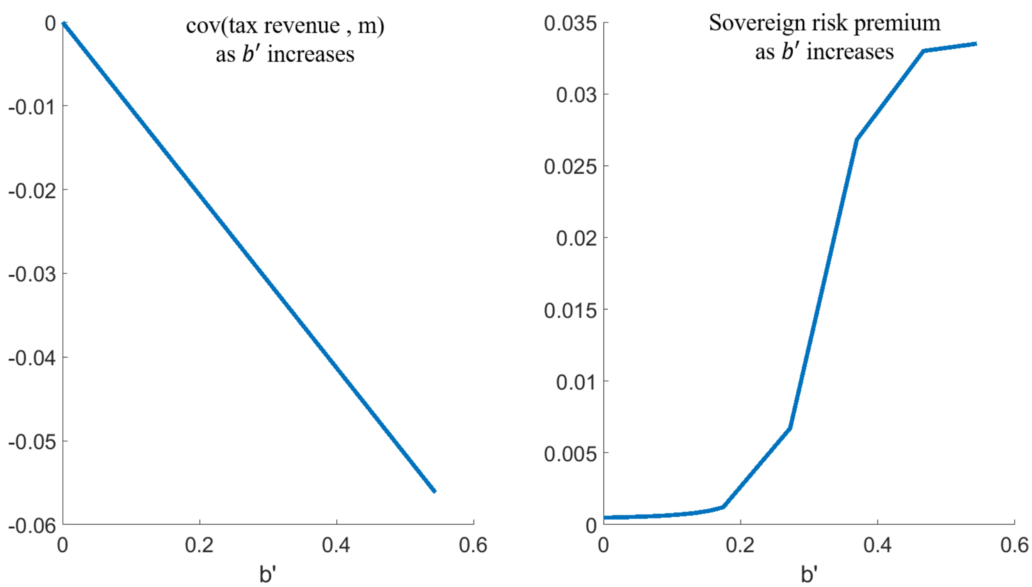
The set of figures above show the two entrepreneur decisions individually and their relationship to the sovereign bond price. In Figure 1.4.4, we plot a contour map (iso-default probability curve) of the sovereign default probability as k' and b' vary, holding the exogenous variables at their mean values. Each of the contour lines represents a set of (k', b') pairs such

Figure 1.4.2: Effect of a change in bond issuance b'



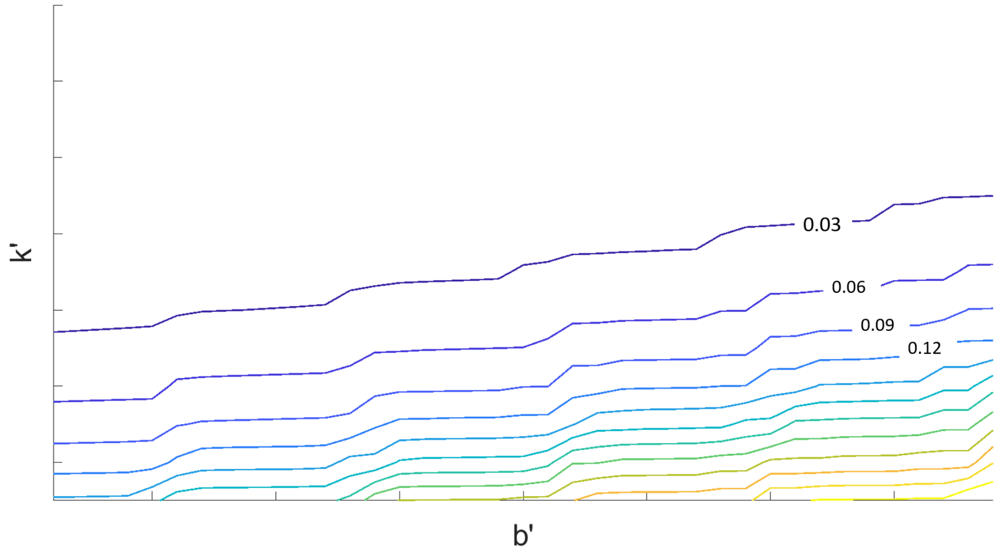
Notes: The figures plot the variance of tax revenue, sovereign default probability, and sovereign bond price as bond issuance b' varies. The state variables are held at their mean level and the other choice variables are held at their simulated mean level.

Figure 1.4.3: Relationship of sovereign risk premium and bond issuance b'



Notes: The figures plot the covariance of tax revenue and stochastic discount factor (m), and sovereign risk premium as bond issuance b' varies. The state variables are held at their mean level and the choice variables are held at their simulated mean level.

Figure 1.4.4: Iso-sovereign default probability contour when entrepreneur bond and capital varies



Notes: The figures plot the iso-default probability curve for the sovereign when next period capital k' and bond issuance b' vary. The state variables are held at their mean level and the other choice variables are held at their simulated mean level.

that sovereign default probability is the same. The contour lines are upward sloping because the two variables have opposite effects on the sovereign bond price, as was shown above. An increase in bond issuance increases the sovereign default probability and an increase in next period capital decreases the sovereign default probability. When entrepreneurs increase their bond issuance, the sovereign default probability can be maintained at the same level if they invest a sufficiently large amount of the bond proceeds to accumulate capital.[55]

Experiment: A reduction in the risk-free interest rate

In the model, both corporate bond issuance and capital are endogenous variables, and the optimal choices of both respond to shocks. The fact that the increase in FC corporate debt is a common phenomenon for many emerging countries suggests it is more plausible that there

[55]Empirically, a quarterly panel two-way fixed effect regression of regressing the country level capital to GDP on FC corporate debt to GDP for the sample countries is significantly positive at 1% level with a coefficient of 0.78. Using a firm level panel regression for a large set of emerging countries, Bruno and Shin (2017) documents that ,on average, for each unit of USD a firm borrows, the firm's CapEx increases by 40 centin the next 3 years.

is a common shock that drives this behavior. Consistent with many empirical findings, we hypothesize a credit supply-side story in which a reduction of the world risk-free interest rate acts as the exogenous driver of the observed increase in FC corporate debt.[56] We examine how a change in the risk-free rate changes the optimal bond level and capital accumulation and therefore the sovereign bond price.

Figure 1.4.5 shows the conditional sovereign default probability, conditioning on the exchange rate in the next period ($\log(S')$) for two different interest rates (2.5% and 0.1%). Conditional on a particular exchange rate level next period,[57] there is some probability of default for the sovereign because of the uncertainty about other stochastic variables such as TFP and sovereign cost of default next period. The figure in the upper panel plots the conditional sovereign default probability when the interest rate is high (2.5%). Given the state variables,[58] the equilibrium decisions pin down the optimal capital accumulation and bond issuance (k'^* and b'^*), which deliver the shape of the conditional sovereign default probability line. The conditional sovereign default probability is upward sloping. The positive slope is due to a local currency depreciation increases the debt burden of the economy and reduces tax revenue, which causes a high marginal utility gain from default. In this case, repayment only happens if TFP or the cost of default are at higher levels. Therefore, the conditional default probability goes up as S' increases.

In the lower panel, we superimpose the conditional sovereign default probability line for high and low interest rate regimes. Upon a reduction in the risk-free interest rate, entrepreneurs

[56]For example, the contemporaneous correlation between FC corporate debt to GDP and the 5-year US Treasury rate ranges from -0.42 to -0.67 for the countries we show in Figure . Papers by Alter and Elekdag (2017), Bruno and Shin (2017), and Bräuning and Ivashina (2019) provide empirical support that the low US interest rate is an important factor for the increase in both bonds and loans to emerging markets.

[57]Note that we are not assuming the sovereign knows the exchange rate next period. The exercise analyzes what would happen if the exchange rate happens to be at a particular point next period.

[58]For this illustration, we hold exogenous variables at their mean. Endogenous state variables are held at the simulated mean. We also hold the sovereign debt level constant, just to focus on the effect of the entrepreneurs' response..

take advantage of the cheap financing by increasing k' and b'. We denote the optimal k' and b' at the low risk-free rate as k'^{**} and b'^{**}, where $k'^{**} > k'^{*}$ and $b'^{**} > b'^{*}$. These optimal choices change the shape of the conditional sovereign default probability, which is the red line in the lower panel. We describe the changes in three steps. First, the increase in bond issuance (b') makes the conditional probability line steeper, increasing default probability when the local currency depreciates (right-hand side of the figure) and decreasing the default probability when the local currency appreciates. Overall, this effect increases the default probability, as the utility curvature makes the loss from a local currency depreciation more painful than the gain from a local currency appreciation. This is the "exchange rate effect" of the corporate debt.

Second, because part of the increase in bond issuance is used to finance more next period capital (k'), the additional capital pulls down the conditional sovereign default probability line for all S'. This can be seen at the point when $\log(S') = 0$. As we hold the exchange rate at the mean level for this illustration (i.e. $\log(S) = 0$), $\log(S') = 0$ means there is no exchange rate change next period and the corporate bond has no effect on the tax revenue. The conditional sovereign default probability at this point is below the one when the interest rate is high, indicating that the additional capital lowers the default probability. This is the "investment effect" of corporate debt. The exchange rate effect and investment effect counteract each other. Graphically, the low interest rate equilibrium (red line) has a larger conditional default probability on the right-hand side of the intersection point but a smaller conditional default probability on the left-hand side. Mathematically, denote $P(D' = 1|S')$ as the conditional sovereign default probability. The default probability is an unweighted integral of the area below the line: $\int [P(D' = 1|S')] \mathrm{d}F(\log(S'))$. In this particular example, the unconditional sovereign default probability of the high interest rate case is 33 basis points, and is 32 basis points for the low interest rate case.[59] The combination of the two effects leads to an insignificant change in sovereign default premium.

Third, in the low interest rate case, because of the higher debt level, the conditional sovereign default probability is tilted towards the region where the local currency depreciates. This means that sovereign default is more likely to happen when the foreign currency appreciates, which is the state when foreign lenders value the repayment more. This is the "state switching effect" of the corporate debt. The increase in corporate debt alters the region where sovereign default is more likely to happen, and it increases the likelihood of sovereign default in the state that the foreign lenders don't prefer. It increases the risk premium that is charged to compensate for taking the risk. Mathematically, the risk premium is a SDF weighted integral of the conditional sovereign default probability: $\int[m' - E(m')]P(D' = 1|S')\mathrm{d}F(\log(S'))$, where the foreign lenders put more weight on the region where the foreign currency appreciates. In this particular example, the risk premium goes up from 37 basis points to 54 basis points.

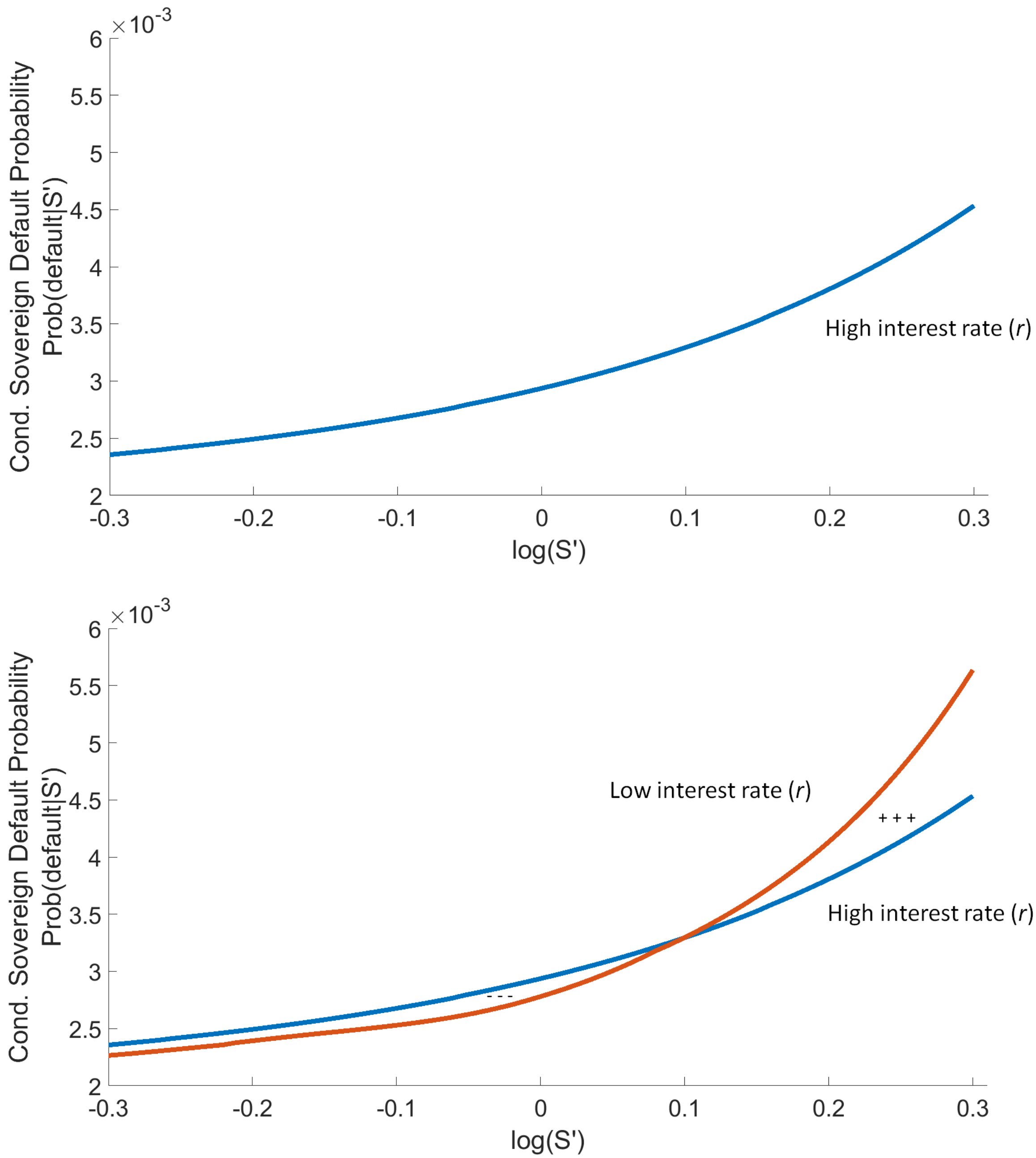
To summarize, when there is a reduction in the risk-free interest rate, the entrepreneurs' optimal behavior increases corporate debt and capital accumulation, which has opposite effects on sovereign default probability. However, the increase in FC corporate debt causes the sovereign to default more often in the region in which foreign lenders value more the repayment (FC appreciates), leading to a higher premium.

Predictions

The model has two testable predictions. First, upon an exchange rate change, a country with a higher corporate FC debt to GDP has a larger change in default premium. Second, holding the debt level constant, an increase in capital stock or investment decreases default premium. Similarly, holding capital stock or investment constant, an increase in corporate debt is associated with an increase in default premium. We test these predictions by augmenting the baseline

[59] The default premium is $E(m')\{\int[P(D' = 1|S')]\mathrm{d}F(\log(S'))\}$, which is the default probabilty weighted by a constant.

Figure 1.4.5: Conditional sovereign default probability under two interest rate regime



Notes: The figure shows sovereign default probability conditioning on $\log(S')$. In this illustration, exogenous variables at their mean (e.g. $\log(S) = 0$). Endogenous state variables are held at the simulated mean. Sovereign debt level is held constant to focus on the effect from entrepreneurs' response.

regression in eq (1.3) in two ways. First, we add exchange shocks identified through high frequency FOMC surprise and interact these exchange rate stocks with corporate FC debt to GDP. Second, we control for investment to GDP and capital stock to GDP. These predictions are verified and reported in Appendix A.10.

1.4.3 Business cycle moments and model performance

In this subsection, we evaluate the model performance by giving the model an unexpected risk-free rate reduction. This reduction in interest rate mimics the low risk-free rate environment post-2008 and incentivizes the increase in FC corporate debt in the model. We then compare the untargeted post-2008 moments with the model moments generated from the low risk-free rate case.

In Table 1.4.3, we reproduce the long-run moments in Table 1.4.2 in Panel (A). Panel (B), reports the model simulated moments that are generated under the low-interest rate scenario (0.01%), showing that the model also mimics the post-crisis period well. First, the FC corporate debt to GDP ratio goes up to 11.4%, which is close to the post-crisis mean of 12.2%.[60] There is a small change in the corporate default rate. This is consistent with some recent empirical findings that an increase in corporate leverage doesn't generate a significant change in corporate default risk.[61] Second, when we look at the moments of interest in the government sector, our model also predicts the untargeted post-2008 period well. This period features a small increase in sovereign FC debt to GDP and default premium, but a large increase in risk premium. Interestingly, in the simulated data, FC corporate debt increases 3.8% across the

[60]This is consistent with Chang et al. (2017) who find that, with the world interest rate shock as the prime driving force, their calibrated model can account for the dynamics of growth in foreign debt in the emerging markets well.

[61]For example, Salomao and Varela (2018) find that Hungarian firms which borrow more in FC do not exit the market more often. Alfaro et al. (2019) also find an insignificant relationship between corporate leverage and default risk, measured by Altman's Z score.

Table 1.4.3: Model generated moments and data

	Panel (A) Pre-2008 period Targeted moments		Panel (B) Post-2008 period Untargeted moments	
	Data (Mexico)	Model	Data (Mexico)	Model
Corporate Sector				
corporate FC debt to GDP	7.6%	7.6%	12.6%	11.4%
corporate default rate*	1.8%	1.8%	2.8%	2%
Sovereign Sector				
sovereign FC debt to GDP	4.2%	4.3%	4.4%	4.8%
sovereign default premium	37 basis points	37 basis points	42 basis points	47 basis points
sovereign risk premium	57 basis points	56 basis points	94 basis points	83 basis points

Notes: Panel (A) is simulated with the parameters reported in Table 1.4.1 (with 2.5% risk-free rate). Panel (B) is simulated with the same set of parameters with the risk-free rate changed to 0.1%, matching the post-2008 average. Moments are computed by generating 600 simulation samples of 400 periods each and discarding the first 300 periods. Default and the year after default are excluded.

*Due to the lack of country-specific data, we use Latin America corporate default rate reported by M&G investments.

two regimes and the sovereign risk premium increases by 27 basis points. This gives an average effect of 1% change in corporate debt to 7 basis points change in sovereign risk premium, which is close to our panel regression results in Table 1.2.1 (5.2 and 5.9 basis points). Overall, given a reduction in the world interest rate, the model predicts both corporate and government sector moments of interest well.

1.5 Social planner

This section focuses on the spillover from the entrepreneurs to the sovereign, which generates an externality to the sovereign and affects sovereign debt pricing. We discuss the key trade-off in 1.5.1 and the social planner solution in 1.5.2.

1.5.1 Trade-offs:

We analyze the effect of increasing FC corporate debt by investigating the Euler equation . For expositional purposes, we assume that the bond price schedule and value functions are differentiable and normalize $S = 1$. The first order condition of the entrepreneur debt decision is:

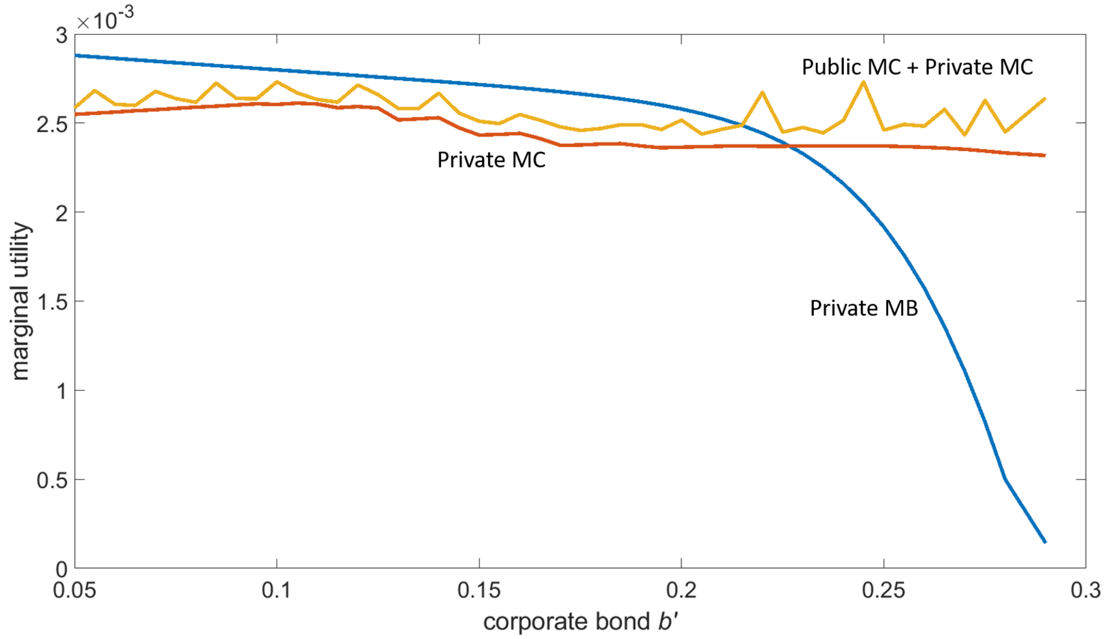
$$\underbrace{u_c'(c,G)[q+\frac{\partial q}{\partial b'}b']}_{\text{private marginal benefit}} = \underbrace{\beta E(u_c'(c',G')[S'-(\tau)\Delta S']|d'=0)}_{\text{private marginal cost}} \tag{1.1}$$

The above Euler equation arises in typical default models as in Arellano (2008) and Arellano and Ramanarayanan (2012), except for the new term $[S'-(1-\tau)\Delta S]$, which is equal to 1 in those models. Entrepreneurs face a trade-off between the marginal benefits (MB) today of having one additional unit of debt and the marginal costs from repaying the debt tomorrow. On the marginal benefit (MB) side, the trade-off takes into account the extensive margin cost of an extra unit of bond (q) and the intensive margin of an extra unit of bond affecting the price of the whole issuance ($\frac{\partial q}{\partial b'}b'$). On the marginal cost side, the trade-off takes into account that bond repayment is relevant only in the states where the entrepreneur repays. The new term $S'-(\tau)\Delta S'$ arises as exchange rate affect the entrepreneurs' income. The constant tax rate serves as an automatic stabilizer, as the tax duty goes down when repayment is high.

Private decisions also influence the sovereign bond price schedule. From the social planner's standpoint, the optimal trade-off takes into account the equilibrium effect that if everyone increases b' by Δb, the aggregate corporate debt $\overline{b'}$ also increases by Δb. In other words, $\partial\overline{b'} = \partial b'$. The first-order condition of choosing the debt level from the social stand point is thus:

The second term on the right-hand side represents an additional trade-off because an additional unit of corporate bond also translates into a bigger change in corporate tax revenue when the exchange rate fluctuates. Because this effect alters the future period resources of the sovereign,

Figure 1.5.1: Marginal benefits and marginal costs of corporate bond (b')



it changes the sovereign bond price in the current period, which is the second term on the left-hand side.

Figure 1.5.1 plots the trade-off numerically from the quantitative model. The private MB always slopes downward, as more debt lowers the price of the corporate bond.[62] The private MC first slopes upward but later slopes downward when the private default probability increases far enough.[63] We also take the term $u'_G(c,G)[\frac{\partial \overline{b'}}{\partial b'}\frac{\partial Q}{\partial \overline{b'}}B']$ to the right-hand side of eq (**??**) to combine the private MC and public MC as the social MC. The social MC is always above the private MC, which means the public MC is positive. The entrepreneur always exerts a negative externality on the sovereign.

1.5.2 Social planner solution

In this subsection, we analyze the social planner's solution, which internalizes the externality from the corporate sector to the sovereign sector.

Specifically, we consider a constrained social planner's solution where the social planner chooses both the entrepreneurs' choice variables (k', b') and the sovereign choice variable (B').[64] It is also subject to the same set of frictions and technology as in the decentralized solution. For example, the social planner cannot commit to repay, thus the bonds are still subject to default risk and the corporate tax rate is fixed.

Mathematically, the social planner problem is:

$$
\begin{gathered}
V^S(B,k,b;X) = \max_{B',k',b'} \{u(c,G) + \beta E_{X'|X} U(k',b';X')\} \ , \\
\text{subject to} \\
G + (1-D)SB \leq \tau[z\bar{k}^{\alpha} - \Delta S\bar{b}] + SQ(B',k',b',X)B' \\
c + k' \leq (1-\tau)[zk^{\alpha} - (\Delta S)b] - (1-d)Sb + Sq(k',b',X)b' + (1-\delta)k \\
\text{and default and pricing condition eq (1.11, 1.13, 1.15, 1.16) as in the decentralized equilibrium.}
\end{gathered}
\tag{1.2}
$$

Table 1.5.1 compares the decentralized solution to the social planner's solution. The decentralized solution is the same as the model prediction in Table 1.4.3. In Panel (A), the social planner's solution has a lower FC corporate debt to GDP and a higher FC sovereign debt to GDP than the decentralized solution. The FC corporate debt to GDP is lower because the social planner internalizes the spillover from the corporate sector to the sovereign sector.

[62] Private MB could be negative (not shown) when the debt reaches the right-hand side of the Laffer curve.

[63] This is a common property of sovereign default models. See discussion in Kim and Zhang (2012).

[64] Another way to interpret this is that the sovereign in the decentralized problem also chooses the entrepreneurs' variables on their behalf.

Table 1.5.1: Model generated moments: decentralized and social planner solution

	Panel (A) Pre-2008 period		Panel (B) Post-2008 period	
	Decentralized	Social Planner	Decentralized	Social Planner
Corporate Sector				
corporate FC debt to GDP	7.6%	6.1%	11.4%	9.6%
corporate default rate	1.8%	1.7%	2%	1.9%
Sovereign Sector				
sovereign FC debt to GDP	4.3%	4.6%	4.8%	5.6%
sovereign default premium	37 basis points	35 basis points	47 basis points	51 basis points
sovereign risk premium	56 basis points	49 basis points	83 basis points	72 basis points

Notes: Panel (A) is simulated with the parameters reported in Table 1.4.1 (with 2.5% risk-free rate). Panel (B) is simulated with the same set of parameters with the risk-free rate changed to 0.1%, matching the post-2008 average. Moments are computed by generating 600 simulation samples of 400 periods each and discarding the first 300 periods. Default and the year after default are excluded.

This thus leads to a lower sovereign risk premium in equilibrium. The reduction in risk premium improves sovereign financing conditions, increasing the equilibrium FC sovereign debt to GDP.[65] All these patterns hold true in the low-interest rate case (post-2008) as well. Compared to the decentralized equilibrium, the transition from a high- to low-interest rate in the social planner's case has a smaller increment in FC corporate debt to GDP, a higher increment in FC sovereign debt to GDP, and a smaller increment in sovereign risk premium.

1.6 Conclusion

This paper investigates the spillover from corporate external debt to sovereign debt pricing.

[65]Conditional on the same amount of sovereign debt, the risk premium is reduced in the social planner solution. The higher FC sovereign debt actually increases the risk premium, but the simulated risk premium is still lower than the decentralized case.

We argue that the recent surge in FC corporate debt in many emerging countries has an unintended consequence in increasing sovereign credit spread. In making this argument, we first show empirically that an increase in FC corporate debt has a significant positive association with a higher sovereign risk premium but no significant association with the sovereign default premium. The empirical findings pose a challenge to standard sovereign default models, which put more focus on risk-neutral foreign investors and an endowment economy setup.

To reconcile the empirical findings, we build a sovereign default model with a corporate sector and risk-averse foreign investor. We calibrate the model quantitatively to Mexico and find that it can replicate the targeted pre-2008 crisis moments and untargeted post-2008 moments well. The model's main mechanism goes through corporate tax revenue to the sovereign. Entrepreneurs in the model borrow from abroad in FC and accumulate capital for production. The extra borrowing facilitates productive investment and production, which translates to lower sovereign default probability. The foreign currency nature of the corporate debt increases the exchange rate risk of profit and tax revenue, which translates to a higher sovereign default probability. These two opposite forces result in an insignificant effect on sovereign default premium (default probability). The increase in FC exposure, however, leads to profit reduction and makes it more likely for the sovereign to default when FC appreciates, which often coincides with bad times in foreign investor economy. This leads to a higher risk premium in sovereign debt pricing.

The paper provides counterfactual analysis by studying the social planner problem that internalizes the externality from corporate to sovereign debt pricing. The analysis finds excessive borrowing in FC corporate debt when compared to the decentralized economy. The social planner solution has on average a 1.5 percentage point lower corporate debt to GDP, a 0.5 percentage point higher sovereign debt to GDP, and a 10 basis point lower sovereign risk premium. This calls for a policy intervention such as a Pigovian tax or capital control to reduce the external FC corporate debt level and implement the social planner allocation.

Chapter 2

Liquidity and Exchange Rates: An Empirical Investigation

2.1 Introduction

The economics literature on foreign exchange rate determination has not had much success linking exchange-rate movements to standard macroeconomic variables. This problem has come to be known at the "exchange-rate disconnect" puzzle, as coined by Obstfeld and Rogoff (2000).[1]

Our tack is to look for the role of the liquidity return on government bonds in driving exchange rates. Engel (2016) suggests that this return – the non-monetary return that government short-term bonds provide because of their safety, the ease with which they can be sold, and their value as collateral, which is sometimes referred to as the "convenience yield" – may be important in understanding exchange rate puzzles.[2]

Our study uses measures of the liquidity yield on government bonds, as constructed by Du

[1] Engel (2014) provides a recent survey. Itskhoki and Mukhin (2017) is a recent attempt to build a model to account for the disconnect. One notable determinant of nominal exchange rate movements is the lagged real exchange rate, which arises from adjustment to real exchange rate disequilibrium. This point was made clearly by Mark (1995), and has found strong recent support by Eichenbaum et al. (2017).

[2] Krishnamurthy and Vissing-Jorgensen (2012)and Nagel (2016) study the convenience yield on U.S. Treasury assets. Valchev (2020) also studies a model in which the convenience yield plays a role in accounting for exchange-rate puzzles. Del Negro et al. (2019) find that convenience yields account for the long-run drop in global real interest rates.

et al. (2018a). These measures take the difference between a riskless market rate and the government bond rate to quantify the implicit liquidity yield on the government bond. Moreover, the Du et al. (2018a) measure "corrects" for frictions in foreign exchange forward markets and for sovereign default risk.

The liquidity yield can be associated with the deviation from uncovered interest parity that is now introduced as a standard feature in open-economy New Keynesian models. It is usually included so that the model can reproduce to some extent the observed volatility of real exchange rates.[3] Indeed, Itskhoki and Mukhin (2017) show that this deviation is key to being able to account for the disconnect puzzle. These models inevitably treat the deviation as an unobserved variable. One interpretation of our model and findings is that the uncovered interest parity deviation is partly observable and can be well-measured by the relative liquidity yield on government bonds.

The intuition for why the government bond convenience yield influences the exchange rate is straightforward. The liquidity that these bonds provide is attractive to investors and influences their investment decisions as if the bonds were paying an unobserved convenience dividend. The government bonds can pay a lower monetary return than other bonds with similar risk characteristics, and still be desirable. An increase in the liquidity yield, as measured by the difference between the private bond return and government bond return, will ceteris paribus lead to a currency appreciation much in the same way that an increase in the interest rate would affect the currency value. However, we note that in our equilibrium model, the liquidity return and the interest rate play somewhat different roles arising from the role of government bond returns and liquidity yield in the monetary policy rule. Thus, interest rates respond endogenously to inflation in a way that the convenience yield does not.

We find for each of the so-called G10 currencies that the relative liquidity yield (the home

[3] See Kollmann (2002) for an early example.

country yield relative to foreign country yields) has significant explanatory power for exchange rate movements.[4] That is, the role of the liquidity yield in driving exchange rates is not limited to the U.S., but is evident across all of the major currencies. Moreover, using guidance from a standard New Keynesian model but augmented with a role for liquidity returns on government bonds, we find that the customary determinants of exchange rate movements are statistically and quantitatively important after controlling for the liquidity yields. In particular, interest rate differentials and a lagged adjustment term for the real exchange rate (as in Eichenbaum et al. (2017)) are also important determinants of exchange rate movements. We subject our results to a large number of robustness tests, but find the models perform consistently well. Additionally, we undertake an instrumental variables specification to control for possible endogeneity of the relative liquidity yields, and again find consistently strong support for the model. In an exercise in the spirit of Meese and Rogoff (1983), we find our empirical model has a significantly better out-of-sample fit than a random walk model.

Our study is contemporaneous with Jiang et al. (2018), but with the following differences: First, our empirical specification is derived from a simple theoretical general equilibrium model, which is important in pinning down the permanent component of non-stationary nominal exchange rates.[5] The model merely augments the "canonical" three-equation open economy New Keynesian model (see Engel (2014), for a survey) with a model of the liquidity yield, which emphasizes that the liquidity yield is a "missing link" that helps solve the disconnect puzzle. Second, consistent with the model, our empirical work finds strong evidence for the role of government liquidity yields, interest rates and adjustment toward purchasing power

[4]Namely, Australian Dollar (AUD), Canadian Dollar (CAD), Euro (EUR), Japanese Yen (JPY), New Zealand Dollar (NZD), Norwegian Krone (NOK), Swedish Krona (SEK), Swiss Franc (CHF), British Pound (GBP) and United States Dollar (USD).

[5]Linnemann and Schabert (2015) also posit a relationship between liquidity returns and exchange rate behavior. Their paper does not provide an empirical test of the relationship between the liquidity return and exchange rates. Their model postulates a negative relationship between the liquidity yield and interest rates, contrary to the model of Nagel (2016), Engel (2016), and this paper, and contrary to the evidence in Nagel (2016) and this paper.

parity in monthly data for ten different currencies, while Jiang, et al. look only at quarterly changes in the U.S. dollar. That is, we emphasize that the liquidity yield is not solely a U.S. dollar story. We include an instrumental variables specification and do numerous robustness checks. Finally, using the decomposition of Du et al. (2018a), we find additional explanatory power arising from default risk and forward market frictions in a way that is compatible with our model.[6] This latter is important because the premium on government bonds is influenced not only by the liquidity yield, or "convenience yield", of government bonds, but also by default risk and frictions in forward markets for foreign exchange.[7]

We think of the liquidity return or convenience yield as arising from the usefulness of some government securities either as collateral for very short-term loans, or from the ease with which they can be sold for cash. Nickolas (2018) defines liquid assets as: "cash on hand or an asset that can be readily converted to cash. An asset that can readily be converted into cash is similar to cash itself because the asset can be sold with little impact on its value." But there is only a fine distinction between liquidity so defined and "safety" as defined by Gorton (2017): "A safe asset is an asset that is (almost always) valued at face value without expensive and prolonged analysis. By design, there is no benefit to producing (private) information about its value, and this is common knowledge." From these definitions, it is clear that safe assets will be liquid, and liquid assets are safe. The role of safe assets in the global economy has been studies extensively in recent literature. In Caballero et al. (2008), Mendoza et al. (2009), Gourinchas (2012), Maggiori (2017), and Farhi and Maggiori (2018), safe assets play a key role in accounting for global imbalances. Caballero et al. (2016, 2017) explore the role of a shortage of safe assets and their role in the global financial crisis. Gourinchas and Jeanne

[6] A small bit of our preliminary findings were first reported at a conference at the Bank for International Settlements on "International macro, price determination and policy cooperation" in September, 2017. The publicly available slides for that lecture can be found at https://www.bis.org/events/confresearchnetwork1709/programme.htm

[7] In fact, Avdjiev et al. (2019) document the role of deviations from covered interest parity for the value of the U.S. dollar.

(2012) explore the consequences of a shortage of safe assets for the stability of the global financial system.

Liquidity and its role in exchange-rate determination has been explored from a variety of angles. The aforementioned papers of Engel (2016) and Valchev (2020) offer models in which certain assets have a convenience yield arising from their liquidity. Grilli and Roubini (1992) and Engel (1992) are earlier, related works. Brunnermeier and Pedersen (2009), Adrian et al. (2010) and Bruno and Shin (2015) consider a liquidity effect on exchange rates arising from banks' balance sheets. One can identify the notions of liquidity in these studies with "funding" liquidity, as defined in Brunnermeier and Pedersen (2009), but other work has looked at the role of "market" liquidity. A prominent recent study is Gabaix and Maggiori (2015) that considers financial constraints that prevent full liquidity to arbitrage international money markets. A related study is Pavlova and Rigobon (2008) which investigates the role of portfolio constraints. Melvin and Taylor (2009), Banti et al. (2012), and Mancini et al. (2013) empirically study of the role of liquidity in foreign exchange markets.

There is a long history of attributing a role to the "safe haven" effect on currency values. Recently, Fatum and Yamamoto (2016), which looks at this phenomenon during the global financial crisis, defines a safe currency as "a currency that increases its relative value against other currencies as market uncertainty increases." The idea of a safe haven effect is an old one – see, for example, Dooley and Isard (1985), Isard and Stekler (1985) or Dornbusch (1986). Here we could argue that one channel for the safe haven effect is through the demand for safe assets. During times of global uncertainty, certain assets such as short-term government securities become more valued for their liquidity. There certainly can be other channels through which the safe haven phenomenon works. Farhi and Gabaix (2016) model safe haven currencies as ones that appreciate during times of global downturns, a concept that has been tested empirically by Ranaldo and Söderlind (2010). Obstfeld and Rogoff (2003) speak of risk more generally, which could encompass both the liquidity channel and the hedging channel.

Section 2, which guides our empirical work, presents an equilibrium New Keynesian model in which government bonds pay a liquidity return. Section 3 presents the results of our empirical investigation. Section 4 concludes.

2.2 Liquidity and Exchange Rates

Following Krishnamurthy and Vissing-Jorgensen (2012), Engel (2016), Nagel (2016), and Jiang et al. (2018), we posit that the ex ante excess return on short-term government bonds in one country relative to another is attributable to an unobserved liquidity payoff.

In particular, let i_t be the one-period interest rate in the "home" country government bonds (we present the model in the context of two countries, "home" and "foreign".) i_t^m is the return on a short-term, one-period market instrument. The liquidity premium represents the difference in these two rates: $\gamma_t = i_t^m - i_t$. For now, we assume that there is no default risk on either instrument. The empirical section will adjust the returns for default risk using credit default swap (CDS) data.

Under this formulation, we should observe $\gamma_t > 0$, as long as the government bond is more liquid. Investors are willing to hold the government bond instead of the market instrument, because the government bond is more easily sold on markets or is more readily accepted as collateral. It may be the case that some agents in the economy have no need for liquidity, in which case their holdings of the government bonds would be zero. In particular, it might be that foreign agents hold no home government bonds because they do not value the liquidity of those assets. But private agents cannot short government bonds – that is, private agents (in either economy) cannot borrow at the rate i_t, because the assets they issue do not have the same liquidity as government bonds.

Analogously, in the foreign country, there is a liquidity yield given by $\gamma_t^* = i_t^{*m} - i_t^*$, where the variables with the * superscript denote the foreign-country equivalents of the home-country variables.

We will assume that there is a deviation from uncovered interest parity for the market instruments, r_t, that is stochastic, exogenous and uncorrelated with the other shocks (monetary and liquidity) in the model. We remain agnostic about the source of this deviation. r_t could be a deviation from rational expectations, some sort of market friction, or perhaps a foreign exchange risk premium. In Jeanne and Rose (2002), Devereux and Engel (2002), and Itskhoki and Mukhin (2017), this term arises because of the presence of noise traders. We assume that r_t is uncorrelated with other shocks introduced into the model, to the monetary policy rule and to the liquidity return.[8]

$$i_t^{*m} + E_t s_{t+1} - s_t - i_t^m = r_t, \tag{2.1}$$

where is the log of the exchange rate (expressed as the home currency price of the foreign currency.)[9]

Let η_t be defined as the liquidity return on home government bonds relative to foreign government bonds:

$$\eta_t = \gamma_t - \gamma_t^* = (i_t^m - i_t) - (i_t^{m*} - i_t^*) = (i_t^m - i_t^{m*}) - (i_t - i_t^*)\,. \tag{2.2}$$

Then we can rewrite 2.1 as:

$$i_t^* + E_t s_{t+1} - s_t - i_t = \eta_t + r_t. \tag{2.3}$$

[8]Because we do not actually give a structural interpretation to the coefficient estimates of the predictive equation we derive, 2.3, we can assume something weaker than that the noise term is strictly uncorrelated with the other shocks.

[9]A simplification implicit here is that the standard "Fama" regression would not reject the null hypothesis. Under our specification for monetary policy, introduced below, with inflation predetermined and monetary shocks that are independent of the shocks to , we should not be able to reject uncovered interest parity using our measures of returns on market instruments. Supplementary Appendix A. shows, however that during our time sample, the null hypothesis is not rejected in the Fama regression for any of the G10 currencies.

Now, iterate equation 2.3 forward, as in Campbell and Clarida (1987) and others:

$$s_t = -E_t \sum_{j=0}^{\infty} (i_{t+j} - i^*_{t+j} - (\overline{i - i^*})) - E_t \sum_{j=0}^{\infty} (\eta_{t+j} - \overline{\eta}) - E_t \sum_{j=0}^{\infty} (r_{t+j} - r) + \lim_{k \to \infty} (E_t s_{t+k} - k(\overline{s_{+1} - s})). \tag{2.4}$$

We will assume that the interest differential, $i_t - i^*_t$; the liquidity return, η_t, and the u.i.p. deviation, r_t, are all stationary random variables, but s_t follows a unit root process.[10] The unconditional mean difference in the home and foreign interest rate is denoted $\overline{i - i^*}$, the mean of the relative liquidity return is $\bar{\eta}$, and the mean of the interest parity deviation is $\bar{r}$. Here, $\lim_{k \to \infty} (E_t s_{t+k} - k(\overline{s_{+1} - s}))$, which is a random variable when the exchange rate has a unit root, is the permanent component of the nominal exchange rate – in the sense that Beveridge and Nelson (1981) use that term in their permanent-transitory decomposition. The term $\overline{s_{+1} - s}$ represents the trend in the log of the nominal exchange rate.

There is some consensus that nominal exchange rates among high-income countries contain unit roots. For example, if monetary policy is set by a rule for money supplies, any permanent change in the money supply would lead to a permanent change in the nominal exchange rate. If monetary policy is set by an interest-rate rule such as a Taylor rule, the exchange rate will contain a unit root unless the interest rate rule targets the nominal exchange rate.[11]

Equation 2.4 already points to the intuition of our empirical specification. It says that when the infinite sum of the expected current and future home interest rates rises relative to the expected infinite sum of current and future foreign interest rate, the home currency appreciates (s_t falls.) That is a well-known channel of influence, which is at work in, for example, the famous Dornbusch (1976) model.

However, this comparative statics exercise is made holding the permanent component of the

[10] Technically, we assume $i_t - i^*_t$, η_t, and r_t are square summable, which insures that the infinite sums converge. Any finite order ARMA process, for example, is square summable.

[11] See Benigno and Benigno (2008).

exchange rate constant. All nominal interest rate changes may not be the same. For example, in a traditional monetarist model of exchange rates, a permanent one-time increase in the monetary growth rate in the home country would immediately raise inflation, and therefore raise the inflation premium incorporated in the nominal interest rate. $i_{t+j} - i^*_{t+j}$ would increase for all time periods, but that also implies an increase in the unconditional mean of the relative interest rates, $\overline{i - i^*}$. In that case, there would be no change in the first term on the right hand side of equation 2.4: $E_t \sum_{j=0}^{\infty} \left(i_{t+j} - i^*_{t+j} - \left(\overline{i - i^*}\right)\right)$ would be unaffected. However, this change would lead to an increase in the permanent component of the exchange rate. The size of the increase is model-dependent, but a classic result is that an increase in the growth rate of x percent leads to an immediate permanent depreciation of greater than x percent, which the literature referred to as the "magnification effect".[12] The conclusion is that equation 2.4 by itself, which represents the international financial market equilibrium condition, is not sufficient to determine the exchange rate. In order to determine the exchange rate, we need a model of the determination of interest rates, and of the permanent component of the nominal exchange rate.[13]

Before proceeding to close the model, we note that a higher relative liquidity return on home government bonds also leads to an appreciation of the domestic currency. In this equation, the liquidity return and the interest rate are just two components of the return on government bonds, and so their impact on the exchange rate is identical. In the model that we now present, the interest rates and liquidity return play different roles in the monetary policy rule, and are endogenously determined.

As a first step, we incorporate the model from Engel (2016), based in turn on Nagel (2016), in which the liquidity return on the home bond is positively related to the interest rate:

[12] See, for example, Frenkel (1976).

[13] Here we differ from Jiang et al. (2018), who take nominal interest rates as exogenous and assume the nominal exchange rate is stationary.

$$\eta_t = \alpha\,(i_t - i_t^*) + v_t, \alpha > 0. \tag{2.5}$$

Appendix B.1 derives this equation, extending the analysis of Engel (2016). The positive relationship between the relative liquidity return and the interest differential arises as in Nagel (2016). Specifically, when the monetary authority tightens monetary policy by reducing the supply of money and raising interest rates, liquid assets that can substitute for money become more valued for their liquidity services and so pay a higher liquidity return.[14]

The remainder of the model adopts a New Keynesian framework. First, we assume that nominal prices in each country are sticky in nominal terms. We posit that there is local-currency pricing, so that each firm, in both countries, sets two prices – one in home currency for sale in the home country, and one in foreign currency for sale in the foreign currency.

We modify the standard Calvo-pricing equation in two ways. First, we assume that nominal prices must be set one period in advance. We make this assumption because, in practice, the response of nominal prices to current period shocks is so small relative to the response of nominal exchange rates, that a model with predetermined prices better represents reality in an open-economy framework. A fraction of firms, θ, are allowed to change their prices optimally each period, but the price they set at time $t-1$ is for the time t period. Let $p_t^{r,H}$be the price for firms that reset their prices (which is identical for all such firms, because as in the standard New Keynesian framework, they face identical costs and demand functions.)

The remaining firms do not change their price optimally, but we assume that these firms build in an automatic price adjustment. We do not specify the trend term but impose a particular consistency restriction below. We let τ_t^H be the trend adjustment for home prices in the home country (set at time $t-1$.) The firms that adjust their price optimally consider any current

[14] This equation does not necessarily imply a positive relationship between the relative liquidity yields and the relative interest rates in equilibrium. We introduce below a monetary policy rule in which these two variables are negatively related. An increase in v_t here leads to an increase in η_t, which in turn will lead monetary policy makers to reduce $i_t - i_t^*$, leading to a negative correlation between $i_t - i_t^*$ and v_t.

disequilibrium in prices in planning their price increase, while the other firms simply adjust the price at the trend rate.

We have:

$$p_t^H - p_{t-1}^H = \theta\left(p_t^{r,H} - p_{t-1}^H\right) + (1-\theta)\,\tau_t^H. \tag{2.6}$$

15

The foreign currency price of home goods is set in a similar way:

$$p_t^{*H} - p_{t-1}^{*H} = \theta\left(p_t^{*r,H} - p_{t-1}^{*H}\right) + (1-\theta)\,\tau_t^{*H}$$

We now make two simplifying assumptions about the price setting process. The first is that firms, when they reset their price, set prices in such a way that there is no expected pricing to market: $p_t^{*r,H} = p_t^{r,H} - E_{t-1}s_t$. We can justify that assumption on the grounds that it is too costly for firms to calculate reset prices for each market they serve. As in the producer currency pricing model, we assume that firms calculate a single reset price, but then translate that price into the currency of each market they service. The local-currency price then remains unchanged until the next opportunity for price resetting. The second assumption is that, while we are agnostic about the process by which firms set the trend adjustment of their prices, we impose the following consistency requirement: $\tau_t^{*H} = \tau_t^H + E_{t-1}s_t - s_{t-1}$. That is, firms form a forecast of the exchange rate change, and then align their trend adjustments so that they are expected to be consistent, when expressed in a common currency, in the home and foreign market. These assumptions imply:

$$p_t^{*H} - p_{t-1}^{*H} = \theta\left(p_t^{r,H} - E_{t-1}s_t - p_{t-1}^{*H}\right) + (1-\theta)\left(\tau_t^H - (E_{t-1}s_t - s_{t-1})\right) \tag{2.7}$$

Subtracting 2.7 from 2.6, we find:

$$E_{t-1}s_t - s_{t-1} + p_t^{*H} - p_{t-1}^{*H} - \left(p_t^H - p_{t-1}^H\right) = \theta\left(p_{t-1}^H - s_{t-1} - p_{t-1}^{*H}\right) \tag{2.8}$$

[15] See Engel (2019) for a study of the relationship of the price setting behavior in this model compared to the more standard Calvo pricing framework.

The expected change in the pricing to market arises from the adjustments of the fraction of firms that reset their prices each period.

An analogous equation can be derived for the prices set by the foreign firm: p_t^{*F} in foreign currency for sale in the foreign country, and p_t^F in home currency for sale in the home country:

$$E_{t-1}s_t - s_{t-1} + p_t^{*F} - p_{t-1}^{*F} - \left(p_t^F - p_{t-1}^F\right) = \theta\left(p_{t-1}^F - s_{t-1} - p_{t-1}^{*F}\right) \tag{2.9}$$

We assume that consumption preferences over the two goods are identical so that the real exchange rate is driven entirely by the deviations from the law of one price that arise from pricing to market. The log of the consumer price basket in each country is a weighted average of the logs of the prices of foreign-produced and home-produced goods. Taking the weighted average of equations 2.8 and 2.9, we arrive at:

$$\pi_t - \pi_t^* = \theta q_{t-1} + E_{t-1}s_t - s_{t-1}. \tag{2.10}$$

In this equation, q_{t-1} is the log of the real exchange rate (the price of the consumer basket in the foreign country relative to the home country), π_t is home consumer price inflation between $t-1$ and t, and π_t^* is foreign consumer price inflation. Note that because prices are set one period in advance, the inflation rates, π_t and π_t^*, are observable at time $t-1$. Under this specification of price adjustment, the real exchange rate is a stationary random variable and long-run purchasing power parity holds. The pricing to market disequilibria are expected to dissipate over time.

These small modifications to the standard open-economy Phillips curve are introduced here in order to motivate our empirical model of the exchange rate in an intuitive way. In particular, as is well-known from Benigno (2004), price stickiness would not matter at all for the adjustment of the real exchange rate with a standard Calvo-pricing equation, unless interest-rate smoothing is introduced into the monetary policy rule. Engel (2019) shows how the Phillips curve here, along with serially correlated errors in the monetary policy rule produces very similar real exchange rate behavior as the Calvo pricing model with interest rate smoothing, but this model is more analytically convenient.

The final component of the model is the characterization of monetary policy behavior. We model this as a very simple Taylor rule that targets inflation. We assume that the monetary authority has control of a policy rate that is a weighted average of the government bond rate and the market rate. In the home country:

$$(1-\psi)\,i_t + \psi i_t^m = \sigma\pi_t + u_t, 0 \le \psi \le 1 \tag{2.11}$$

In practice, the policy rate is closely aligned with the government bond rate in the countries in this study.[16] We use this specification to avoid introducing yet another interest rate, the monetary policy rate, and remain agnostic on the correct value of ψ. None of the qualitative conclusions from the model depend on the value of ψ. Another interpretation of this equation is that the government interest rate is the policy rate, and the policy maker targets the liquidity premium by lowering the policy rate when the market places a high value on liquidity:

$$i_t = \sigma\pi_t - \psi\,(i_t - i_t^m) + u_t$$

The stability condition in this model is given by $\sigma > \frac{1+\alpha}{1+\alpha\psi}$, and so we assume $\sigma > 1$. u_t is a deviation from the monetary policy rule. There is an analogous equation in the foreign country, which targets consumer price inflation in that country. Subtracting the foreign Taylor rule from the home Taylor rule gives us:

$$i_t - i_t^* = \sigma\,(\pi_t - \pi_t^*) - \psi\eta_t + u_t - u_t^*. \tag{2.12}$$

We assume that the relative error terms in the monetary rules follow a first-order autoregressive process:

$$u_t - u_t^* = \delta\left(u_{t-1} - u_{t-1}^*\right) + \xi_t, 0 \le \delta < 1 \tag{2.13}$$

[16]Supplementary Appendix A provides evidence to support this statement.

where ξ_t is a mean-zero, i.i.d. random variable.

Equations 2.3, 2.5, 2.10 and 2.12 – the international financial market equilibrium condition, the model of the liquidity premium, the (relative home to foreign) open economy Phillips curve, and the (home relative to foreign) monetary policy rule – give us a complete dynamic system for the real exchange rate, inflation and interest rates. The model incorporates slow adjustment of the real exchange rate because of nominal price stickiness, governed by the parameter θ, the fraction of the firms that reset their price optimally each period. As Eichenbaum et al. (2017) have recently emphasized, empirically almost all the adjustment of real exchange rate comes through adjustment by the nominal exchange rate. That is, inflation rates in each currency play little role in the expected convergence of the real exchange rate to its unconditional mean (which is normalized to zero, meaning the deviations from the law of one price are expected to disappear in the long run.) Eichenbaum et al. (2017) demonstrate that this empirical regularity can be captured in a New Keynesian model with strong inflation targeting (large value of σ). When inflation targeting is strong, inflation has a low variance even if the variance of the real exchange rate is large. If inflation does not move enough to achieve real exchange rate adjustment, that role is left to the nominal exchange rate.

–

The sources of shocks in this simplified model are monetary shocks (in equation (2.12)), the uncovered interest parity shocks in equation (2.1), and liquidity shocks in equation (2.5). We have already noted that monetary shocks are assumed to be follow an AR(1) process. We assume that there is persistence in liquidity, and that also follows a first-order autoregressive process:

$$v_t = \rho v_{t-1} + \varepsilon_t, \tag{2.14}$$

where ε_t is mean-zero, i.i.d., and $0 \leq \rho < 1$. Furthermore, we assume that the deviation from uncovered interest parity also follows an autoregressive process given by:

$$r_t = \varsigma r_{t-1} + \omega_t, 0 \leq \varsigma < 1. \tag{2.15}$$

The model can be solved by hand.[17] For the real exchange rate, we find:

$$\begin{aligned} q_t = \quad & -\left(\tfrac{\sigma(1+\alpha)-(1-\theta)(1+\alpha\psi)}{\theta(1+\alpha\psi)}\right)(\pi_t - \pi_t^*) \\ & -\left(\tfrac{(1+\alpha)[\sigma(1+\alpha)-(1-\theta)(1+\alpha\psi)]}{\theta(1+\alpha\psi)(\sigma(1+\alpha)-\delta(1+\alpha\psi))}\right)(u_t - u_t^*) \\ & -\left(\tfrac{(1-\psi)[\sigma(1+\alpha)-(1-\theta)(1+\alpha\psi)]}{\theta(1+\alpha\psi)[\sigma(1+\alpha)-\rho(1+\alpha\psi)]}\right)v_t - \left(\tfrac{\sigma(1+\alpha)-(1-\theta)(1+\alpha\psi)}{\theta[\sigma(1+\alpha)-\zeta(1+\alpha\psi)]}\right)r_t \end{aligned} \tag{2.16}$$

The inflation variables at time t are predetermined, so 2.16 expresses the real exchange rate in terms of predetermined and exogenous variables. A relative monetary tightening in the home country (an increase in $u_t - u_t^*$) causes a real appreciation of the home currency. Similarly, an increase in the liquidity yield on home government bonds leads to a real appreciation. Note that as inflation targeting becomes more stringent, so σ is larger, the real exchange rate reacts more to monetary policy shocks if $\delta < 1 - \theta$. If $\rho < 1 - \theta$, a larger σ increases the response of the real exchange rate to changes in the relative liquidity return. We assume in all following discussion that both preceding inequalities are satisfied. Also, the greater price stickiness (smaller θ), the larger the response of the real exchange rate to monetary policy shocks and the relative liquidity returns.

We note that the nominal interest differential is simply a linear combination of the predetermined relative inflation rates and the exogenous errors in the monetary policy rules, as given by equation 2.12. It is intuitive to replace the monetary errors, using 2.12, with

$$u_t - u_t^* = (1 + \alpha\psi)(i_t - i_t^*) - \sigma(\pi_t - \pi_t^*) + \psi v_t.$$

Then with some rearranging, we can write the solution for the real exchange rate in terms of relative inflation, the nominal interest rate differential, and the liquidity shock:

[17] The full derivation of the model is in Supplementary Appendix B.

$$
\begin{aligned}
q_t =& \frac{\delta\left[\sigma\left(1+\alpha\right)-\left(1-\theta\right)\left(1+\alpha\psi\right)\right]}{\theta\left(\sigma\left(1+\alpha\right)-\delta\left(1+\alpha\psi\right)\right)}\left(\pi_t-\pi_t^*\right) \\
&-\left(\frac{\left(1+\alpha\right)\left[\sigma\left(1+\alpha\right)-\left(1-\theta\right)\left(1+\alpha\psi\right)\right]}{\theta\left(\sigma\left(1+\alpha\right)-\delta\left(1+\alpha\psi\right)\right)}\right)\left(i_t-i_t^*\right) \\
&-\left(\frac{\left[\sigma\left(1+\alpha\right)-\left(1-\theta\right)\left(1+\alpha\psi\right)\right]\left[\sigma\left(1+\alpha\right)-\left(\delta\left(1-\psi\right)+\rho\psi\left(1+\alpha\right)\right)\right]}{\theta\left(\sigma\left(1+\alpha\right)-\delta\left(1+\alpha\psi\right)\right)\left(\sigma\left(1+\alpha\right)-\rho\left(1+\alpha\psi\right)\right)}\right)v_t \\
&-\left(\frac{\sigma\left(1+\alpha\right)-\left(1-\theta\right)\left(1+\alpha\psi\right)}{\theta\left[\sigma\left(1+\alpha\right)-\zeta\left(1+\alpha\psi\right)\right]}\right)r_t
\end{aligned}
\tag{2.17}
$$

In this equation, tighter monetary policy is represented by higher nominal interest rates, which imply a currency appreciation.

Our empirical analysis aims at explaining movements in the log of the nominal exchange rate, $s_t - s_{t-1}$. With some manipulation, using equations 2.5, 2.10, and 2.17, we derive:

$$
s_t - s_{t-1} = \beta_1 q_{t-1} + \beta_2(\eta_t - \eta_{t-1}) + \beta_3(i_t - i_t^* - (i_{t-1} - i_{t-1}^*)) + \beta_4 \eta_{t-1} + \beta_5(i_{t-1} - i_{t-1}^*) + z_{j,t}
\tag{2.18}
$$

where

$\beta_1 = -\left(\frac{\sigma(1+\alpha)(1-\theta-\delta)}{\sigma(1+\alpha)-\delta(1+\alpha\psi)}\right) < 0,$

$\beta_2 = -\left(\frac{[\sigma(1+\alpha)-(1-\theta)(1+\alpha\psi)][\sigma(1+\alpha)-(\delta(1-\psi)+\rho\psi(1+\alpha))]}{\theta(\sigma(1+\alpha)-\delta(1+\alpha\psi))(\sigma(1+\alpha)-\rho(1+\alpha\psi))}\right) < 0,$

$\beta_3 = -\left(\frac{[\sigma(1+\alpha)-(1-\theta)(1+\alpha\psi)][(1+\alpha)(\sigma-\rho)+\alpha\delta(1-\psi)]}{\theta(\sigma(1+\alpha)-\delta(1+\alpha\psi))(\sigma(1+\alpha)-\rho(1+\alpha\psi))}\right) < 0.$

and $z_t = -\left(\frac{\sigma(1+\alpha)+\theta-1}{\theta(\sigma(1+\alpha)-\varsigma)}\right)\omega_t + z_1 r_{t-1}$

The full expressions for β_4,β_5 and z_1 are presented in Supplementary Appendix B.

Our empirical specification for the depreciation of the exchange rate includes, first, an error correction term as the nominal exchange rate adjusts to disequilibrium in the real exchange rate. Second, the change in the interest differential affects the exchange rate as in standard New Keynesian models. Third, the change in the relative liquidity return on government bonds plays a role in influencing the exchange rate. Lagged levels of the relative interest differentials and liquidity returns capture the dynamic adjustment. Under the parameter restrictions of the model – $\sigma > 1$, $\alpha > 0$, $0 \leq \theta < 1$, $0 \leq \rho < 1$, and $\rho < 1 - \theta$ – ceteris paribus, an increase in

q_{t-1}, and increase in $i_t - i_t^* - (i_{t-1} - i_{t-1}^*)$, and an increase in $\eta_t - \eta_{t-1}$ all lead to a decline in $s_t - s_{t-1}$. That is, the home currency appreciates to correct for a real undervaluation, and it appreciates in response to a relative increase in either the home interest rate or the home liquidity return. The error term, z_t, is a function of the dynamics of the deviation from uncovered interest parity, which is assumed not to be observable by the econometrician. It is by construction uncorrelated with the explanatory variables in the regression. The derivation implies that there may be serial correlation in the regression error. However, as shown in Supplementary Appendix B, for parameters calibrated to the data, the serial correlation of the residual is very low (around 0.02, for example), as it is in the data.[18]

Before turning to the data, we note a few features of our empirical specification based on 2.18. As in our model, we follow convention and treat nominal exchange rates as non-stationary random variables. Considering much evidence, from Mark (1995) to more recent empirical evidence in Engel (2016) and Eichenbaum et al. (2017), the real exchange rate is stationary, and the nominal exchange rate adjusts in the direction of restoring purchasing power parity. Relative interest rates and relative liquidity returns are stationary. We allow dynamics by including contemporaneous and lagged values of these variables. Because these variables are serially correlated, we enter them in the specification as in 2.18 with the first difference in the returns and the lagged level of the returns. This reduces the multicollinearity that would be present if these variables were included in contemporaneous and lagged levels and gives us the natural interpretation that changes in relative interest rates and changes in relative liquidity yields influence changes in the log of the nominal exchange rate.

It is important to note that β_3 measures the impact of monetary policy shocks, $u_t - u_t^*$, on s_t, while β_2 quantifies the effect of shocks to the relative liquidity yield, v_t, on the log of the exchange rate. To see this, first observe from the relative Taylor rules, 2.12, that the home

[18] See Supplementary Appendix B for the derivation of equation 2.18, and of the serial correlation of the residual.

relative to foreign interest rate differential depends on relative inflation, η_t and the monetary policy shocks. However, from equations 2.10 and 2.3, we see that relative inflation, $\pi_t - \pi_t^*$ is predetermined and a function of the lagged interest rate differential and liquidity yield, $i_{t-1} - i_{t-1}^*$ and η_{t-1}.[19] Because these latter two variables and η_t are controlled for in 2.18, the independent effect of $i_t - i_t^*$ arises only from the monetary policy shocks. Equation 2.5 finds η_t is a function of the interest rate differential as well as the independent shocks to liquidity. Since the regression equation controls for $i_t - i_t^*$, the independent effects of the shocks to liquidity are measured by the coefficient on η_t.

2.3 Empirical Investigation of Government Bond Liquidity and Exchange Rates

In this section, we present our empirical results. We first describe how we construct the measure of government bond liquidity in 3.1. Subsection 3.2 presents our baseline result that the change in the relative government bond liquidity returns is strongly correlated with exchange rate movements. We show our results are robust to controlling for certain market frictions in section 3.3, and we estimate instrumental variable regressions in subsection 3.4. In subsection 3.5, we further confirm that country-specific government bond liquidity matters. Finally, in subsection 3.6, we conduct an out-of-sample fit exercise a la Meese and Rogoff (1983) and find that our model's prediction significantly outperforms a random walk model.

Throughout the section, we denote the foreign variable as $X_{j,t}^*$ if the context is not country j specific. For example, we use i_t^* for the foreign interest rate on a government bond. Whenever needed, we denote the variables of a foreign country j as $X_{j,t}^*$, for example, $i_{j,t}^*$ for the interest rate of a government bond for the foreign country j.

[19] Relative inflation would also be a function of lagged r, but we have already argued that because serial correlation is essentially zero in our regressions, the impact of lagged r as a "left out" variable in our regressions is minimal.

2.3.1 Construction of Liquidity Measure

The word "liquidity" appears in different economic contexts with different meanings. Here, it refers to a non-observable non-pecuniary return that investors enjoy when holding the asset. We consider two measures of the term in equation 2.2. The first uses the forward premium:

$$\tilde{\eta}_t \equiv f_{t,t+1} - s_t + i_t^* - i_t \tag{2.1}$$

where $f_{t,t+1}$ is the log of forward rate and s_t is the log of the spot exchange rate, both expressed in home currency price of a foreign currency. The second uses LIBOR swap rates:

$$\hat{\eta}_t \equiv IRS_t - IRS_t^* + i_t^* - i_t \tag{2.2}$$

where IRS_t (IRS_t^*) refers to the home (foreign) return on LIBOR swaps.

There are two ways to interpret η_t. First, as the term $(i_t^m - i_t) - (i_t^{m*} - i_t^*)$ suggests, it is a relative measure of difference between marketable securities and government bond yield in the home and foreign country. This interpretation accords well with the $\hat{\eta}_t$ measure in equation 2.2, where we are using LIBOR swap rates as the empirical counterpart of our model's market interest rates.

Second, as described by $f_{t,t+1} - s_t + i_t^* - i_t$, the first three terms can be understood as the payoff of a synthetic home government bond that is constructed by buying the foreign government bond, and eliminating exchange rate risk by entering a forward contract. Since the home government bond and the synthetic home government bond pay equivalent pecuniary returns, the difference between the two gives a measure of the relative difference in liquidity services the home and foreign government bonds provide. Under this interpretation, we are measuring relative liquidity yields by looking at relative government interest rates, correcting for foreign exchange risk. This motivates our baseline measure $\tilde{\eta}_t$ in equation 2.1.

As will become clear, our results – qualitatively, quantitatively, and by statistical significance – are essentially the same for both measures of η_t. The difference between the two measures,

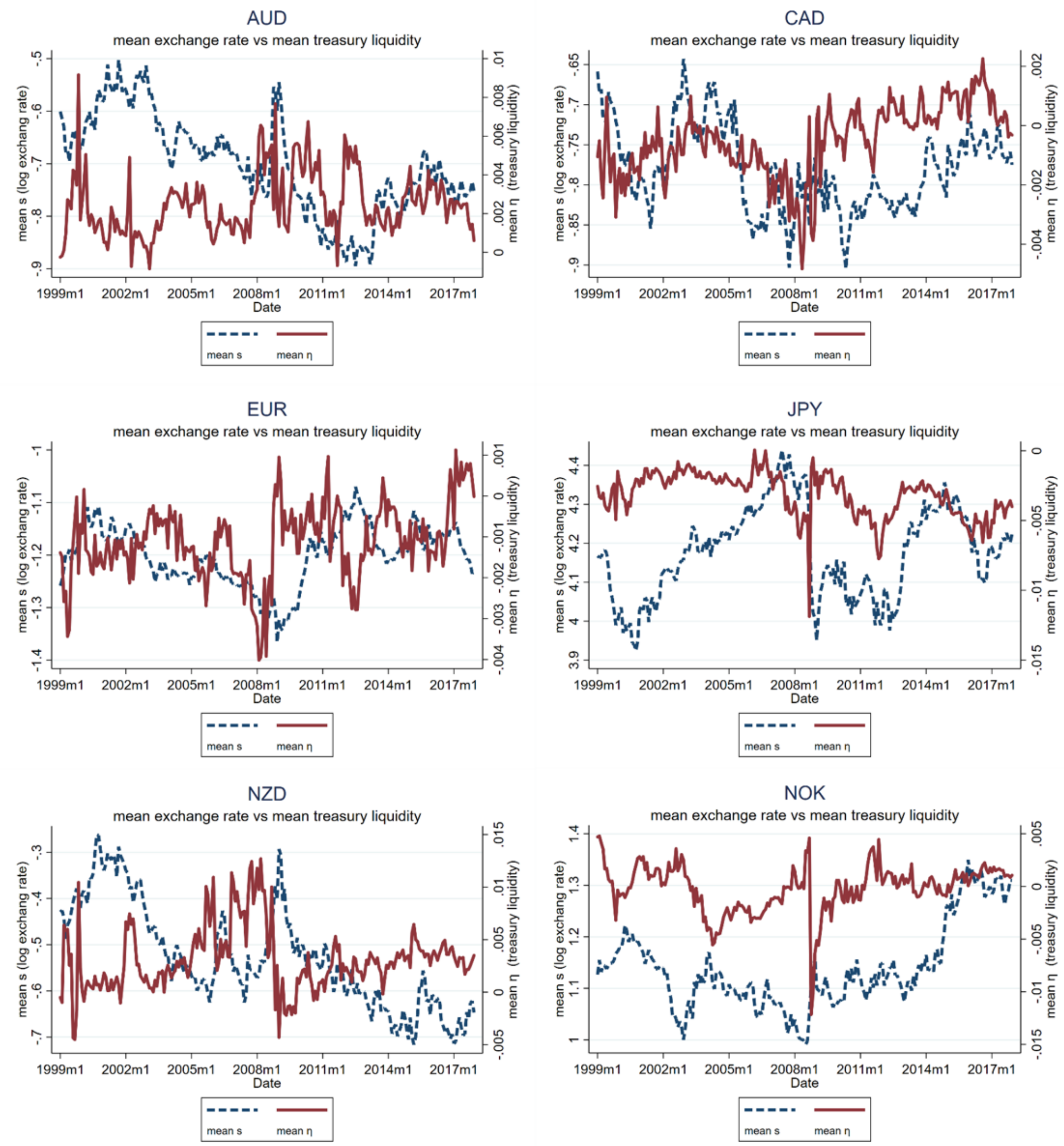
$\tau_t = f_{t,t+1} - s_t + IRS_t^* - IRS_t$, is a measure of deviations from covered interest rate parity. In section 3.3, we explore the relationship between the covered interest parity deviation per se and exchange-rate changes.

We present many of our detailed results and robustness tests using the measure given in 2.1 for three reasons. First, Baba and Packer (2009) note that financial institutions that prefer a short position in one currency and long in another find it cheaper to use a foreign currency swap (earning $f_{t,t+1} - s_t$) rather than taking a long deposit in one currency and borrowing in the other (earning $IRS_t - IRS_t^*$.) Second, we use definition 2.1 in order for our results to be most directly related to those in other recent studies. In the case where the U.S. is assumed to be the home country, Du et al. (2018a) denotes the $\tilde{\eta}_t$ term here as the U.S. Treasury Premium, $\Phi_{j,n,t}$, which is the n-year deviation from covered interest parity between government bond yields in the United States and country j. Jiang et al. (2018) take the U.S. as the home country and define $-\tilde{\eta}_t$ as a cross-country average over nine large markets relative to the dollar. Third, for some currencies, there are slightly longer samples using the measure from 2.1 rather than from 2.2.

We employ the procedure developed by Du et al. (2018a) to obtain $\tilde{\eta}_t$ for any pair of home currency i and foreign currency j (90 pairs in total) for the G-10 currencies. To give a sense of how this liquidity measure behaves, we plot the liquidity measure against the nominal exchange rate of each home currency i and foreign currency j in Figure 2.3.1. For each time period, we take a simple average across foreign currency j to improve visual representation. There is already a negative relationship between the mean exchange rate and mean liquidity measure, meaning a higher government bond liquidity relative to the rest of the G10 currency country is associated with a strong currency contemporaneously.

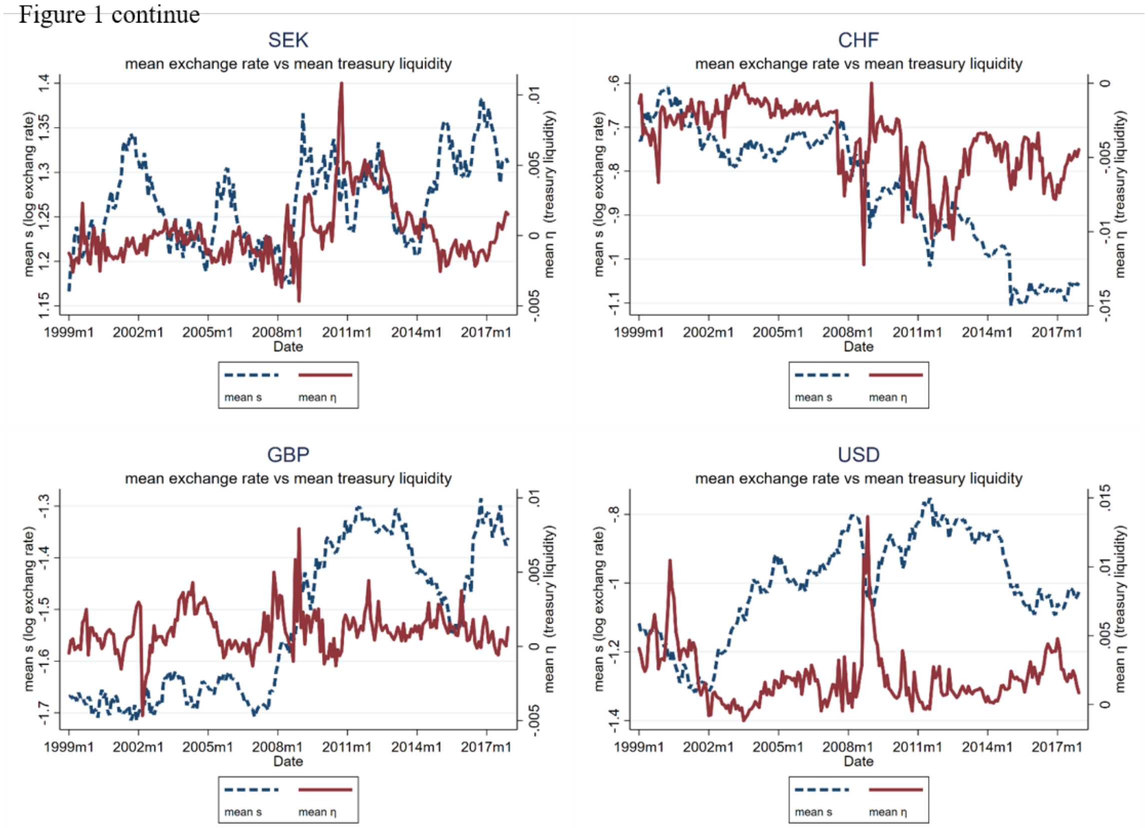
Unless otherwise specified, our study uses end-of-month monthly data from January 1999 to

Figure 2.3.1: Foreign country averaged liquidity measure and exchange rates



(Figure 1 continued)

Figure 1 continue



January 2018.[20] We use exchange rates and forward rates from Thomson Reuters Datastream. The consumer price indexes and unemployment rates are from the IMF IFS. The government yield data is obtained from Bloomberg, Datastream and central banks. The LIBOR swap rates are from Bloomberg. The Credit Default Swap data is from Bloomberg and IHS Markit. The gold price, VIX index and unemployment rates are from FRED and the government debt to GDP data is from the BIS credit to the non-financial sector dataset (nominal value). We provide the data source details in Appendix B.2. Supplementary Appendix A reports a large number of robustness checks. We employ panel fixed effect regressions in all the reported estimates to make use of cross-country time series information but at the same time allow for time-invariant heterogeneity. To account for the possibility of cross-sectional correlated estimation errors, we report standard errors that allow for non-diagonal covariance of the error terms. We estimate the regression using ordinary least squares (OLS). The error terms estimated from the OLS are then used to construct estimates of the variance-covariance matrix of the error term. Consistent statistical inference (for example, significance) can be conducted using this estimated variance-covariance matrix.

2.3.2 Baseline Results

To investigate the empirical relationship between government bond liquidity and exchange rates for the G10 countries, we estimate the following panel monthly fixed effect regression from equation 2.18:,

$$\Delta s_{j,t} = \alpha_j + \beta_1 q_{j,t-1} + \beta_2 \left(\Delta\tilde{\eta}_{j,t}\right) + \beta_3 \left(\Delta i^R_{j,t}\right) + \beta_4 \eta_{j,t-1} + \beta_5 i^R_{j,t-1} + u_{j,t} \tag{2.3}$$

where $i^R_t = i_t - i^*_t$, $\Delta X_t \equiv X_t - X_{t-1}$ for any variable X.

[20]Whenever needed, we linearly interpolate the quarterly variable to monthly variable. For example, we interpolate the Australia and New Zealand CPI to obtain monthly real exchange rates.

Table 2.3.1 reports the regression coefficient estimates of 2.3.[21] Each row of the table represents the estimation results that take the country of the currency in the first column as the home country and rest of the nine countries as the foreign countries. When constructing the variables, we use one-year forward rates and one-year government yields.[22] The real exchange rates are constructed using consumer price levels.

First, consistent with our theoretical prediction and the empirical results of Eichenbaum et al. (2017), the coefficient estimates for $q_{j,t-1}$ are all negatively significant, implying that real exchange rates adjust through nominal exchange rates. The average coefficient estimate is approximately -0.023, implying a 2.3% adjustment of the nominal exchange rate in the direction of the long-run real exchange rate, per month. It is interesting to note that the estimated adjustment of the dollar exchange rate is around half the size of the average (across currencies) adjustment coefficient, suggesting a more persistent real exchange rate.

Second, we find that a positive change in the relative interest rate (home minus foreign) drives a contemporaneous home currency appreciation, which matches the traditional interest rate and exchange rate relationship. While almost all monetary, sticky-price models of exchange rates predict such a relationship, empirical support for even a contemporaneous relationship between interest rates and exchange rates has not been universally strong in previous studies.[23] It may be that the importance of the interest rate channel requires controlling for the error-correction term and liquidity yields, as in our specification. We find the interest rate effect is strongly statistically significant for all ten currencies. The average coefficients, across the currencies, is -5.07, which means that a 100 basis point increase in the annualized interest rate in the home currency relative to the foreign country leads on average to a 5.07 percent

[21] To keep the table visibly clear, we only report the main coefficient estimates of interest and refer readers to Supplementary Appendix A for the full regression tables.

[22] See the discussion and robustness tests below for the choice of one-year tenor. Supplementary Appendix A shows that for our countries, the average correlation rate between the policy rate and the one-year bond rate that we use is 0.967.

[23] See Engel (2014) for a recent survey.

Table 2.3.1: Baseline regression

Estimation result of $\Delta s_{j,t} = \alpha_j + \beta_1 q_{j,t-1} + \beta_2 \Delta\tilde{\eta}_{j,t} + \beta_3 \Delta i^R_{j,t} + \beta_4 \tilde{\eta}_{j,t-1} + \beta_5 i^R_{j,t-1} + u_{j,t}$

Home currency	$q_{j,t-1}$	$\Delta\tilde{\eta}_{j,t}$	$\Delta i^R_{j,t}$	Observations	Within R^2
(1)	(2)	(3)	(4)	(5)	(6)
AUD	-0.0284***	-5.2710***	-5.7441***	2052	0.1891
	(0.0071)	(0.7181)	(0.5356)		
CAD	-0.0267***	-4.6086***	-5.4603***	2052	0.1723
	(0.0062)	(0.6238)	(0.4910)		
EUR	-0.0203***	-4.6406***	-5.0187***	2052	0.1434
	(0.0059)	(0.5179)	(0.4103)		
JPY	-0.0400***	-4.3863***	-6.3171***	2052	0.1692
	(0.0102)	(0.9532)	(0.7367)		
NZD	-0.0276***	-6.2906***	-6.0200***	2052	0.1955
	(0.0082)	(0.7275)	(0.6082)		
NOK	-0.0190***	-4.0106***	-4.8711***	2052	0.1537
	(0.0068)	(0.6138)	(0.4877)		
SEK	-0.0226***	-4.5193***	-4.5991***	2052	0.1315
	(0.0062)	(0.5796)	(0.4631)		
CHF	-0.0129**	-2.3197***	-2.7587***	2052	0.0509
	(0.0065)	(0.7129)	(0.5557)		
GBP	-0.0227***	-3.3495***	-5.2385***	2052	0.1283
	(0.0067)	(0.6655)	(0.5212)		
USD	-0.0113*	-6.4388***	-4.7717***	2052	0.1689
	(0.0068)	(0.7198)	(0.5691)		

Notes: The table reports the OLS estimates of the coefficient of the panel fixed effect regression listed above. The 10 currencies used are Australian Dollar (AUD), Canadian Dollar (CAD), Euro (EUR), Japanese Yen (JPY), New Zealand Dollar (NZD), Norwegian Krone (NOK), Swedish Krona (SEK), Swiss Franc (CHF), British Pound (GBP) and United States Dollar (USD). Each row represents a regression estimation using the column (1) currency as the home currency and the other 9 currencies as foreign currency j. $s_{j,t}$ is the nominal exchange rate between home and foreign country j, defined as home currency price of foreign currency, $q_{j,t}$ is the real exchange rate. $\tilde{\eta}_t$ is the measure of government bond liquidity, $i^R_{j,t}$ is the home minus foreign interest rates. Δ is a difference operator. The sample period is 1999M1-2018M1. Germany government interest rate is used for EUR case. Standard errors in parentheses are standard errors adjusted for cross-sectional correlation. *, **, and *** indicate that the alternative model significantly different from zero at 10%, 5%, and 1% significance level, respectively, based on standard normal critical values for the two-sided test. *, **, and *** for $q_{j,t}$ is based on critical values from distribution for Augmented Dickey Fuller test with a constant. The table only reports the coefficient estimates of interest. A table that reports all coefficient estimates is available in Supplementary Appendix A.

appreciation from the previous month.

Our main novel results concern the effects of the liquidity yield on exchange rates. The coefficient estimates for $\Delta\tilde{\eta}_{j,t}$ are all negative and statistically significant at the 1% level, with a range from -2.32 to -6.64. This indicates a 2.32% to 6.64% home currency appreciation in a month when there is a positive change of 100 basis points (annualized rate) in relative liquidity. The statistical significance and economic significance of these coefficient estimates are striking given the well-known exchange rate disconnect puzzle. We find that the relative government bond liquidity exhibits a very strong relationship with exchange rate movements for all the G-10 countries.

Table 2.3.1 points to two important aspects of the impact of the liquidity yield. First, it is not just a U.S. dollar phenomenon. While a great deal of attention has been paid to the convenience yield on U.S. government bonds, our regression results show that the relative liquidity yield is an important factor in explaining exchange rate changes for all of the G10 currencies. Further results reported in Table 2.3.5 (discussed below), and in section 3.5 emphasize this point.

However, secondly, the U.S. is still a special case in the sense that the impact of the relative convenience yields on the exchange rate is largest in the U.S. The estimated coefficient on the liquidity yield is largest in absolute value for the U.S., and the size of that impact is substantially larger than for all currencies excepting the Australian dollar and New Zealand dollar.

Omitting the liquidity return

For comparison, we also conduct the regression 2.3 but excluding the liquidity yield variables. That is:

$$\Delta s_{j,t} = \alpha_j + \beta_1 q_{j,t-1} + \beta_2(\Delta i^R_{j,t}) + \beta_3(i^R_{j,t-1}) + u_{j,t} \tag{2.4}$$

The regression estimates are reported in Table 2.3.2. The coefficient estimates on lagged real exchange rates and change in interest rate differential remain negatively significant for all country pairs. However, the within R-squared for this specification are universally much lower compared to Table 2.3.1.[24] This indicates including relative government bond liquidity returns brings strong explanatory power to exchange rate determination, in addition to and independent of the traditional factors.

The statistical significance of the effect of $\Delta\tilde{\eta}_{j,t}$ in our baseline regression, as well as the large drop in R-squared values when this variable is omitted, points to the fact that there is variation in $\Delta\tilde{\eta}_{j,t}$ that is independent of variation in $\Delta i^R_{j,t}$, and important in explaining exchange rate changes. Appendix A.3 shows that while the standard deviation of $\tilde{\eta}_{j,t}$ is small relative to the standard deviation of $i^R_{j,t}$ (on average across the ten currencies, the relative liquidity yields have standard deviations less than 20 percent of the relative interest rates), that is much less true for $\Delta\tilde{\eta}_{j,t}$ and $\Delta i^R_{j,t}$. The average over the currencies of the standard deviation of $\Delta\tilde{\eta}_{j,t}$ is about 80 percent of the standard deviation of $\Delta i^R_{j,t}$. It might be tempting to simply add together the liquidity yield and the interest payments as two components of the return on investments in a country, but our results show that would be a mistaken approach because those two different returns are not highly correlated and have separate effects on exchange rates.

Estimation on sub-samples

Next, we investigate whether the relationship between government bond liquidity and exchange rates are driven by 1) the Global Financial Crisis, 2) the post-crisis period or 3) only by the U.S. dollar. In Table 2.3.3, we re-estimate 2.3 but split the sample period into two periods, pre-2008 and post (and including)-2008. We see that the contemporaneous relationship between the change of the liquidity measure and the change of exchange rates holds in both time periods. As in the full sample, all the estimated coefficients on the impact of the estimated government liquidity return are negative. They are all individually statistically significant at

[24] The average R-squared in the baseline regression is 0.150, but only 0.081 in the regressions that omit the liquidity yield.

Table 2.3.2: Modified baseline regression (without liquidity)
Estimation result of $\Delta s_{j,t} = \alpha_j + \beta_1 q_{j,t-1} + \beta_2 \Delta i^R_{j,t} + \beta_3 i^R_{j,t-1} + u_{j,t}$

Home currency (1)	$q_{j,t-1}$ (2)	$\Delta i^R_{j,t}$ (3)	$i^R_{j,t}$ (4)	Observations (5)	Within R^2 (6)
AUD	-0.0316***	-4.0715***	-0.2823***	2052	0.1134
	(0.0074)	(0.5134)	(0.1087)		
CAD	-0.0276***	-4.5353***	-0.2493**	2052	0.1166
	(0.0064)	(0.4682)	(0.0985)		
EUR	-0.0226***	-3.8297***	-0.1958**	2052	0.0895
	(0.0060)	(0.3850)	(0.0909)		
JPY	-0.0340***	-5.3243***	-0.1493	2052	0.1000
	(0.0105)	(0.7255)	(0.1294)		
NZD	-0.0308***	-2.6695***	-0.0946	2052	0.0563
	(0.0093)	(0.5950)	(0.1333)		
NOK	-0.0177**	-3.4970***	-0.1255	2052	0.0820
	(0.0070)	(0.4693)	(0.0951)		
SEK	-0.0267***	-3.2092***	-0.1359	2052	0.0711
	(0.0063)	(0.4350)	(0.0983)		
CHF	-0.0097	-2.0012***	-0.2245**	2052	0.0239
	(0.0061)	(0.5164)	(0.1026)		
GBP	-0.0225***	-3.7205***	-0.3344***	2052	0.0856
	(0.0068)	(0.4902)	(0.0994)		
USD	-0.0141*	-3.6842***	-0.1376	2052	0.0684
	(0.0075)	(0.5813)	(0.1122)		

Notes: The table reports the OLS estimates of the coefficient of the panel fixed effect regression listed above. The 10 currencies used are Australian Dollar (AUD), Canadian Dollar (CAD), Euro (EUR), Japanese Yen (JPY), New Zealand Dollar (NZD), Norwegian Krone (NOK), Swedish Krona (SEK), Swiss Franc (CHF), British Pound (GBP) and United States Dollar (USD). Each row represents a regression estimation using the column (1) currency as the home currency and the other 9 currencies as foreign currency j. $s_{j,t}$ is the nominal exchange rate between home and foreign country j, defined as home currency price of foreign currency, $q_{j,t}$ is the real exchange rate. $\tilde{\eta}_t$ is the measure of government bond liquidity, $i^R_{j,t}$ is the home minus foreign interest rates. Δ is a difference operator. The sample period is 1999M1-2018M1. Germany government interest rate is used for EUR case. Standard errors in parentheses are standard errors adjusted for cross-sectional correlation. *, **, and *** indicate that the alternative model significantly different from zero at 10%, 5%, and 1% significance level, respectively, based on standard normal critical values for the two-sided test. *, **, and *** for $q_{j,t}$ is based on critical values from distribution for Augmented Dickey Fuller test with a constant. The table only reports the coefficient estimates of interest. A table that reports all coefficient estimates is available in Supplementary Appendix A.

the one percent level in the post-crisis period. In the pre-crisis data, the p-values for these coefficients are all less than 0.01 except for Japan and Switzerland but both of them still have a negative coefficient. The coefficient estimates in all cases have larger values in absolute terms after 2008, ranging from -2.86 to -7.11. In addition to the significant and larger coefficients, the post-2008 R^2 are markedly improved, with a maximum of 33%, reflecting the importance of the relationship between the government bond liquidity and exchange rate determination.[25]

It is not the case that the results are driven by the global financial crisis years, 2007-2009. Table 2.3.4 reestimates the model using the full sample but excluding those crisis years. Compared to our baseline results, the findings excluding the crisis years are nearly identical.[26] The estimated coefficients on the change in $\hat{\eta}_t$ and the change in $i_t - i_t^*$ are very similar in magnitude to those we report in Table 2.3.1, and all are statistically significant as in our baseline estimates. The error-correction terms for the adjustment of the nominal exchange rate to lagged real exchange rates is marginally statistically insignificant for Switzerland and the U.S. in this sample, and the overall fit of the model is not as good as indicated by generally lower values of the R-squared statistics. But the message of this table is that the principle findings are clearly not determined solely by the crisis years.

Table 2.3.5 displays estimates of the model that exclude the U.S. dollar from the sample. Each of the panel regressions is left with eight foreign currencies. We find that the relationship between government bond liquidity and exchange rates is largely unchanged. The coefficients on the liquidity measure are negative and significant, though generally slightly smaller in absolute term than those estimated in Table 2.3.1 (except for JPY and GBP). The R-squared statistics are also largely unchanged. This exercise shows that our results are not simply a U.S.

[25] In a country by country estimation of 2.3 reported in Supplementary Appendix A, the maximum is 49%, which is the AUD – JPY pair.

[26] Supplementary Appendix A reports regression that excludes 2000-2001 (dot com bubble and 9/11), 2007-2013 (GFC and European debt crisis). The main findings are robust to this.

Table 2.3.3: Modified baseline regression (before and after 2008)
Estimation result of $\Delta s_{j,t} = \alpha_j + \beta_1 q_{j,t-1} + \beta_2 \Delta\tilde{\eta}_{j,t} + \beta_3 \Delta i^R_{j,t} + \beta_4 \tilde{\eta}_{j,t-1} + \beta_5 i^R_{j,t-1} + u_{j,t}$

Home currency	$q_{j,t-1}$	$\Delta i^R_{j,t}$	$i^R_{j,t}$	Observations
(1)	(2)	(3)	(4)	(5)
	1999M1-2007M12		2008M1-2018M1	
AUD	-3.7828***	0.0860	-6.0254***	0.2958
	(1.2048)		(0.8766)	
CAD	-2.7138**	0.0899	-5.7275***	0.2921
	(1.0860)		(0.7300)	
EUR	-2.8935***	0.0463	-5.2961***	0.2587
	(0.8520)		(0.6488)	
JPY	-1.1698	0.0413	-5.7308***	0.3300
	(1.3160)		(1.2351)	
NZD	-4.4680***	0.0987	-6.9225***	0.3205
	(1.1189)		(0.9474)	
NOK	-3.5820***	0.0890	-4.8783***	0.2584
	(0.9969)		(0.7696)	
SEK	-2.9760***	0.0743	-5.6023***	0.2276
	(0.9147)		(0.7307)	
CHF	-1.1317	0.0262	-2.8630***	0.0918
	(1.0144)		(1.0104)	
GBP	-4.1039***	0.0988	-3.4219***	0.2086
	(0.8843)		(0.9195)	
USD	-3.9766***	0.0791	-7.1136***	0.3262
	(1.1134)		(0.8594)	

Notes: The table reports the OLS estimates of the coefficient of the panel fixed effect regression listed above. The 10 currencies used are Australian Dollar (AUD), Canadian Dollar (CAD), Euro (EUR), Japanese Yen (JPY), New Zealand Dollar (NZD), Norwegian Krone (NOK), Swedish Krona (SEK), Swiss Franc (CHF), British Pound (GBP) and United States Dollar (USD). Each row represents a regression estimation using the column (1) currency as the home currency and the other 9 currencies as foreign currency j. $s_{j,t}$ is the nominal exchange rate between home and foreign country j, defined as home currency price of foreign currency, $q_{j,t}$ is the real exchange rate. $\tilde{\eta}_t$ is the measure of government bond liquidity, $i^R_{j,t}$ is the home minus foreign interest rates. Δ is a difference operator. The sample period is 1999M1-2018M1. Germany government interest rate is used for EUR case. Standard errors in parentheses are standard errors adjusted for cross-sectional correlation. *, **, and *** indicate that the alternative model significantly different from zero at 10%, 5%, and 1% significance level, respectively, based on standard normal critical values for the two-sided test. *, **, and *** for $q_{j,t}$ is based on critical values from distribution for Augmented Dickey Fuller test with a constant. The table only reports the coefficient estimates of interest. A table that reports all coefficient estimates is available in Supplementary Appendix A.

Table 2.3.4: Modified baseline regression (excluding 2007-2009)
Estimation result of $\Delta s_{j,t} = \alpha_j + \beta_1 q_{j,t-1} + \beta_2 \Delta\tilde{\eta}_{j,t} + \beta_3 \Delta i^R_{j,t} + \beta_4 \tilde{\eta}_{j,t-1} + \beta_5 i^R_{j,t-1} + u_{j,t}$

Home currency	$q_{j,t-1}$	$\Delta\tilde{\eta}_{j,t}$	$\Delta i^R_{j,t}$	Observations	Within R^2
(1)	(2)	(3)	(4)	(5)	(6)
AUD	-0.0229***	-5.0274***	-4.9028***	1719	0.1274
	(0.0070)	(0.9224)	(0.6239)		
CAD	-0.0225***	-4.7266***	-4.6251***	1719	0.1266
	(0.0060)	(0.7771)	(0.5477)		
EUR	-0.0173***	-5.1489***	-3.7518***	1719	0.0899
	(0.0059)	(0.7045)	(0.4968)		
JPY	-0.0350***	-2.2265*	-3.4653***	1719	0.0576
	(0.0101)	(1.2139)	(0.8794)		
NZD	-0.0226***	-5.8416***	-4.4753***	1719	0.1083
	(0.0082)	(0.9511)	(0.7274)		
NOK	-0.0146**	-4.1858***	-4.1295***	1719	0.1068
	(0.0070)	(0.8479)	(0.5888)		
SEK	-0.0179***	-4.1802***	-3.3752***	1719	0.0782
	(0.0061)	(0.7760)	(0.5545)		
CHF	-0.0081	-2.1892**	-0.8891	1719	0.0207
	(0.0063)	(0.8846)	(0.6284)		
GBP	-0.0161**	-4.7377***	-3.9819***	1719	0.0820
	(0.0065)	(0.8639)	(0.5979)		
USD	-0.0080	-7.1290***	-4.3299***	1719	0.1254
	(0.0069)	(0.9607)	(0.6697)		

Notes: The table reports the OLS estimates of the coefficient of the panel fixed effect regression listed above. The 10 currencies used are Australian Dollar (AUD), Canadian Dollar (CAD), Euro (EUR), Japanese Yen (JPY), New Zealand Dollar (NZD), Norwegian Krone (NOK), Swedish Krona (SEK), Swiss Franc (CHF), British Pound (GBP) and United States Dollar (USD). Each row represents a regression estimation using the column (1) currency as the home currency and the other 9 currencies as foreign currency j. $s_{j,t}$ is the nominal exchange rate between home and foreign country j, defined as home currency price of foreign currency, $q_{j,t}$ is the real exchange rate. $\tilde{\eta}_t$ is the measure of government bond liquidity, $i^R_{j,t}$ is the home minus foreign interest rates. Δ is a difference operator. The sample period is 1999M1-2018M1. Germany government interest rate is used for EUR case. Standard errors in parentheses are standard errors adjusted for cross-sectional correlation. *, **, and *** indicate that the alternative model significantly different from zero at 10%, 5%, and 1% significance level, respectively, based on standard normal critical values for the two-sided test. *, **, and *** for $q_{j,t}$ is based on critical values from distribution for Augmented Dickey Fuller test with a constant. The table only reports the coefficient estimates of interest. A table that reports all coefficient estimates is available in Supplementary Appendix A.

dollar phenomenon, instead observed in all currency pairs.[27]

One-month forward rates

As we have noted, in our baseline regressions we use one-year forward rates and one-year government yields as regressors, while the regressions are conducted in monthly frequency. The choice of one-year tenor is a tradeoff between model consistency and data availability. Ideally, for model consistency, we would use one-month forward rates and government yields to construct the variables. However, the data availability of one-month government yields is rather limited for some of the sample countries. In addition, in section 3.3, we use credit default swap (CDS) data to make an adjustment for the probability of non-repayment of government debt. The CDS data is more extensively available only for tenors of one year or above. Therefore, we use one-year forward rates and one-year government yields to construct the variables in our analysis. To be fully consistent with the model, investors would need to have no uncertainty about the one-month own-currency return on one-year bonds, but the variation in that return (annualized) relative to the one-year interest rate is very small relative to changes in exchange rate. The monthly correlation of one-year and one-month interest rates is over 0.90 in our sample for all countries.

Nevertheless, to make sure our result is robust to the choice of tenor, we report in Table 2.3.6 the regression coefficient estimates of equation 2.3, using one-month forward rates and one-month government yield data.[28] The empirical relationship between the change of nominal exchange rate and the independent variables is largely consistent with the result we discussed in Table 2.3.1, which uses one-year forward rates and one-year government yields data. Considering this, to make our empirical results comparable across different specifications, we use one-year forward rates and one-year government yields throughout the analysis.

Table 2.3.5: Modified baseline regression (excluding U.S. dollar)
Estimation result of $\Delta s_{j,t} = \alpha_j + \beta_1 q_{j,t-1} + \beta_2 \Delta\tilde{\eta}_{j,t} + \beta_3 \Delta i^R_{j,t} + \beta_4 \tilde{\eta}_{j,t-1} + \beta_5 i^R_{j,t-1} + u_{j,t}$

Home currency	$q_{j,t-1}$	$\Delta\tilde{\eta}_{j,t}$	$\Delta i^R_{j,t}$	Observations	Within R^2
(1)	(2)	(3)	(4)	(5)	(6)
AUD	-0.0322***	-4.7984***	-5.6396***	1824	0.1843
	(0.0077)	(0.7149)	(0.5278)		
CAD	-0.0325***	-4.3134***	-5.4166***	1824	0.1779
	(0.0072)	(0.6501)	(0.5027)		
EUR	-0.0261***	-4.3161***	-4.9467***	1824	0.1413
	(0.0063)	(0.5333)	(0.4095)		
JPY	-0.0441***	-4.7844***	-6.6379***	1824	0.1801
	(0.0113)	(1.0061)	(0.7713)		
NZD	-0.0333***	-5.9481***	-5.9658***	1824	0.1942
	(0.0087)	(0.7216)	(0.6017)		
NOK	-0.0230***	-3.4899***	-4.9305***	1824	0.1533
	(0.0072)	(0.6049)	(0.4810)		
SEK	-0.0292***	-4.0158***	-4.5171***	1824	0.1249
	(0.0064)	(0.5704)	(0.4522)		
CHF	-0.0153**	-1.8779***	-2.7105***	1824	0.0491
	(0.0073)	(0.7056)	(0.5466)		
GBP	-0.0243***	-3.4335***	-5.4040***	1824	0.1358
	(0.0073)	(0.7056)	(0.5466)		

Notes: The table reports the OLS estimates of the coefficient of the panel fixed effect regression listed above. The 10 currencies used are Australian Dollar (AUD), Canadian Dollar (CAD), Euro (EUR), Japanese Yen (JPY), New Zealand Dollar (NZD), Norwegian Krone (NOK), Swedish Krona (SEK), Swiss Franc (CHF), British Pound (GBP) and United States Dollar (USD). Each row represents a regression estimation using the column (1) currency as the home currency and the other 9 currencies as foreign currency j. $s_{j,t}$ is the nominal exchange rate between home and foreign country j, defined as home currency price of foreign currency, $q_{j,t}$ is the real exchange rate. $\tilde{\eta}_t$ is the measure of government bond liquidity, $i^R_{j,t}$ is the home minus foreign interest rates. Δ is a difference operator. The sample period is 1999M1-2018M1. Germany government interest rate is used for EUR case. Standard errors in parentheses are standard errors adjusted for cross-sectional correlation. *, **, and *** indicate that the alternative model significantly different from zero at 10%, 5%, and 1% significance level, respectively, based on standard normal critical values for the two-sided test. *, **, and *** for $q_{j,t}$ is based on critical values from distribution for Augmented Dickey Fuller test with a constant. The table only reports the coefficient estimates of interest. A table that reports all coefficient estimates is available in Supplementary Appendix A.

Table 2.3.6: Modified baseline regression (using one-month rates)
Estimation result of $\Delta s_{j,t} = \alpha_j + \beta_1 q_{j,t-1} + \beta_2 \Delta\tilde{\eta}_{j,t} + \beta_3 \Delta i^R_{j,t} + \beta_4 \tilde{\eta}_{j,t-1} + \beta_5 i^R_{j,t-1} + u_{j,t}$

Home currency (1)	$q_{j,t-1}$ (2)	$\Delta\tilde{\eta}_{j,t}$ (3)	$\Delta i^R_{j,t}$ (4)	Observations (5)
AUD	-0.0543**	-7.2292	-22.9042	360
	(0.0259)	(10.5997)	(14.9001)	
CAD	-0.0299***	-12.7346***	-29.1263***	1228
	(0.0099)	(4.6383)	(7.2838)	
EUR	-0.0826***	-18.6085**	-20.0382**	609
	(0.0167)	(7.4739)	(9.0270)	
JPY	-0.1023***	-23.3412**	-11.6606	462
	(0.0237)	(10.1332)	(11.6918)	
NZD	-0.0331***	-18.7123***	-28.5861***	1228
	(0.0103)	(4.8520)	(6.9774)	
SEK	-0.0332***	-14.9686***	-17.2230***	1228
	(0.0085)	(3.8834)	(5.6090)	
CHF	-0.0572***	-10.8859	9.7523	731
	(0.0138)	(8.9118)	(8.5222)	
GBP	-0.0221*	-8.1728*	-19.2894***	1228
	(0.0115)	(4.9056)	(7.0342)	
USD	-0.0254***	-17.1716***	-15.1574**	1228
	(0.0088)	(3.9433)	(6.1518)	

Notes: The table reports the OLS estimates of the coefficient of the panel fixed effect regression listed above. The 10 currencies used are Australian Dollar (AUD), Canadian Dollar (CAD), Euro (EUR), Japanese Yen (JPY), New Zealand Dollar (NZD), Norwegian Krone (NOK), Swedish Krona (SEK), Swiss Franc (CHF), British Pound (GBP) and United States Dollar (USD). Each row represents a regression estimation using the column (1) currency as the home currency and the other 9 currencies as foreign currency j. $s_{j,t}$ is the nominal exchange rate between home and foreign country j, defined as home currency price of foreign currency, $q_{j,t}$ is the real exchange rate. $\tilde{\eta}_t$ is the measure of government bond liquidity, $i^R_{j,t}$ is the home minus foreign interest rates. Δ is a difference operator. The sample period is 1999M1-2018M1. Germany government interest rate is used for EUR case. Standard errors in parentheses are standard errors adjusted for cross-sectional correlation. *, **, and *** indicate that the alternative model significantly different from zero at 10%, 5%, and 1% significance level, respectively, based on standard normal critical values for the two-sided test. *, **, and *** for $q_{j,t}$ is based on critical values from distribution for Augmented Dickey Fuller test with a constant. The table only reports the coefficient estimates of interest. A table that reports all coefficient estimates is available in Supplementary Appendix A.

Alternative measure of relative convenience yield

Table 2.3.7 displays the findings from estimation of the model using the measure of the relative convenience yield as defined in equation 2.2. The results are almost identical to those of the baseline estimation in Table 2.3.1, qualitatively, quantitatively, in precision of parameter estimates and in overall fit of the equation.

Regularization

Equation 2.3 presents a model for the exchange rate of a given currency, such as the Australian dollar or the Swiss franc. Our results in Tables 2.3.1 – 2.3.7 present strong support for this model for each of the G10 currencies. But, as in all the empirical exchange rate literature of which we are aware, our estimates allow the parameters to be different for different base currencies. If equation 2.3 were the "true" model of exchange rates, the coefficients should be invariant across exchange rates. In fact, if the parameters were invariant, there would be no need to estimate a separate panel for each currency. We could, for example, take the panel estimates with the Swiss franc as the base currency, and from the equations for the Swiss franc/Australian dollar and Swiss franc/Norwegian krone, infer the model for the Australian dollar/Norwegian krone. Even if equation 2.3 were the true model, the parameter estimates for the Australian dollar/Norwegian krone derived from the panel with the Swiss franc as the base currency almost certainly would be different than the model for that exchange rate when the Australian dollar is the base currency in finite samples because of estimation error. But even if the parameter estimates were the same, it is still interesting to ask whether the model can explain non-dollar exchange rates. That is, even if the model has explanatory power for one currency, it may not for others. We can consider each of the panel estimates we present as restricted versions of a general unrestricted model in which each nominal exchange rate

[27] Table 4B and Supplementary Appendix A summarize and report the regression results country by country.

[28] Norway is excluded in this exercise as a home country and foreign country due to lack of Norway one-month government yield data.

Table 2.3.7: Modified baseline regression (using alternative measure $\hat{\eta}_t$)
Estimation result of $\Delta s_{j,t} = \alpha_j + \beta_1 q_{j,t-1} + \beta_2 \Delta\hat{\eta}_{j,t} + \beta_3 \Delta i^R_{j,t} + \beta_4 \hat{\eta}_{j,t-1} + \beta_5 i^R_{j,t-1} + u_{j,t}$

Home currency	$q_{j,t-1}$	$\Delta\tilde{\eta}_{j,t}$	$\Delta i^R_{j,t}$	Observations	Within R^2
(1)	(2)	(3)	(4)	(5)	(6)
AUD	-0.0280***	-5.8403***	-5.6436***	2028	0.1925
	(0.0071)	(0.7792)	(0.5336)		
CAD	-0.0292***	-3.6792***	-6.2239***	1836	0.1780
	(0.0068)	(0.7446)	(0.5409)		
EUR	-0.0208***	-3.5247***	-5.0296***	2028	0.1199
	(0.0059)	(0.5774)	(0.4158)		
JPY	-0.0379***	-4.1970***	-6.1899***	2028	0.1433
	(0.0102)	(1.0210)	(0.7619)		
NZD	-0.0286***	-6.0615***	-5.8825***	2028	0.1689
	(0.0086)	(0.8071)	(0.6286)		
NOK	-0.0177***	-2.8878***	-4.3967***	2028	0.1213
	(0.0069)	(0.6514)	(0.4989)		
SEK	-0.0235***	-4.2018***	-4.4555***	2028	0.1128
	(0.0063)	(0.6442)	(0.4750)		
CHF	-0.0101*	-3.1277***	-3.0788***	2028	0.0509
	(0.0061)	(0.7759)	(0.5552)		
GBP	-0.0204***	-4.0860***	-5.3545***	2028	0.1336
	(0.0067)	(0.7353)	(0.5244)		
USD	-0.0139*	-6.0432***	-4.7403***	2028	0.1341
	(0.0071)	(0.8433)	(0.5988)		

Notes: The table reports the OLS estimates of the coefficient of the panel fixed effect regression listed above. The 10 currencies used are Australian Dollar (AUD), Canadian Dollar (CAD), Euro (EUR), Japanese Yen (JPY), New Zealand Dollar (NZD), Norwegian Krone (NOK), Swedish Krona (SEK), Swiss Franc (CHF), British Pound (GBP) and United States Dollar (USD). Each row represents a regression estimation using the column (1) currency as the home currency and the other 9 currencies as foreign currency j. $s_{j,t}$ is the nominal exchange rate between home and foreign country j, defined as home currency price of foreign currency, $q_{j,t}$ is the real exchange rate. $\tilde{\eta}_t$ is the measure of government bond liquidity, $i^R_{j,t}$ is the home minus foreign interest rates. Δ is a difference operator. The sample period is 1999M1-2018M1. Germany government interest rate is used for EUR case. Standard errors in parentheses are standard errors adjusted for cross-sectional correlation. *, **, and *** indicate that the alternative model significantly different from zero at 10%, 5%, and 1% significance level, respectively, based on standard normal critical values for the two-sided test. *, **, and *** for $q_{j,t}$ is based on critical values from distribution for Augmented Dickey Fuller test with a constant. The table only reports the coefficient estimates of interest. A table that reports all coefficient estimates is available in Supplementary Appendix A.

change depends on all lagged nine real exchange rates, all nine relative convenience yields (and lags), and all ten interest rates (and lags). That unrestricted panel requires estimation of 432 parameters, but, as Supplementary Appendix B demonstrates, such an unrestricted model is the only way to have an equation for each exchange rate that is the same irrespective of which currency is used as the base currency. Each of our panels, which estimate 14 parameters (nine intercepts and five slope coefficients) is a restricted version of the general panel. As we report in Supplementary Appendix B, we can strongly reject our restricted panels in favor of the general panel. However, we have followed the practice of all the empirical exchange rate literature, which might be described as regularization – the process of selecting the level of complexity of the model to avoid overfitting and to advance the interpretation of the economic forces at work. The model of a bilateral exchange rate that depends on 47 variables (and an intercept) has obviously been overfit, and theory does not motivate such a model. Yet, the "true" model is still not the unrestricted model – if it were, the fit of the unrestricted model would be perfect. The key lesson from our estimates is that the relative convenience yield matters for exchange rates, and this set of results provides evidence that government bond liquidity at the individual country level plays an important role in exchange rate determination. The relative liquidity yield matters for non-U.S. dollar exchange rates, as well as for the dollar. We have seen so far that the inclusion of that variable greatly increases the explanatory power of the model for all G10 currencies, and the model is not very sensitive to estimation over sub-samples of the time span of our data, or to alternative measures of the relative convenience yield. We next dig deeper into the data to get a better understanding of what drives these results.

2.3.3 Decomposing the Liquidity Measure

Up to this point, we have maintained the assumption that markets are frictionless, so we have

$$\tilde{\eta}_t \equiv f_{t,t+1} - s_t + i_t^* - i_t$$

to serve as the main measure of relative government bond liquidity. In this subsection, we discuss some frictions that could possibly drive the movement of η_t other than the liquidity of government bonds. As we have noted, $\tilde{\eta}_t$ can be interpreted as the difference of a synthetic home government bond $f_{t,t+1} - s_t + i_t^*$ and a home government bond i_t. There are two possible frictions to consider – sovereign default risk and a currency derivative market friction. These frictions are important in the recent literature in international finance, and there are readily available prices that can be used to quantify these frictions.[29]

First, investors might not be able to construct the synthetic home government bond as we have posited because of some distortions in currency derivative markets. If covered interest parity held for market returns, we should find $f_{t,t+1} - s_t + IRS_t^* = IRS_t$, where $IRS_t (IRS_t^*)$ refers to the home (foreign) return on LIBOR swaps. Baba et al. (2008), Baba and Packer (2009), and Mancini-Griffoli and Ranaldo (2011) attribute the failure of covered interest arbitrage in the years immediately following the global financial crisis to both a liquidity and a default factor. In particular, there appeared to be profitable arbitrage opportunities that involved borrowing in dollars and making covered investments in foreign interest-earning assets. These papers provide evidence that investors were reluctant to take advantage of such opportunities both because of counterparty risk, and because there was a global demand for liquid dollar assets. Du et al. (2018b) find that in recent years, for some currencies (particularly, when the U.S.

[29] See Della Corte et al. (2018) for the effects of sovereign default on exchange rates. Du et al. (2018b) investigate deviations from covered interest parity and Avdjiev et al. (2019) consider the relationship between the currency swap friction and the exchange rate.

dollar is the home currency), $IRS_t < f_{t,t+1} - s_t + IRS_t^*$, but financial institutions do not undertake the arbitrage that would result in riskless profits. In order to earn those profits, banks would need to go short in dollars, and purchase the foreign currency on the spot market and go long in foreign currency (which they sell forward.) Such an arbitrage investment, while risk free, expands the size of the financial institutions' balance sheets, and may cause them to run afoul of regulatory constraints. Financial institutions that held home assets could sell those and acquire synthetic home assets, but they might be unwilling to do so if they value the home assets for non-pecuniary reasons. Hence, when home assets are especially valued, then $\tau_t \equiv f_{t,t+1} - s_t + IRS_t^* - IRS_t$ will be high, and the home currency will be strong. The same relationship could arise if there were default risk on LIBOR rates, as might have been the case in 2008 during the global financial crisis. When foreign LIBOR is considered risky, τ_t is high, and the home currency is strong. We note that Cerutti et al. (2019) associate the failure of covered interest parity for the U.S. dollar with periods of a strong dollar. This opens the question of the channel of causality, which we address in the next section.

Our secondary measure of the relative liquidity yield, , defined in equation 2.2, relates τ_t and $\tilde{\eta}_t$:

$$\tilde{\eta}_t = \tau_t + \hat{\eta}_t. \tag{2.5}$$

Furthermore, even if the currency derivative markets are frictionless, the government bond yields might include expected default risk. If the home government bond is regarded as default-free (say, the U.S. Treasury bond), but the foreign government bond is expected to default with some probability (say, the Japanese Government Bond, due to its high debt to GDP ratio), then the difference between the synthetic home government bond and home government bond could be arise not just because of the difference in government bond liquidity but also the difference in default premium. We define $l_{j,t}^R$ as the home minus foreign country j

expected default loss on government bonds, so that the expected relative return on home government bonds is $i_t - i^*_{j,t} - l^R_{j,t}$. To measure the term $l^R_{j,t}$, we make use of the information from the credit default swap (CDS) market. A CDS contract insures the buyer against credit events. In the case of sovereign default, the CDS sellers make payments to the buyers to compensate for the loss in the credit event. Buyers of the CDS pay a premium to CDS sellers for getting the insurance. Therefore, the CDS premium quote is an appropriately reflects the market implied expected default loss. We take the home minus foreign difference of CDS premium quotes as the measure for the expected default loss term, i.e. $l^R_{j,t} = CDS_t - CDS^*_{j,t}$.

To adjust for these frictions, as in Du et al. (2018a), we can write $\tilde{\eta}_t$ as a sum of three components:

$$\tilde{\eta}_{j,t} = \tau_{j,t} - l^R_{j,t} + \lambda_{j,t} \tag{2.6}$$

where $\lambda_{j,t}$ is a residual term. In the frictionless baseline case, we will have $\tau_{j,t} = l^R_{j,t} = 0$ so $\tilde{\eta}_{j,t} = \lambda_{j,t}$. That is, $\lambda_{j,t}$ can be understood as the relative government bond liquidity after adjusting for the currency derivative market friction and credit default risk. If we have $l^R_{j,t} = 0$, but $\tau_{j,t} \neq 0$, then from 2.5 we see that $\hat{\eta}_{j,t} = \lambda_{j,t}$.

We below summarize the components of $\eta_{j,t}$ introduced in this subsection:[30]

$$\tau_{j,t} = f_{t,t+1} - s_t + IRS^*_{j,t} - IRS_t, l^R_{j,t} = CDS_t - CDS^*_{j,t}, \lambda_{j,t} = \tilde{\eta}_{j,t} - \tau_{j,t} + l^R_{j,t} \tag{2.7}$$

In all cases, we use IRS and CDS data with one-year tenor as the CDS data are extensively available only for tenors of one-year or above.

With these decomposed components, we modify the baseline regression by putting each into the equation. Specifically,

$$\begin{aligned} \Delta s_{j,t} = \quad & \alpha_j + \beta_1 q_{j,t-1} + \beta_2 \Delta\lambda_{j,t} + \beta_3 \Delta\tau_{j,t} + \beta_4 \Delta l^R_{j,t} + \beta_5 \Delta i^R_{j,t} \\ & + \beta_6 \lambda_{j,t-1} + \beta_7 \tau_{j,t-1} + \beta_8 l^R_{j,t-1} + \beta_9 i^R_{j,t-1} + u_{j,t} \end{aligned} \tag{2.8}$$

[30] Details of the full derivation of these expressions are available at Du et al. (2018a).

As discussed above, we expect to find a negative estimate of β_3, because a larger $\Delta\tau_{j,t}$ indicates an unwillingness to sell home assets to buy the foreign currency, which appreciates the home currency. The estimated $\beta_4$should be positive, since a larger $\Delta l^R_{j,t}$ means there is a greater default risk for home government bonds. $\Delta\lambda_{j,t}$ is the residual measure of the change in the home relative to foreign liquidity yields, and for that we posit a negative value of β_2. As in our model, we should also find negative values for the estimates of β_1 and β_5.

We estimate the regression in two ways. First, since CDS data for many of the sample countries are only available after 2008, we start the sample from 2008M1 and estimate 2.8. Second, to make use of the full sample information and test whether the adjusted liquidity measure is important in explaining the change of exchange rates throughout the sample, we estimate the regression from 1999M1, but excluding the CDS data (dropping $\Delta l^R_{j,t}$ and $l^R_{j,t-1}$).[31]

In Table 2.3.8, the coefficient estimates on $\Delta\lambda_{i,t}$, which represents the effect of changes in government bond liquidity after adjusting for credit risk and derivative market friction, are still significantly negative in all cases. The range of coefficient is from -3.04 to -8.91 for the left panel, indicating a monthly 3.04% to 8.91% immediate home currency appreciation when there is a monthly positive change of 100 basis points (annualized rate) in relative liquidity. These coefficients are also larger than the coefficients of $\Delta\tilde{\eta}_{i,t}$ estimated in Table 2.3.1 or Table 1C. These results reaffirm our baseline result that there is a strong linkage between government bond liquidity and exchange rates.

In many cases, we also see that credit risk variation and derivative market frictions are important variables in explaining the change of exchange rates.[32] The positive coefficient on $\Delta l^R_{j,t+1}$ indicates that an increase in home default risk relative to foreign default risk is associated with an immediate home currency depreciation. Holding the nominal government bond interest

[31] In the second case, the $\lambda_{j,t}$ is effectively $\eta_{j,t} - \tau_{j,t}$.

[32] See Della Corte et al. (2018) who find similar findings of the relationship between exchange rate and sovereign risk.

Table 2.3.8: Regression with decomposed liquidity measure
Estimation result of $\Delta s_{j,t} = \alpha_j + \beta_1 q_{j,t-1} + \beta_2 \Delta\lambda_{j,t} + \beta_3 \Delta\tau_{j,t} + \beta_4 \Delta l^R_{j,t} + \beta_5 \Delta i^R_{j,t} + \beta_6 \lambda_{j,t-1} + \beta_7 \tau_{j,t-1} + \beta_8 l^R_{j,t-1} + \beta_9 i^R_{j,t-1} + u_{j,t}$

Home currency	$\Delta\lambda_{j,t}$	$\Delta\tau_{j,t}$	$\Delta\lambda_{j,t}$	$\Delta\tau_{j,t}$	$\Delta l^R_{j,t}$
(1)	(2)	(3)	(4)	(5)	(6)
	Full sample, no default risk		Post 2008, with default risk		
AUD	-6.1475***	-2.9797**	-7.0027***	-3.1133**	14.3663***
	(0.7910)	(1.2262)	(1.1219)	(1.5396)	(2.3547)
CAD	-4.6021***	-5.2004***	-8.8567***	-6.8906***	8.3213***
	(0.7235)	(1.1252)	(1.5154)	(1.7969)	(2.5681)
EUR	-4.6613***	-4.9050***	-6.0993***	-3.9164***	8.2139***
	(0.5684)	(0.8672)	(0.7990)	(0.9455)	(1.6760)
JPY	-4.1648***	-4.9939***	-6.7890***	-4.4253**	10.1977***
	(1.0016)	(1.5866)	(1.3763)	(1.8491)	(3.1745)
NZD	-6.6165***	-5.7714***	-7.7871***	-5.8429***	12.2542***
	(0.7968)	(1.2968)	(1.1415)	(1.4849)	(2.5075)
NOK	-3.8436***	-5.0816***	-5.1123***	-5.7420***	4.0843**
	(0.6526)	(1.0437)	(0.8095)	(1.2013)	(1.9590)
SEK	-4.4583***	-5.0234***	-5.5565***	-4.1789***	7.4308***
	(0.6435)	(0.9849)	(0.8854)	(1.1469)	(1.9029)
CHF	-3.0442***	-1.1689	-3.2384**	-1.1997	5.6024**
	(0.7725)	(1.1966)	(1.4895)	(1.8080)	(2.6065)
GBP	-4.1890***	-1.4009	-6.1288***	-0.4453	5.6119**
	(0.7457)	(1.1224)	(1.1158)	(1.4105)	(2.3529)
USD	-6.3166***	-6.7369***	-8.9086***	-3.2019**	12.5574***
	(0.8213)	(1.1889)	(1.1126)	(1.2482)	(2.1570)

Notes: The table reports the OLS estimates of the coefficient of the panel fixed effect regression listed above. The 10 currencies used are Australian Dollar (AUD), Canadian Dollar (CAD), Euro (EUR), Japanese Yen (JPY), New Zealand Dollar (NZD), Norwegian Krone (NOK), Swedish Krona (SEK), Swiss Franc (CHF), British Pound (GBP) and United States Dollar (USD). Each row represents a regression estimation using the column (1) currency as the home currency and the other 9 currencies as foreign currency j. $s_{j,t}$ is the nominal exchange rate between home and foreign country j, defined as home currency price of foreign currency, $q_{j,t}$ is the real exchange rate. $\tau_{j,t}$ is the measure of currency derivative friction, $l^R_{j,t}$ is the measure of home minus foreign default risk, $\lambda_{j,t}$ is the measure of the government bond liquidity after adjusting for derivative market friction and default risk, $i^R_{j,t}$ is the home minus foreign interest rates. Δ is a difference operator. The sample period is 1999M1-2018M1 (column (2) and (3)) and 2008M1-2018M1 (column (4) to (6)). Germany government interest rate and default risk are used for EUR case. Standard errors in parentheses are standard errors adjusted for cross-sectional correlation. *, **, and *** indicate that the alternative model significantly different from zero at 10%, 5%, and 1% significance level, respectively, based on standard normal critical values for the two-sided test. The table only reports the coefficient estimates of interest. A table that reports all coefficient estimates is available in Supplementary Appendix A.

rate fixed, an increase in default risk implies the default risk adjusted nominal interest rate goes down, resulting in a home currency depreciation.

There are two ways we could interpret the negative coefficient on $\Delta\tau_{j,t}$. First, the channel could go through the change in $IRS^*_{j,t} - IRS_t$. If there is default risk in the IRS contract an increase in the home IRS rate drives a home currency depreciation. Second, the channel could go through the change in $f_{t,t+1} - s_t$. In the case in which $\Delta\tau_{j,t}$ is positive, market conditions are now more favorable to borrow in home currency and construct a synthetic home market bond than before. As explained by Du et al. (2018b), this could be the case that when there is excess international demand for both the home assets and forward contracts to hedge exchange rate risk in investing in home assets, therefore the financial intermediaries have to mark up the forward rate $f_{t,t+1}$, as issuing a forward contract is costly for them. This mark-up of the forward rate then goes hand in hand with a strong home currency that is driven by excess international demand.

To confirm our results are robust to different specifications, we conduct the estimation in 2.8 by including one or two sub-components at a time. The results are reported at Table 2.3.9. Once again, we find the regression coefficients for $\Delta\lambda_{j,t}$ are significantly negative in all cases. How much of the variation of is driven by each of the sub-components? We can answer this with a variance decomposition. Table 2.3.10 reports the decomposition given by:

$$1 = \frac{var(\Delta\lambda_t)}{var(\Delta\tilde{\eta}_t)} + \frac{var(\Delta\tau_t)}{(\Delta\tilde{\eta}_t)} + \frac{var(\Delta l_t^R)}{var(\Delta\tilde{\eta}_t)} + 2\frac{cov(\Delta\lambda_t, \Delta\tau_t)}{var(\Delta\tilde{\eta}_t)} - 2\frac{cov(\Delta\tau_t, \Delta l_t^R)}{var(\Delta\tilde{\eta}_t)} - 2\frac{cov(\Delta l_t^R, \Delta\lambda_t)}{var(\Delta\tilde{\eta}_t)} \tag{2.9}$$

For most of the countries, the variation of $\Delta\lambda_t$ contributes a large share of variation of $\Delta\tilde{\eta}_t$. However, the sums of the variance shares of $\Delta\lambda_t$, $\Delta\tau_t$, and Δl_t^R are greater than one. This arises because Δl_t^R is positively correlated with $\Delta\lambda_t$(and Δl_t^R enters the expression for $\Delta\eta_t$ with a negative sign in equation 2.6), and because $\Delta\lambda_t$ and $\Delta\tau_t$ are negatively correlated for most countries. Because all three components contribute to the variation in $\Delta\tilde{\eta}_t$, it is important to

Table 2.3.9: Regression with decomposed liquidity measure one by one

Estimation result of $\Delta s_{j,t} = \alpha_j + \beta_1 q_{j,t-1} + \beta_2 \Delta X_{j,t} + \beta_3 \Delta i^R_{j,t} + \beta_4 X_{j,t-1} + \beta_5 i^R_{j,t-1} + u_{j,t}$ where $X_{j,t}$ is the column head variable

Home currency	$\Delta\lambda_{j,t}$	$\Delta\tau_{j,t}$	$\Delta l^R_{j,t}$	$\Delta(\eta + l^R)_{j,t}$	$\Delta(\eta - \tau)_{j,t}$	$\Delta(\tau - l^R)_{j,t}$
(1)	(2)	(3)	(4)	(5)	(6)	(7)
AUD	-4.3320***	-1.4191	9.9450***	-4.2517***	-5.8403***	-4.6466***
	(1.0848)	(1.2782)	(2.2182)	(0.9598)	(0.7792)	(1.3055)
CAD	-3.6265***	-4.3619***	0.7547	-5.2887***	-3.6792***	-1.8207
	(1.3326)	(1.1244)	(2.2708)	(1.2257)	(0.7446)	(1.4376)
EUR	-3.1217***	-3.1629***	2.0777	-3.7550***	-3.5247***	-2.3862***
	(0.7396)	(0.8745)	(1.5476)	(0.6173)	(0.5774)	(0.8126)
JPY	-4.8998***	-5.8142***	4.5740	-4.5229***	-4.1970***	-6.1640***
	(1.3625)	(1.6352)	(3.1035)	(1.1374)	(1.0210)	(1.6355)
NZD	-4.9252***	-4.0584***	4.5388*	-5.1871***	-6.0615***	-5.2129***
	(1.1290)	(1.4135)	(2.5778)	(0.9127)	(0.8071)	(1.3696)
NOK	-4.1387***	-3.0231***	-1.2069	-4.7337***	-2.8878***	-3.3848***
	(0.7748)	(1.0557)	(1.9480)	(0.6652)	(0.6514)	(1.0826)
SEK	-4.0382***	-4.3694***	3.0840*	-4.1673***	-4.2018***	-3.7094***
	(0.8195)	(0.9940)	(1.8008)	(0.6806)	(0.6442)	(0.9927)
CHF	-1.7916	-1.4794	2.4456	-1.5402	-3.1277***	-2.0616
	(1.3227)	(1.2040)	(2.2902)	(1.0703)	(0.7759)	(1.4542)
GBP	-5.0370***	-0.6742	0.7847	-3.3605***	-4.0860***	-0.4514
	(1.0264)	(1.1406)	(2.2277)	(0.8669)	(0.7353)	(1.2028)
USD	-5.1253***	-6.1304***	5.1429**	-4.5722***	-6.0432***	-4.6762***
	(1.1080)	(1.2345)	(2.1134)	(0.8519)	(0.8433)	(1.1607)

Notes: The table reports the OLS estimates of the coefficient of the panel fixed effect regression listed above. The 10 currencies used are Australian Dollar (AUD), Canadian Dollar (CAD), Euro (EUR), Japanese Yen (JPY), New Zealand Dollar (NZD), Norwegian Krone (NOK), Swedish Krona (SEK), Swiss Franc (CHF), British Pound (GBP) and United States Dollar (USD). Each row represents a regression estimation using the column (1) currency as the home currency and the other 9 currencies as foreign currency j. $s_{j,t}$ is the nominal exchange rate between home and foreign country j, defined as home currency price of foreign currency, $q_{j,t}$ is the real exchange rate. $\tau_{j,t}$ is the measure of currency derivative friction, $l^R_{j,t}$ is the measure of home minus foreign default risk, $\lambda_{j,t}$ is the measure of the government bond liquidity after adjusting for derivative market friction and default risk, $i^R_{j,t}$ is the home minus foreign interest rates. Δ is a difference operator. The sample period is 1999M1-2018M1 and 2008M1-2018M1 for those with $l^R_{j,t}$ involved. Germany government interest rate and default risk are used for EUR case. Standard errors in parentheses are standard errors adjusted for cross-sectional correlation. *, **, and *** indicate that the alternative model significantly different from zero at 10%, 5%, and 1% significance level, respectively, based on standard normal critical values for the two-sided test. The table only reports the coefficient estimates of interest. A table that reports all coefficient estimates is available in Supplementary Appendix A.

Table 2.3.10: Variance composition

Home currency	$\Delta\lambda_{j,t}$	$\Delta\tau_{j,t}$	$\Delta l^R_{j,t}$	$\Delta(\eta+l^R)_{j,t}$	$\Delta(\eta-\tau)_{j,t}$	$\Delta(\tau-l^R)_{j,t}$
(1)	(2)	(3)	(4)	(5)	(6)	(7)
AUD	73%	36%	13%	-7%	-4%	19%
CAD	139%	55%	56%	-46%	-6%	109%
EUR	119%	54%	22%	-50%	-7%	53%
JPY	64%	37%	15%	12%	1%	27%
NZD	80%	39%	12%	-5%	1%	26%
NOK	96%	25%	9%	-10%	2%	17%
SEK	87%	26%	14%	0%	-3%	32%
CHF	67%	42%	18%	12%	1%	38%
GBP	80%	36%	16%	-6%	1%	26%
USD	73%	39%	25%	4%	0%	41%

Notes: The table reports the OLS estimates of the coefficient of the panel fixed effect regression listed above. The 10 currencies used are Australian Dollar (AUD), Canadian Dollar (CAD), Euro (EUR), Japanese Yen (JPY), New Zealand Dollar (NZD), Norwegian Krone (NOK), Swedish Krona (SEK), Swiss Franc (CHF), British Pound (GBP) and United States Dollar (USD). Each row represents the variance and covariance using the column (1) currency as the home currency and the other 9 currencies as foreign currency j. $s_{j,t}$ is the nominal exchange rate between home and foreign country j, defined as home currency price of foreign currency, $q_{j,t}$ is the real exchange rate. $\tau_{j,t}$ is the measure of currency derivative friction, $l^R_{j,t}$ is the measure of home minus foreign default risk, $\lambda_{j,t}$ is the measure of the government bond liquidity after adjusting for derivative market friction and default risk, $i^R_{j,t}$ is the home minus foreign interest rates. Δ is a difference operator. Germany government interest rate and default risk are used for EUR case.

clarify the role of each in driving changes in currency values. In this section, we have seen that even controlling for default and swap-market frictions, the liquidity yield is still a significant determinant of exchange rates.

2.3.4 Instrumental Variable Regressions

The empirical analysis above shows a strong relation between relative government bond liquidity and the exchange rate. In this subsection, we instrument for the liquidity returns, which allows us to give a causal interpretation – that a change in the relative government bond liquidity leads to a change in the bilateral exchange rates.

As we have already discussed in the introduction, government bonds are more valuable than similar marketable securities because of their safety and liquidity. Our first set of instruments are measures of changes in global uncertainty. In the face of this uncertainty, there may be a safe-haven demand of government bonds which is reflected in the relative liquidity return. We use several different measures of global uncertainty: the log of VIX, log of the gold price, G10 cross-country average square inflation rates, G10 cross-country average unemployment rates, G10 cross-country average square of change in bilateral exchange rates and G10 cross-country average absolute change of bilateral exchange rates. The VIX and gold price are well-known measures for global uncertainty. The other four variables are meant to capture the fact that when global uncertainty is high, inflation, unemployment and exchange rate volatility tend to be high as well. We posit that these cross-country instruments are exogenous to bilateral exchange rate movements because of their "global" nature. That is, we hypothesize that the channel through which global uncertainty affects the value of one currency relative to another is the relative government bond premium.

Our second set of instruments gauges the scarcity of liquid assets available in an economy. We adopt general government debt to GDP for each country as an instrument. The smaller general government debt, the more valued at the margin those instruments are for their liquidity services, hence they pay a higher liquidity yield. Our underlying assumption is that the general government debt to GDP ratio influences exchange rate movements only through their liquidity effect. The sample of countries we considered are developed economies with independent fiscal policy and monetary policy, so it is not the case that there is fiscal dominance that determines inflation and currency values.

Specifically, we conducted the same panel fixed-effect regressions as in 2.3 and 2.8 but we instrument the variables $\Delta\tilde{\eta}_{j,t}$, $\tilde{\eta}_{j,t-1}$ in 2.3 and $\Delta\lambda_{j,t}$, $\lambda_{j,t-1}$ in 2.8 by the level and the change of the instruments discussed above.[33] We present three different specifications in Table 2.3.11 to 2.3.13. In table 2.3.11, the variable $\Delta\tilde{\eta}_{j,t}$, $\tilde{\eta}_{j,t-1}$ in 2.3 are instrumented. The lagged real exchange rates and change in interest rate differential are universally negatively significant, which is consistent with what we found earlier. The instrumented change of government bond liquidity has a significantly negative coefficient in 7 out of the 10 regressions.

In table 2.3.12 and 2.3.13, the variables $\Delta\lambda_{j,t}$, $\lambda_{j,t-1}$ in 2.8 are instrumented. For the same reason discussed above for estimating 2.8, we estimate the regression in two ways. We estimate the regression from 1999M1 in table 2.3.12, but excluding the CDS data (dropping $\Delta l^R_{j,t}$ and $l^R_{j,t-1}$) and we estimate 2.8 from 2008M1 in table 2.3.13, with the CDS adjustments. The instrumented change of government bond liquidity are negatively significant in 8 out of the 10 and 9 out of the 10 countries respectively. Overall, we find that the instrumental variable regressions are consistent with what we find in the baseline result and offer empirical support of the causal relationship that a change in relative government bond liquidity causes exchange rate movements.

Our instrumental variables regression is primarily designed to show that there is a causal channel running from relative convenience yields to exchange rates. When the relative convenience yield is conditioned on the variables that plausibly might drive η_t, we find changes in η_t still correlate with changes in the exchange rate. That is, the correlation does not arise, at least entirely, from a channel in which changes in η_t are driven directly from exchange rate changes. We do not consider our parameter estimates to be structural parameter estimates of the model, which was deliberately made simple in order to illustrate the channel through which a liquidity premium could influence the exchange rate. It is almost impossible in macroeconomic models to find instruments that genuinely are uncorrelated with any possible "left-out" variables in the regression. We can consider some possible sources of correlation. The error term in our model

[33]The government debt instrument is the contemporaneous quarter's debt for the last month of each quarter, and the previous quarter's debt for the first two months of each quarter.

Table 2.3.11: IV regression (1)
Estimation result of $\Delta s_{j,t} = \alpha_j + \beta_1 q_{j,t-1} + \beta_2 \Delta\tilde{\eta}^{IV}_{j,t} + \beta_3 \Delta i^R_{j,t} + \beta_4 \tilde{\eta}^{IV}_{j,t-1} + \beta_5 i^R_{j,t-1} + u_{j,t}$

Home currency	$q_{j,t-1}$	$\Delta\tilde{\eta}^{IV}_{j,t}$	$\Delta i^R_{j,t}$	Observations
(1)	(2)	(3)	(4)	(5)
AUD	-0.0195**	-17.1046***	-8.8422***	1974
	(0.0087)	(4.0284)	(1.2111)	
CAD	-0.0269***	-8.3050**	-6.3508***	1974
	(0.0071)	(3.9009)	(0.9129)	
EUR	-0.0287***	7.3881	-2.9917**	1890
	(0.0079)	(5.4521)	(1.1969)	
JPY	-0.0424***	-10.5292***	-7.6696***	1974
	(0.0114)	(2.6983)	(0.8745)	
NZD	-0.0255***	-9.8073***	-8.1706***	1974
	(0.0085)	(2.8657)	(1.4261)	
NOK	-0.0286***	-3.2492**	-5.3851***	1890
	(0.0083)	(1.4491)	(0.6601)	
SEK	-0.0186***	-9.7457***	-6.2337***	1974
	(0.0069)	(2.8174)	(1.0450)	
CHF	-0.0232***	0.3754	-2.2843***	1974
	(0.0075)	(2.2549)	(0.8269)	
GBP	-0.0341***	0.8344	5.1738***	1890
	(0.0089)	(3.2398)	(1.2746)	
USD	-0.0132*	-9.2552***	-4.8838***	1974
	(0.0071)	(2.3061)	(0.7756)	

Notes: The table reports the OLS estimates of the coefficient of the panel fixed effect regression listed above. The 10 currencies used are Australian Dollar (AUD), Canadian Dollar (CAD), Euro (EUR), Japanese Yen (JPY), New Zealand Dollar (NZD), Norwegian Krone (NOK), Swedish Krona (SEK), Swiss Franc (CHF), British Pound (GBP) and United States Dollar (USD). Each row represents a regression estimation using the column (1) currency as the home currency and the other 9 currencies as foreign currency j. $s_{j,t}$ is the nominal exchange rate between home and foreign country j, defined as home currency price of foreign currency, $q_{j,t}$ is the real exchange rate. $\tilde{\eta}^{IV}_t$ is the instrumented measure of government bond liquidity, $i^R_{j,t}$ is the home minus foreign interest rates. Δ is a difference operator. The sample period is 1999M1-2018M1. Germany government interest rate is used for EUR case. Standard errors in parentheses are standard errors adjusted for cross-sectional correlation. *, **, and *** indicate that the alternative model significantly different from zero at 10%, 5%, and 1% significance level, respectively, based on standard normal critical values for the two-sided test. *, **, and *** for $q_{j,t}$ is based on critical values from distribution for Augmented Dickey Fuller test with a constant. The table only reports the coefficient estimates of interest. The table only reports the coefficient estimates of interest. A table that reports all coefficient estimates and first stage regression statistics is available in Supplementary Appendix A.

Table 2.3.12: IV regression (2)

Estimation result of
$$\Delta s_{j,t} = \alpha_j + \beta_1 q_{j,t-1} + \beta_2 \Delta\lambda^{IV}_{j,t} + \beta_3 \Delta i^R_{j,t} + \beta_4 \Delta\tau_{j,t} + \beta_5 \lambda^{IV}_{j,t-1} + \beta_6 i^R_{j,t-1} + \beta_7 \tau_{j,t-1} + u_{j,t}$$

Home currency (1)	$q_{j,t-1}$ (2)	$\Delta\lambda^{IV}_{j,t}$ (3)	$\Delta i^R_{j,t}$ (4)	Observations (5)
AUD	-0.0093	-27.5752***	-10.3024***	1950
	(0.0103)	(5.8304)	(1.4141)	
CAD	-0.0340***	6.5334	-4.3087***	1797
	(0.0086)	(7.3334)	(1.4242)	
EUR	-0.0193***	-10.8729*	-6.8631***	1879
	(0.0068)	(5.7600)	(1.4817)	
JPY	-0.0456***	-14.4024***	-8.3858***	1950
	(0.0111)	(4.4724)	(1.1170)	
NZD	-0.0281***	-7.3717**	-7.1022***	1950
	(0.0080)	(3.2207)	(1.5089)	
NOK	-0.0276***	-3.2628**	-5.4440***	1879
	(0.0080)	(1.4410)	(0.6407)	
SEK	-0.0193***	-8.6039***	-5.8412***	1950
	(0.0069)	(3.1815)	(1.0957)	
CHF	-0.0188***	-2.1306	-3.0601**	1950
	(0.0071)	(3.8759)	(1.2781)	
GBP	-0.0285***	-10.5929**	-9.0123***	1879
	(0.0086)	(4.6454)	(1.7064)	
USD	-0.0138*	-13.7265***	-5.8169***	1950
	(0.0074)	(3.1895)	(0.9177)	

Notes: The table reports the OLS estimates of the coefficient of the panel fixed effect regression listed above. The 10 currencies used are Australian Dollar (AUD), Canadian Dollar (CAD), Euro (EUR), Japanese Yen (JPY), New Zealand Dollar (NZD), Norwegian Krone (NOK), Swedish Krona (SEK), Swiss Franc (CHF), British Pound (GBP) and United States Dollar (USD). Each row represents a regression estimation using the column (1) currency as the home currency and the other 9 currencies as foreign currency j. $s_{j,t}$ is the nominal exchange rate between home and foreign country j, defined as home currency price of foreign currency, $q_{j,t}$ is the real exchange rate. λ^{IV}_t is the instrumented measure of government bond liquidity, $i^R_{j,t}$ is the home minus foreign interest rates. Δ is a difference operator. The sample period is 1999M1-2018M1. Germany government interest rate is used for EUR case. Standard errors in parentheses are standard errors adjusted for cross-sectional correlation. *, **, and *** indicate that the alternative model significantly different from zero at 10%, 5%, and 1% significance level, respectively, based on standard normal critical values for the two-sided test. *, **, and *** for $q_{j,t}$ is based on critical values from distribution for Augmented Dickey Fuller test with a constant. The table only reports the coefficient estimates of interest. A table that reports all coefficient estimates and first stage regression statistics is available in Supplementary Appendix A.

Table 2.3.13: IV regression (3)
Estimation result of $\Delta s_{j,t} = \alpha_j + \beta_1 q_{j,t-1} + \beta_2 \Delta\lambda^{IV}_{j,t} + \beta_3 \Delta\tau_{j,t} + \beta_4 \Delta l^R_{j,t} + \beta_5 \Delta i^R_{j,t} + \beta_6 \lambda^{IV}_{j,t-1} + \beta_7 \tau_{j,t-1} + \beta_8 l^R_{j,t-1} + \beta_9 i^R_{j,t-1} + u_{j,t}$

Home currency	$q_{j,t-1}$	$\Delta\lambda^{IV}_{j,t}$	$\Delta i^R_{j,t}$	Observations
(1)	(2)	(3)	(4)	(5)
AUD	-0.0484***	-13.2473***	-8.3996***	919
	(0.0170)	(4.3327)	(1.1408)	
CAD	-0.0224	-17.8063**	-10.9378***	363
	(0.0176)	(7.8070)	(2.1128)	
EUR	-0.0527***	-9.3953*	-8.8569***	930
	(0.0120)	(4.9112)	(1.6354)	
JPY	-0.0676***	-10.9707**	-11.9658***	930
	(0.0180)	(4.8368)	(1.4490)	
NZD	-0.0434***	-8.5808***	-8.3854***	907
	(0.0146)	(3.0861)	(1.0968)	
NOK	-0.0451***	-4.4693***	-7.2782***	930
	(0.0115)	(1.3368)	(0.9397)	
SEK	-0.0457***	-10.3657***	-7.6937***	930
	(0.0123)	(3.5008)	(1.3588)	
CHF	-0.0258*	12.4148**	4.2037**	852
	(0.0133)	(5.7549)	(2.1425)	
GBP	-0.0427***	-10.4258**	-11.2803***	930
	(0.0157)	(4.4255)	(2.0339)	
USD	-0.0598***	-18.2381***	-12.3656***	777
	(0.0155)	(3.4163)	(1.2290)	

Notes: The table reports the OLS estimates of the coefficient of the panel fixed effect regression listed above. The 10 currencies used are Australian Dollar (AUD), Canadian Dollar (CAD), Euro (EUR), Japanese Yen (JPY), New Zealand Dollar (NZD), Norwegian Krone (NOK), Swedish Krona (SEK), Swiss Franc (CHF), British Pound (GBP) and United States Dollar (USD). Each row represents a regression estimation using the column (1) currency as the home currency and the other 9 currencies as foreign currency j. $s_{j,t}$ is the nominal exchange rate between home and foreign country j, defined as home currency price of foreign currency, $q_{j,t}$ is the real exchange rate. $\tilde{\eta}^{IV}_t$ is the instrumented measure of government bond liquidity, $i^R_{j,t}$ is the home minus foreign interest rates. Δ is a difference operator. The sample period is 1999M1-2018M1. Germany government interest rate is used for EUR case. Standard errors in parentheses are standard errors adjusted for cross-sectional correlation. *, **, and *** indicate that the alternative model significantly different from zero at 10%, 5%, and 1% significance level, respectively, based on standard normal critical values for the two-sided test. *, **, and *** for $q_{j,t}$ is based on critical values from distribution for Augmented Dickey Fuller test with a constant. The table only reports the coefficient estimates of interest. A table that reports all coefficient estimates and first stage regression statistics is available in Supplementary Appendix A.

arises from z_t, the ex-ante excess return on foreign investments in the market instrument, which the model assumes to be uncorrelated with η_t.

It is commonplace to attribute these excess returns, z_t, to a foreign exchange risk premium, though in the model we remain agnostic about whether z_t is a risk premium, or arises from some other source. If z_t is indeed primarily a foreign exchange risk premium, and η_t actually is correlated z_t, then we might conclude that at least part of the relationship between η_t and exchange rates that we find in the data is proxying for correlation of z_t with exchange rates.

It is often argued in the literature that certain "safe haven" currencies (such as the U.S. dollar, the yen, or the Swiss franc) are less risky because their currencies appreciate during times of global turmoil. That is, with those currencies as the base currency, the average level of z_t is positive – the unconditional expected return on the safe haven currencies relative to other currencies is negative. These effects will be captured by the intercept terms in the regression. That relationship, however, does not explain why these currencies happen to get stronger during global downturns. For example, in Farhi and Gabaix (2016), marginal utilities of consumption in the safe-haven countries rise less than in other countries during such times, in turn because productivity declines are smaller in these countries, but there is little direct evidence to support this channel. Gabaix and Maggiori (2015) build a model in which countries that are net debtors suffer a depreciation during times of global financial disruption, as financial intermediaries wish to unload debt securities as financial constraints tighten. As the paper notes, this conclusion runs counter to the evidence for the United States. Perhaps the liquidity return story can complement the risk premium story by providing one reason why some currencies are safe havens – because their government assets are more liquid, and therefore during global recessions demand for the safe haven currencies increases as the demand for liquidity rises.

In order for there to be a positive correlation between η_t and z_t, it is not enough to posit a model of safe haven currencies. The foreign exchange risk premium, z_t, must not only be positive on average for the safe haven currencies (as the base currency), but it must get larger (smaller) at the same time η_t rises (falls). Moreover, since our regression controls for the nominal interest rate differential, in order for there to be a positive correlation between z_t and η_t, there must be a component of the risk premium that is uncorrelated with the interest rate differential but that is positively correlated with η_t. This is a particular challenge for existing models of the risk premium, which are built explicitly to account for the correlation of the foreign exchange risk premium with the interest-rate differential. Moreover, that component of the risk premium must also be driven by the same instruments that we posit are driving η_t for the correlation to remain even in the instrumental-variable regression. The difficulty is even greater when we note that our model finds that the relationship between η_t and exchange rates holds not only for the traditional safe haven currencies, but indeed for all ten currencies in our panel. So, while we cannot rule out the possibility that to some extent fluctuations in η_t proxy for movements in the foreign-exchange risk premium in our IV regressions, the economic genesis of that relationship is not immediately clear.[34]

2.3.5 Country-specific Government Bond Liquidity

So far, we have conducted all our analysis with different measures of bilateral relative government bond liquidity. However, the impact of the own-country liquidity service and the aggregate foreign country liquidity service might have different effects on the home exchange rate. We measure the home and foreign liquidity returns on government bonds as $\gamma_t = IRS_t - i_t$ and $\gamma^*_{j,t} = IRS^*_t - i^*_t$. Motivated by the decomposition above, we will include also the currency derivative market friction, $\tau_{j,t}$. We have then that $\tilde{\eta}_{j,t}$ used in our baseline regressions can be decomposed as:

$$\tilde{\eta}_{j,t} = \tau_{j,t} + \gamma_t - \gamma^*_{j,t} \tag{2.10}$$

[34]Supplementary Appendix A includes some estimates that incorporate a direct measure of the risk premium using the difference between forward rates and a survey measure of expected future exchange rates. The relative liquidity yield remains highly statistically significant in these regressions.

We estimate the following equation with the country specific liquidity measures, controlling for the derivative market friction:

$$\Delta s_{j,t} = \alpha_j + \beta_1 q_{j,t-1} + \beta_2 \Delta\tau_{j,t} + \beta_3 \Delta\gamma_t + \beta_4 \Delta\gamma^*_{j,t} + \beta_5 \Delta i^R_{j,t} + \beta_6 \tau_{t-1} + \beta_7 \gamma_{t-1} + \beta_8 \gamma^*_{j,t-1} + \beta_9 i^R_{j,t-1} + u_{j,t} \tag{2.11}$$

Estimates of β_3 and β_4 in 2.11 show how the change of country-specific government bond liquidity affects exchange rate movements. We expect a negative sign for β_3 and a positive sign for β_4.

Table 2.3.14 presents the estimation results for the country specific government bond liquidity. The second column gives the coefficient estimates for the change in government bond liquidity for all the foreign currencies. The coefficient estimates are all significantly positive, indicating an increase in government bond liquidity of the foreign country is associated with a depreciation of the home currency, which is consistent with our theory and the empirical finding above. All the coefficient estimates of the home government bond liquidity, $\Delta\gamma_t$, term are significantly negative with the exception of the Japanese Yen and Swiss Franc. Both estimates are negative but with smaller absolute size compared to others.

These results then show that our findings regarding the effect of the relative liquidity returns on exchange rates are, for each country, driven at least in part by the liquidity return of that country. That is, the effects on exchange rates of the relative liquidity returns are not all determined by liquidity returns in one or a few larger countries.

We provide further evidence that our findings are not driven by one or a few countries by performing our baseline regression 2.3 country-by-country. Table 2.3.15 provides a summary of those regression results. (We report all 45 country-by-country regressions in Supplementary Appendix A.) For the analysis that uses the entire 1999-2017 sample, among the 45 country pairs, 37 country pairs have coefficients on $\Delta\tilde{\eta}_t$ that are negatively statistically different from zero at the 10% level. We find that 42 of the 45 pairs have a negatively significant coefficient

Table 2.3.14: Regression with country-specific liquidity measure
Estimation result of $\Delta s_{j,t} =$
$\alpha_j + \beta_1 q_{j,t-1} + \beta_2 \Delta\tau_{j,t} + \beta_3 \Delta\gamma_t + \beta_4 \Delta\gamma^*_{j,t} + \beta_5 \Delta i^R_{j,t} + \beta_6 \tau_{t-1} + \beta_7 \gamma_{t-1} + \beta_8 \gamma^*_{j,t-1} + \beta_9 i^R_{j,t-1} + u_{j,t}$

Home currency (1)	$\Delta\gamma^*_{j,t}$ (2)	$\Delta\gamma_{j,t}$ (3)	$\Delta\tau_{j,t}$ (4)	Observations (5)	Within R^2 (6)
AUD	5.4814***	-6.7622***	-2.7406**	2028	0.2016
	(0.6856)	(1.2114)	(1.2096)		
CAD	4.4218***	-5.9115***	-5.2253***	1836	0.2078
	(0.6851)	(1.9789)	(1.1260)		
EUR	4.5771***	-4.9551***	-5.0824***	2028	0.1472
	(0.5595)	(1.0948)	(0.9051)		
JPY	4.2658***	-2.0942	-4.8186***	2028	0.1737
	(0.9865)	(5.1736)	(1.5829)		
NZD	6.1084***	-6.7754***	-5.5521***	2028	0.2082
	(0.8609)	(0.8970)	(1.2860)		
NOK	5.5907***	-3.3078***	-5.0194***	2028	0.1640
	(0.7336)	(0.7600)	(1.0395)		
SEK	4.7890***	-4.0441***	-5.0347***	2028	0.1342
	(0.6331)	(1.2212)	(0.9868)		
CHF	3.0852***	-2.7329	-1.2225	2028	0.0562
	(0.7469)	(1.8882)	(1.1921)		
GBP	4.7472***	-3.6829***	-1.1670	2028	0.1385
	(0.7047)	(1.0823)	(1.1121)		
USD	6.2173***	-5.8436***	-6.4704***	2028	0.1875
	(0.8044)	(1.3712)	(1.2023)		

Notes: The table reports the OLS estimates of the coefficient of the panel fixed effect regression listed above. The 10 currencies used are Australian Dollar (AUD), Canadian Dollar (CAD), Euro (EUR), Japanese Yen (JPY), New Zealand Dollar (NZD), Norwegian Krone (NOK), Swedish Krona (SEK), Swiss Franc (CHF), British Pound (GBP) and United States Dollar (USD). Each row represents a regression estimation using the column (1) currency as the home currency and the other 9 currencies as foreign currency j. s_(j,t) is the nominal exchange rate between home and foreign country j, defined as home currency price of foreign currency, q_(j,t) is the real exchange rate. ${{\tau }_{j,t}}$ is the measure of currency derivative friction, γ^_(j,t)^* is the measure of foreign government bond liquidity, γ^_(j,t)^ is the measure of the home government bond liquidity, i_(j,t)^R is the home minus foreign interest rates. $\Delta $is a difference operator. The sample period is 1999M1-2018M1. Germany government interest rate is used for EUR case. Standard errors in parentheses are standard errors adjusted for cross-sectional correlation. *, **, and *** indicate that the alternative model significantly different from zero at 10%, 5%, and 1% significance level, respectively, based on standard normal critical values for the two-sided test. The table only reports the coefficient estimates of interest. A table that reports all coefficient estimates is available in Supplementary Appendix A.

Table 2.3.15: Summary of country by country regressions of 2.3

	q_{t-1} (1)	$\Delta\tilde{\eta}_t$ (2)	Δi_t^R (3)	Adjusted R^2 (4)
Whole sample: 1999M1-2018M1				
Max	-0.003	1.714	0.250	0.334
Min	-0.116	-9.985	-9.208	0.003
Median	-0.031	-4.160	-5.151	0.170
Mean	-0.038	-4.398	-4.956	0.160
Pairs that are negatively significant at:				
10%	29	37	42	
5%	25	33	42	
1%	13	29	42	
2008M1-2018M1				
Max	-0.011	2.905	0.767	0.487
Min	-0.198	-11.860	-14.336	0.012
Median	-0.069	-5.251	-6.993	0.281
Mean	-0.070	-5.393	-7.616	0.267
Pairs that are negatively significant at:				
10%	31	38	41	
5%	25	36	40	
1%	11	26	39	

Notes: Total number of country pair is 45 (9*10/2). $s_{j,t}$ is the nominal exchange rate between home and foreign country j, defined as home currency price of foreign currency, $q_{j,t}$ is the real exchange rate. $\tilde{\eta}_t$ is the measure of government bond liquidity, $i_{j,t}^R$ is the home minus foreign interest rates. Δ is a difference operator. A table that reports all coefficient estimates is available in Supplementary Appendix A.

on Δi_t^R at the 1% level. This evidence makes manifest that our results are not driven by a single country. Country-by-country regressions also allow the coefficients to be unconstrained and leave room for higher explanatory power. While the median adjusted R-squared of the full sample regressions (17%) is close to the average R-squared of the panel regressions, the maximum adjusted R-squared is 33% for the full sample and 49% post-2008 (in both cases for the AUD-JPY pair).

2.3.6 Out-of-sample fit

The influential work by Meese and Rogoff (1983) shows that standard macroeconomic exchange rate models, even with the aid of ex post data on the fundamentals, forecast exchange rates at short to medium horizons no better than a random walk. In this subsection, we conduct an out-of-sample forecasting exercise as in Meese and Rogoff (1983) and find that our empirical model significantly outperforms the random walk prediction.

We estimate 2.4, the model with only interest rate differential and the lagged real exchange rate as explanatory variables, and 2.3, the empirical model that also includes the liquidity return, using a rolling regression approach.[35] We first use the sample from 1999M1 to 2007M12 for the estimation of regression coefficients. The rolling window is therefore 108 months and the forecast horizon is one month. The first prediction is 2008M1 and the last prediction is 2018M1. We then compare the root-mean-square-error (RMSE) of these models verse the RMSE of a random walk no change prediction ($\Delta\hat{s}^{RW}_{j,t} = 0$). As in the Meese-Rogoff exercise, we use actual realized values of the right-hand-side variables to generate the forecasts.

Table 2.3.16 reports the RMSEs of the predictions of models 2.3, 2.4 and the random walk prediction. The RMSEs of forecasts from 2.3 and 2.4) are lower than the RMSEs of the random walk prediction in 9 out of the 10 countries. We are also interested in testing whether these differences in RMSEs are statistically significant. We adopt the test statistics by Diebold and Mariano (1995) and West (1996) (DMW) which tests the following three null hypothesis: A) mean-square-error (MSE) of the prediction model 2.4 and the random walk model are equal, B) MSE of the prediction model 2.3 and the random walk model are equal and C) MSE of the prediction model 2.4 and MSE of the prediction model 2.3 are equal. The DMW statistics are reported in column (5)-(7) in Table 2.3.16. Since model 2.3 nests model 2.4 and

[35] We also estimate using a recursive regression approach. The results are robust to the recursive specification and are reported in Supplementary Appendix A.

the random walk model, Clark and West (2006) shows that the DMW test statistic should be corrected to account for the fact the regression coefficients are estimated. The Clark-West adjusted test statistic (CW statistics) is asymptotically standard normal and suitable for usual statistics inference. We report the CW statistics and the corresponding p-value of the one-sided alternative test in columns (8)-(13). We find that the prediction model 2.4, which includes only the lagged real exchange rate and the interest-rate differential, performs significantly better than random walk in 9 out of the 10 cases (p-values in column (9).) We find the baseline model with liquidity returns, 2.3, outperforms the random walk model in all cases (p values in column (12).) In all cases, we find that the MSE of model 2.3 are significantly lower than model 2.4 (p-values in column (13).) Thus, the random-walk model and the model that does not include liquidity returns are rejected in favor of our baseline model for all currencies using the Meese-Rogoff criterion.

Switzerland, January 2015

The model with the liquidity yield included significantly outperforms the random walk model and the traditional model for all currencies, but the RMSE for both the liquidity model and the traditional model are higher than the random walk for the single exception of Switzerland.[36] If we eliminate one month from the Swiss sample, January 2015, the models also have lower RMSEs than the random walk.

Until that month, the Swiss National Bank had been trying to keep the Swiss franc from appreciating, setting very low interest rates and engaging in massive foreign exchange intervention to keep a ceiling on the value of the franc of CHF1.20 per euro. The SNB lifted the cap in January 2015, which led to a very large franc appreciation that month, despite the low Swiss interest rates. The model performs poorly in that month because the low interest rates should

[36]Note that because the CW statistic takes into account estimation error, both models are found to have a significantly better fit than the random walk, even including January 2015, even though their RMSEs are higher than the random walk model's RMSE.

Table 2.3.16: Out-of-sample fit comparison of different models
Model 2.3: Rolling window prediction error of regression with liquidity return:
$\Delta\hat{s}_{j,t} = \hat{\alpha}_j + \hat{\beta}_1 q_{j,t-1} + \hat{\beta}_2 \Delta\tilde{\eta}_{j,t} + \hat{\beta}_3 \Delta i^R_{j,t} + \hat{\beta}_4 \tilde{\eta}_{j,t-1} + \hat{\beta}_5 i^R_{j,t-1}$
Model 2.4: Rolling window prediction error of regression without liquidity return:
$\Delta\hat{s}_{j,t} = \hat{\alpha}_j + \hat{\beta}_1 q_{j,t-1} + \hat{\beta}_2 \Delta i^R_{j,t} + \hat{\beta}_3 i^R_{j,t-1}$
and random walk (RW) model: $\Delta\hat{s}^{RW}_{j,t} = 0$

Home currency (1)	RMSE of RW (2)	RMSE of model 2.4 (3)	RMSE of model 2.3 (4)	DMW stat 2.4 vs RW (5)	DMW stat 2.3 vs RW (6)	DMW stat 2.3 vs 2.4 (7)
AUD	0.0333	0.0311	0.0295	5.144	4.953	3.029
CAD	0.0305	0.0281	0.0268	6.291	6.090	4.203
EUR	0.0285	0.0269	0.0259	5.137	4.106	4.126
JPY	0.0428	0.0404	0.0395	5.888	4.868	3.183
NZD	0.0311	0.0298	0.0282	4.502	3.956	3.015
NOK	0.0363	0.0349	0.0316	5.837	3.739	5.493
SEK	0.0296	0.0287	0.0276	3.992	2.616	3.700
CHF	0.0328	0.0333	0.0332	-0.748	-1.368	0.480
GBP	0.0332	0.0317	0.0313	4.241	3.991	1.341
USD	0.0349	0.0336	0.0312	7.068	4.217	5.834

	DMW stat 2.4 vs RW (8)	p-value 2.4 vs RW (9)	DMW stat 2.3 vs RW (10)	p-value 2.3 vs RW (11)	DMW stat 2.3 vs 2.4 (12)	p-value 2.3 vs 2.4 (13)
AUD	10.270	0.000***	10.064	0.000***	5.357	0.000***
CAD	10.995	0.000***	10.671	0.000***	6.300	0.000***
EUR	7.880	0.000***	9.189	0.000***	6.341	0.000***
JPY	9.460	0.000***	10.675	0.000***	6.550	0.000***
NZD	8.170	0.000***	8.016	0.000***	5.051	0.000***
NOK	7.858	0.000***	11.076	0.000***	9.007	0.000***
SEK	6.409	0.000***	8.290	0.000***	6.465	0.000***
CHF	0.809	0.209	2.014	0.022**	2.647	0.004***
GBP	7.299	0.000***	8.305	0.000***	3.829	0.000***
USD	8.585	0.000***	11.873	0.000***	9.371	0.000***

The 10 currencies used are Australian Dollar (AUD), Canadian Dollar (CAD), Euro (EUR), Japanese Yen (JPY), New Zealand Dollar (NZD), Norwegian Krone (NOK), Swedish Krona (SEK), Swiss Franc (CHF), British Pound (GBP) and United States Dollar (USD). Each row represents a rolling window predictive regression using the column (1) currency as the home currency and the other 9 currencies as foreign currency j. $s_{j,t}$ is the nominal exchange rate between home and foreign country j, defined as home currency price of foreign currency, $q_{j,t}$ is the real exchange rate. $\tilde{\eta}_t$ is the measure of government bond liquidity, $i^R_{j,t}$ is the home minus foreign interest rates. Δ is a difference operator. The rolling window is 108 months. The first estimated coefficient uses sample from 1999M1 to 2007M12. Germany government interest rate is used for EUR case. DMW stands for Diebold and Mariano (1995) and West (1996) and CW stands for Clark and West (2007) The null hypotheses are that the models MSE are equal. The alternative hypotheses are that the larger models MSE are smaller than the nested models. *, **, and *** indicate that the alternative model significantly outperforms the smaller nested model at 10%, 5%, and 1% significance level, respectively, based on standard normal critical values for the one-sided test.

have led to a depreciation of the franc, as the SNB desired.[37]

In fact, all our results reported in previous table are improved, sometimes markedly, for the Swiss franc if that one month is eliminated from the sample. It is an extreme outlier. The absolute value of the change in the log of the exchange rate during that month is much greater than for any currency during any month, and it is also a month in which Swiss interest rates were at extremely low values. In particular, in a few of the regressions reported above, the sign on the interest differential was positive rather than negative for Switzerland, but that anomaly disappears when January 2015 is dropped from the sample.

2.4 Conclusions

Our empirical findings are good news for macroeconomic models of exchange rates. The government liquidity yield is the "missing link" in exchange rate determination. Not only do we find that liquidity yields are a significant determinant of exchange rate movements for all the largest countries, but we also find that with these included, traditional determinants of exchange rate movements are also important. Our simple regressions have high R-squared values, so can account for a large fraction of exchange rate movements. In short, exchange rates are not so disconnected after all. Our empirical specification is based on a model that is a straightforward extension of the canonical open-economy New Keynesian model to allow for liquidity yields. An important next step is to dig deeper into the origins of the liquidity yield. Does it arise because government bonds are useful as collateral, perhaps because the market can assess their value without any fear that the counterparty has private information? Or because markets for government bonds are deeper, and therefore more liquid in the traditional sense that they are assets that are less expensive to buy and sell? Or perhaps for some reason, our measure of the liquidity yield is correlated with some other fundamental driver, such as a

[37]In Supplementary Appendix A, we report the results with the extreme outlier in January 2015 dropped.

foreign exchange risk premium that is, in fact, the true driving variable for foreign exchange rates. These possibilities suggest avenues for further theoretical and empirical research.

Chapter 3

Original Sin Redux: A Model-Based Evaluation

3.1 Introduction

Many emerging markets (EM) are unable to borrow abroad in their domestic currency, a phenomenon termed as “original sin” (see for instance Eichengreen and Hausmann (1999), Eichengreen et al. (2002) and Eichengreen et al. (2005)). since their assets are typically in local currency, this makes them vulnerable to sudden depreciations of the exchange rate that raises the value of external liabilities compared to assets on account of the currency mismatch, leading to a feedback between the exchange rate and financial conditions that exacerbates a downturn. Indeed, currency mismatches on borrowers’ balance sheet played a critical role in many crises in the 1990s, most notably the Asian financial crisis, where several countries with debt in foreign currency suffered from a sudden and sharp depreciation of their exchange rate that ld to or exacerbated the sharp economic downturn.

In the aftermath of these crises, and with the adoption of inflation targeting regimes following the global trend, many EMs put in place policies to developed their local currency debt markets. Quite a few of them have succeeded in achieving this objective to a large extent, as shown by the significant and rising share of foreign investors in local currency debt markets in many EMs (BIS (2019)).[1]

But this overcoming of the original sin may not have eliminated the financial vulnerability of EMs entirely. EMs still rely heavily on foreign sources of funding, albeit in local currency, as their bond markets have a less developed base of domestic institutional investors. Carstens and Shin (2019) have termed this the "original sin redux". They argue that this still leaves EMs vulnerable to capital flow reversals on account of currency mismatches on the balance sheets of global lenders.

This paper provides a model-based evaluation of the original sin redux. To this end, it sets up a two-country new Keynesian DSGE model featuring a small open EM (the home country) and a large global economy (the United States). EM firms borrow from domestic banks to finance investment. EM banks in turn obtain their funding from global banks and deposits from domestic households. Both domestic and foreign banks face a funding constraint that is governed by their net worth.[2] This set up gives rise to the financial channel of the exchange rate. Moreover, the presence of financial frictions on both lender (global economy) and borrower (EM) balance sheets allows us to study the impact of the financial channel under different scenarios-namely foreign currency borrowing (original sin or OS) and local currency borrowing from foreign sources (original sin redux or OSR). Due to the financial channel, when the EM currency depreciates, the value of loans, which are in local currency, declines relative to the value of the liabilities, which are in foreign currency. This leads to a drop in net worth for the EM bank in the case of the original sin, and for the global bank in the case of the original sin redux. In either case, there is a tightening in lending conditions that affects

[1]See Arslanalp and Tsuda (2014) and Burger et al. (2012) for extensive documentation of rise of local currency EMs sovereign market and Hale et al. (2020) for EMs corporate market.

[2]We focus on the currency mismatch problem in the banking sector, which is the focus in many recent capital flow studies, such as Bruno and Shin (2014) and Bruno and Shin (2015). In the model, production firms and banks can be viewed as one single entity, so the model features broadly currency mismatch in the private sector. As currency denomination is the key for our analysis, we abstract from sovereign debt in our model to avoid any monetary commitment issue (inflating away local currency debt).

the real economy. The effect is muted in the case of the original sin redux, since the exchange rate depreciation does not trigger a feedback loop on the balance sheet of the EM bank, hence preventing a further deterioration in financial conditions.

Using this framework, we highlight four findings. First, in the absence of financial frictions and leverage constraints on lenders' balance sheet, we show that OSR insulates the EM from the financial channel. The trade channel dominates in this case, and output rises in response to a foreign monetary contraction. On the other hand, with OS, the financial channel dominates and output falls.

Second, when financial frictions are present in both AE and EM, then the financial channel is triggered, and output still falls, even under OSR. This is because the EM currency depreciation triggers losses in the AE balance sheets and limit their lending. This mirrors the exchange rate effect on EM balance sheets under the OS scenario. This challenges the traditional notion that local currency debt eliminating vulnerabilities in EMs.

Third, a large domestic investor base helps to further insulate the economy from external shocks, and reduces vulnerability to external shocks compared to both OS and OSR. At the same time though, it increases the impact of domestic shocks in EMs, as foreign sources of funding play a cushioning role in this case. Under domestic shocks, the performance of OSR and OS are similar. Therefore, in a scenario where both domestic and foreign shocks are present, OSR is weakly preferred to OS, whereas its dominance over DD depends on the nature of the shock.

Fourth, we show how FX intervention that influences the balance sheet of domestic financial institutions can help mitigate the negative impact of external shocks via a "debt limit relaxation" channel. A sterilized intervention that sells FX reserves and buys sterilized bonds in the domestic market increases the available funds for lending. On the other hand, FX intervention targeted at agents that are not financially constrained (such as households in our model) does not provide any benefits.

Overall, the results highlight that while EMs may have reduced their vulnerability to external shocks by overcoming the original sin and borrowing in their domestic currency. the vulnerability is not eliminated due to the presence of financial frictions on AE lenders' balance sheet. This phenomenon of original sin redux shows the benefits of a large domestic investor base in reducing vulnerability to external shocks, but at the same time increases vulnerability to domestic shocks.

The remainder of this paper is structured as follows. This section ends with a brief overview of the related literature. Section 3.2 presents the model. Section 3.3 discuss the analysis of the model under different scenarios. Section 3.4 concludes.

Literature Review

The motivation of this paper and much of the literature around it comes from the extensive literature on the original sin, pioneered by Eichengreen et al. (2002) and Eichengreen et al. (2005). These papers emphasized the inability of emerging markets to issue external debt in domestic currency, and provided a rationale for why exchange rates do not play the stabilizing role as in the Mundell-Flemming framework, thereby also providing an explanation for why EMs continue to stay away from freely floating exchange rate regimes, a phenomena that Calvo and Reinhart (2000) term the "fear of floating". This motivated the first generation of models exploring the implications of debt dollarization for spillovers and monetary policy in EMs-see for instance Aghion et al. (2001), Céspedes et al. (2004) and Cook (2004). Post the great financial crisis, the literature moved towards understanding the implications of currency mismatches in the presence of financial amplifications mechanisms, giving rise to the now extensive literature on the financial channel of the exchange rate. These models combine the currency mismatch features of the previous generation of models with financial amplification mechanisms such as those in Bernanke et al. (1999) and Gertler et al. (2010). Prominent recent examples of this strand of the literature include Akinci and Queralto (2018) , Aoki et al. (2016) and Gourinchas (2018) . Akinci and Queralto (2018) consider a two country model with dollar invoicing and debt and show that these features imply large spillovers from US monetary policy on emerging markets. Aoki et al. (2016) consider a model with both domestic and external (foreign currency) debt, and show that foreign shocks, in particular interest rate shocks can lead to large spillovers, with the financial channel dominating the trade channel of exchange rates. Similar to our paper, they show that additional policy tools (macroprudential policies in their case) can be a valuable addition to the toolkit of policymakers. These papers focus on financial frictions on the EM borrowers' (and not lenders') balance sheets. We contribute to the literature by analyzing the effect of financial friction on both EM borrowers and AE lenders, therefore allowing for a distinction between original sin and original sin redux.

Following Rey (2013) and the growing consensus in favor of the existence of a global financial cycle, several recent papers have popularized the shift in focus of financial frictions from borrowers' to lenders' balance sheets. Prominent examples include Morelli et al. (2019), Bruno and Shin (2014), and Banerjee et al. (2016). Among these, our framework is the closest to Banerjee et al. (2016), which in turn builds on the framework of banking frictions in Gertler and Karadi (2011). We show that in the present of lenders' balance sheets constraint, the distinction between local currency and foreign currency debt is less clear cut in understanding the spillover of AE shocks.

On the empirical front, the literature documenting the financial channel of exchange rate has grown sharply, especially on the back of a surge in dollar borrowing by EMs since the great financial crisis. For instance, Kearns and Patel (2016) show that the financial channel of exchange rates is particularly strong in EMs, and more or less offsets the trade channel. Banerjee et al. (2020) document that exchange rates affect corporate investment primarily via a financial, as opposed to a trade channel. Bruno and Shin (2019) show that even when restricting attention to exports where the impact of the trade channel is likely to be the strongest, the financial channel often tends to dominate the trade channel.Hofmann et al. (2019a) analyze the comovement of bond risk premia and exchange rates, and show that currency appreciations lead to a compression of bond spreads, even of local currency bonds. In a DSGE model, we provide support of these relationships and point to the critical role of balance sheet constraints on the lenders' side.

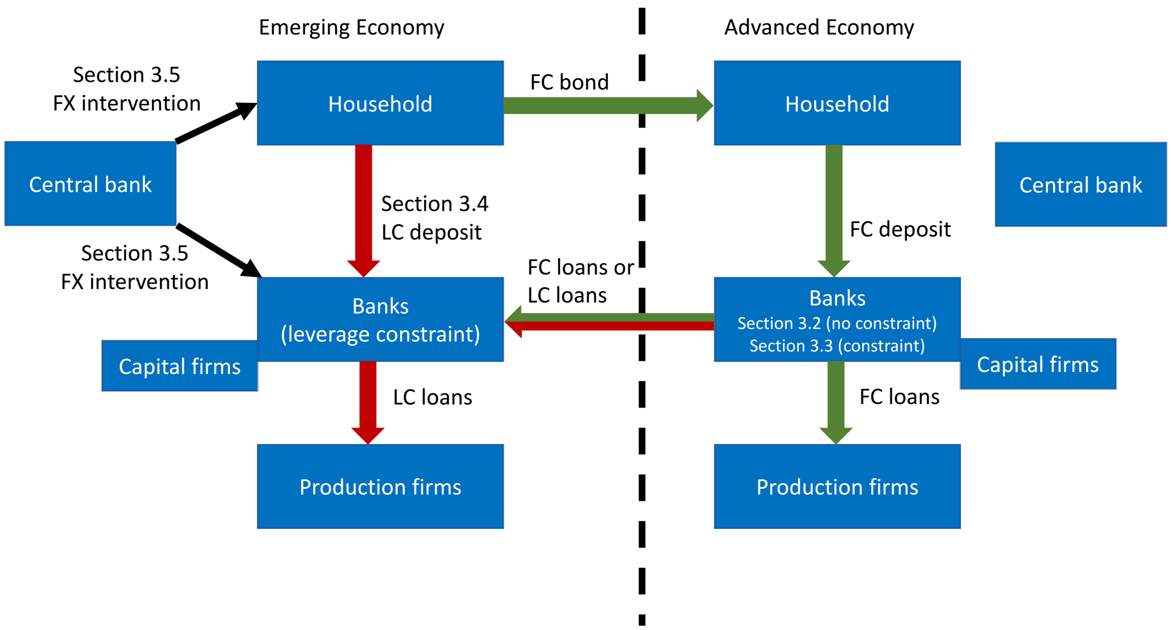
Lastly, the paper also links to the literature evaluating the effectiveness of foreign exchange intervention in the presence of financial frictions-see for instance Cavallino (2019), Chang (2018), Hofmann et al. (2019b). Cavallino and Patel (2019) summarize a recent survey of EM central banks, and highlight that FX interventions are increasingly used to counter the financial, as opposed to the trade channel (price stability and competitiveness) of exchange rates. Consistent with Chang (2018) and Hofmann et al. (2019b), we highlight the role of FX intervention in relaxing domestic financial constraints. In our two-country model, it is an alternative to counteract the effects of financial frictions from the lenders' balance sheets.

3.2 Model

Our model is structured around the asymmetric two country model developed by BDL. Figure 3.2.1 provides a diagramatic representation of the setup. The two countries are Emerging Market (EM) and Advanced Economy (AE). Both economies include households, capital producers, production firms, banks (financial intermediaries)[3] and a monetary authority. The financial sector is modeled as in Gertler and Karadi (2011). The key difference between the AE and EM is that the AE banks (global banks) receive deposit funding from their own household but the EM banks are funded through loans from the AE banks. This feature is designed

[3] We use the word "banks" to represent the financial sector in general, which broadly includes bank finance and non-bank finance such as investment funds, institutional investors and retail asset managers. The non-bank finance sector are also subject to similar leveraged constraint. See for example, Morris et al. (2017).

Figure 3.2.1: Schematic representation of the model



to capture the external capital flows in EM, which are largely originated by global banks.

3.2.1 The Emerging Market setting

The world economy comprises of two countries, a large advanced economy (AE) and a small emerging market economy (EM). The world mass is normalized to 1 and a fraction n of the world is the EM. EM variables are superscripted with e.

3.2.1.1 Household

EM household make consumption and labor supply decisions, and and trade foreign and domestic financial assets with the objective of maximizing the following utility function:

$$E_0 \sum_{t=0}^{\infty} \beta^t \left[\frac{(C_t^e)^{1-\sigma}}{1-\sigma} - \frac{(H_t^e)^{1+\psi}}{1+\psi}\right] \tag{3.1}$$

where C_t^e is a consumption basket and H_t^e is labor supply.

Denote $C^e_{e,t}$ and $C^e_{c,t}$ to be the EM household consumption on EM goods and AE goods. The consumption basket takes the following form:

$$C^e_t = [(\nu^e)^{\frac{1}{\eta}}(C^e_{e,t})^{\frac{\eta-1}{\eta}} + (1-\nu^e)^{\frac{1}{\eta}}(C^e_{c,t})^{\frac{\eta-1}{\eta}}]^{\frac{\eta}{\eta-1}} \tag{3.2}$$

where η is the cross-country elasticity of substitution between EM and AE goods. The price index of EM is:

$$P^e_t = [\nu^e(P^e_{e,t})^{1-\eta} + (1-\nu^e)(P^e_{c,t})^{1-\eta}]^{\frac{1}{1-\eta}} \tag{3.3}$$

The EM household budget constraint in nominal local currency terms is:

$$P^e_t C^e_t + S_t P^c_t B^e_t + \gamma_B(B^e_t - B^e_{SS})^2 + P^e_t D^e_t = P^e_t W^e_t H^e_t + \Pi^e_t + R^c_{t-1} S_t P^c_{t-1} B^e_{t-1} + R^e_{t-1} P^e_{t-1} D^e_{t-1} + T^e_t \tag{3.4}$$

where S_t is the exchange rate, which is price of AE currency in terms of the EM currency. An EM currency depreciation is an increase in S_t. B^e_t is the EM household holding of AE risk-free bond, which is denominated in AE currency and pays a nominal return of R^c_t. D^e_t is the domestic deposit into EM banking system. W^e_t is the real wage rate. Π^e_t is the total nominal profit from EM firms and banks. T^e_t is a lump sum transfer from the government (monetary authority). B^e_{SS} is the steady state EM household holding of AE risk-free bond and γ_B is a parameter that introduce a small convex transaction cost in international portfolio adjustment.

3.2.1.2 Capital goods producers

Capital producing firms in the EM buy back the old capital from banks at price Q^e_t (in units of the consumption aggregator) and produce new capital from the final good in the EM economy subject to the following adjustment cost function:

$$\Gamma(I^e_t, I^e_{t-1}) = \varsigma(\frac{I^e_t}{I^e_{t-1}} - 1)^2 I^e_t \tag{3.5}$$

where I^e_t is the EM investment in terms of aggregate EM good.

The EM banks then rent the capital to production firms. Denote K_t^e as the capital stock of EM. The law of motion of capital is:

$$K_t^e = I_t^e + (1-\delta)K_{t-1}^e \tag{3.6}$$

3.2.1.3 Banks

The banking sector follows Gertler and Karadi (2011). There is a mass n of competitive banks. Each period, a fraction $1-\theta$ of the banks exit and repatriate all the profits to households. The remaining θ continue to operate and accumulate net worth. To replace the exiting banks, the non-bank households are randomly assigned to be new banks, with a start up capital of δ_T of existing banking capital injected by households, to keep the banking mass constant. Banks are subject to an incentive constraint described below. The net worth of bank i is denoted as $N_{i,t}^e$. The banks raise their liabilities from two sources, loans from global banks and deposit in local currency from domestic household (D_t^e). We denote the loans in the contract currency in real terms (CPI of AE) as $V_{i,t}^e$. Bank i's balance sheet in local currency real terms is given by:

$$N_{i,t}^e + (RER_t)^{ld}V_{i,t}^e + D_t^e = Q_t^e K_{i,t}^e + TB_t^e \tag{3.7}$$

where $RER_t \equiv \frac{S_t P_t^c}{P_t^e}$ is the real exchange rate and ld is an indicator which is equal to one if the loan is in foreign (AE) currency and zero if local (EM) currency. The term TB_t^e represents a lump sum transfer from the government (monetary authority).

Each period, the banker i's real net worth is the return generated from last period investment, minus the debt repayment to AE banks and domestic depositors.

$$N_{i,t}^e = R_{k,t}^e Q_{t-1}^e K_{i,t-1}^e - (RER_t)^{ld}\frac{R_{b,t-1}}{(\pi_t^c)^{ld}(\pi_t^e)^{1-ld}}V_{i,t-1}^e - \frac{R_{t-1}^e}{\pi_t^e}D_{t-1}^e \tag{3.8}$$

where $R_{k,t}^e$ is the real capital rate of return, $R_{b,t-1}$ is the nominal interest rate charged by the AE banks, $\pi_t^c \equiv \frac{P_t^c}{P_{t-1}^c}$ and $\pi_t^e \equiv \frac{P_t^e}{P_{t-1}^e}$ are the AE and EM inflation rates.

Incentive constraint

To motivate the financial friction, we follow Gertler and Karadi (2011) to model an incentive problem. Specifically, at the beginning of each period, the banker has the ability to abscond the a fraction κ^e of the assets. Therefore, no one will be willing to lend to the EM banks unless the following incentive compatibility constraint is satisfied.

$$J^e_{i,t} \geq \kappa^e Q^e_t K^e_{i,t} \tag{3.9}$$

where $J^e_{i,t}$ is the value function of bank i.

Limitation of domestic deposit

To put the main focus on external capital flows, we limit the share of domestic deposit in the model, which can be thought as some form of financial sector under-development. Indeed, in many emerging countries households hold deposit in foreign currency. We assume that domestic deposits cannot be larger than $\frac{\varphi_D - 1}{\varphi_D}$ of total liabilites, where $\varphi_D \geq 1$ is an exogenous parameter. In equilibrium, deposits therefore amount to:

$$D^e_{i,t} = (\varphi_D - 1) RER^{ld}_t V^e_{i,t} \tag{3.10}$$

The maximization problem of EM banks is:

$$J^e_{i,t} = \max_{K^e_{i,t}, V^e_{i,t}, D^e_{i,t},} E_t \Lambda^e_{t+1|t} [(1-\theta) N^e_{i,t+1} + \theta J^e_{i,t+1}] \tag{3.11}$$

subject to 3.7, 3.8, 3.9 and 3.10. $\Lambda^e_{t+1|t} \equiv \beta (\frac{C^e_t}{C^e_{t-1}})^{-\sigma}$ is the stochastic discount factor of the household.

In aggregate, we can average the net worth across all EM banks. The aggregate net worth at any point of time is the sum of surviving banks and newly adjusted capital:

$$N^e_t \equiv \int N^e_{i,t} di = \theta [(R^e_{k,t} - (\frac{RER_t}{RER_{t-1}})^{ld} \frac{\tilde{R}_{b,t-1}}{\varphi_D}) Q^e_{t-1} K^e_{t-1} + (\frac{RER_t}{RER_{t-1}})^{ld} \frac{\tilde{R}_{b,t-1}}{\varphi_D} (N^e_{t-1} - TB^e_{t-1})] + \delta_T Q^e_t K^e_{t-1} \tag{3.12}$$

where $\tilde{R}_{b,t-1} = [\frac{R_{b,t-1}}{(\pi_t^c)^{ld}(\pi_t^e)^{1-ld}} + \frac{R_{e,t-1}}{\pi_t^e}(\varphi_D - 1)]$ is the average cost of funding for one unit of loan.

3.2.1.4 Production firms

The productions firms operate as in standard New Keynesian models. There are competitive intermediate firms and monopolistic final good firms. A representative intermediate firm has the following production function:

$$Y_t^e = A_t^e (H_t^e)^{1-\alpha} (K_{t-1}^e)^\alpha \tag{3.13}$$

For each period, the rate of return on investment for the EM banks is:

$$R_{k,t}^e = \frac{R_{z,t}^e + (1-\delta)Q_t^e}{Q_{t-1}^e} \tag{3.14}$$

where $R_{z,t}^e$ is the rental rate on capital and δ is the rate of depreciation of capital.

The competitive assumption yields the following demands for capital and labor:

$$MC_t^e (1-\alpha) A_t^e (H_t^e)^{-\alpha} (K_{t-1}^e)^\alpha = W_t^e \tag{3.15}$$

$$MC_t^e (\alpha) A_t^e (H_t^e)^{1-\alpha} (K_{t-1}^e)^{\alpha-1} = R_{z,t}^e \tag{3.16}$$

where MC_t^e is the real marginal cost of production, the price that intermediate goods firm sell their output.

The monopolistic final good firms buy goods from intermediate firms, re-package them to differentiated goods in a monopolistically competitive markets. They set prices subject to a Calvo (1983) type of friction. A random $1-\varsigma$ fraction of firms adjusts their prices each period. These assumptions generate a standard Phillips curves:

$$\pi_{i,e,t}^* = \frac{\sigma_p}{\sigma_p - 1} \frac{F_{e,t}}{G_{e,t}} \pi_{e,t}^{PPI} \tag{3.17}$$

$$F_{e,t} = Y_{e,t} MC_{e,t} + E_t[\beta \varsigma \Lambda_{t,t+1}^e (\pi_{e,t+1}^{PPI})^\eta F_{e,t+1}] \tag{3.18}$$

$$G_{e,t} = Y_{e,t}P_{e,t} + E_t[\beta\varsigma\Lambda^e_{t,t+1}(\pi^{PPI}_{e,t+1})^{-1+\eta}G_{e,t+1}] \tag{3.19}$$

$$(\pi^{PPI}_{e,t})^{1-\eta} = \varsigma + (1-\varsigma)(\pi^*_{i,e,t})^{1-\eta} \tag{3.20}$$

where $\pi^*_{i,e,t}$ is the optimal inflation rate for each firm i with price reset option. σ_p is the cross-good elasticity among goods within the country. $\pi^{PPI}_{e,t}$ is the PPI inflation rate.

3.2.1.5 Monetary policy

We focus on a simple Taylor rule type of monetary policy:

$$R^e_t = \lambda^e_r R^e_{t-1} + (1-\lambda^e_r)[\lambda^e_\pi(\pi^e_t - \pi^e_{ss}) + \lambda^e_y(Y^e_t - Y^e_{ss})] + \varepsilon^e_t \tag{3.21}$$

3.2.1.6 Foreign exchange intervention (FX intervention)

To introduce a role for FX intervention, we need to describe how the economy responds to the change in foreign exchange reserves (FX reserves), and how FX reserves responses to economic conditions. We model the (sterilized) FX intervention as in Devereux and Yetman (2014),Chang (2018) and Arce et al. (2019), in which the change in FX reserves is financed by a lump sum transfer. The two lump sum taxes to households and banks we described above serve this purpose:

$$\Delta FR_t = FR_t - R^c_{t-1}FR_{t-1} = (1-\Psi)T^e_t + \Psi TB^e_t \tag{3.22}$$

where FR_t is the FX reserves at time t and Ψ is the share of reserves that is distributed to the banking sector. For example, if Ψ=0, then all the reserves accumulation/decumulation is done by interaction with the households.

Denote RER_{SS} as the steady state RER. The monetary authority sets FX reserves response to the exchange rate with the following rule:

$$\Delta FR_t = (\frac{RER_t}{RER_{SS}})^{\chi} - 1 \tag{3.23}$$

where χ is a parameter that governs the strength of the intervention.

3.2.2 The Advanced Economy setting

The AE mass is $1-n$ of the world. AE variables are superscripted with c. The household, capital producer, production firm sectors and monetary policy in advanced economy are the same as the EM. The banking sector is different and is described below.

3.2.2.1 Banks

The bankers directly receive funding from deposits of AE households and invest in domestic capital stock and make loans to EM's banks.

From the presentative AE bank j, the balance sheet accounting in real terms is:

$$N^c_{j,t} + D^c_{j,t} = Q^c_t K^c_{j,t} + V^e_{j,t}/(RER_t)^{1-ld} \tag{3.24}$$

where $N^c_{j,t}$ is the net worth, $D^c_{j,t}$ is the deposit from the domestic households in AE and $Q^c_t K^c_{j,t}$ is the investment in capital stock in AE.

Each period, the banker j's real net worth is the return generated from last period investment in domestic capital stock and EM loans, subtracting the debt repayment to domestic depositors:

$$N^c_{j,t} = R^c_{k,t} Q^c_{t-1} K^c_{i,t-1} + \frac{R_{b,t-1}}{(\pi^c_t)^{ld}(\pi^e_t)^{1-ld}} V^e_{i,t-1}/(RER_{t-1})^{1-ld} - \frac{R^c_{t-1}}{\pi^c_t} D^c_{t-1} \tag{3.25}$$

Incentive constraint

The AE banks face same type of incentive constraint so there could be financial friction in their banking sector:

$$J^c_{j,t} \geq \kappa^c_t (Q^c_t K^c_{j,t} + V^e_{j,t}/(RER_t)^{1-ld}) \tag{3.26}$$

The maximization problem of AE banks is:

$$J^c_{j,t} = \max_{K^c_{j,t}, V^e_{j,t}, D^c_{j,t},} E_t \Lambda^c_{t+1|t} [(1-\theta) N^c_{i,t+1} + \theta J^c_{i,t+1}] \tag{3.27}$$

subject to 3.24, 3.25 and 3.26.

Similar to 3.12, we can write the aggregate banking networth evolution as:

$$N^c_t \equiv$$

$$\int N^c_{j,t} dj = \theta [(R^c_{k,t} - \frac{R^c_{t-1}}{\pi^c_t}) Q^c_{t-1} K^c_{t-1} + \frac{n}{1-n} (\frac{R_{b,t-1}}{(\pi^c_t)^{ld} (\pi^e_t)^{1-ld}} - \frac{R^c_{t-1}}{\pi^c_t}) (\frac{RER_{t-1}}{RER_t})^{1-ld} V^e_{t-1} + \frac{R^c_{t-1}}{\pi^c_t} N^c_{t-1}] \tag{3.28}$$

The first order condition of the AE bank decision w.r.t. $V^e_{j,t}$ is:

$$\Lambda^c_{t+1|t} [(1-\theta) + \theta J^{c'}_{j,t+1}] [\frac{R_{b,t}}{(\pi^c_t)^{ld} (\pi^e_t)^{1-ld}} (\frac{RER_t}{RER_{t+1}})^{1-ld} - \frac{R^c_t}{\pi^c_{t+1}} + \vartheta_t] = \kappa^c_t \gamma^c_t \tag{3.29}$$

where γ^c_t is the Lagrangian multiplier associated with 3.26. ϑ_t introduces a stochastic component to the return of AE banks in investing in EM. This helps us to model capital inflow and outflow shock to the EM. χ_t can be interpreted as a preference or non-monetary return shock of investing in EM. [4]

3.2.3 External shocks

We consider three shocks in the following analysis. Monetary shocks in EM and AE and the capital outflow shock. The monetary shocks are one period shocks since we incorporated lagged interest rate in the Taylor rule and the capital outflow shock follows a AR(1) process with persistence of 0.9.

[4] This is isomorphic to an UIP shock in the exchange rate determination literature. See Kollmann (2001) Devereux and Engel (2002), Engel (2014), Itskhoki and Mukhin (2017) and Engel and Wu (2018).

Table 3.3.1: Parameterization

Variable	Definition	Value
Household		
σ	Household risk aversion	1.02
$\nu^e = \nu^c$	Trade openness	0.97
β	Discount factor	0.99
ψ	Inverse of Frisch elasticity	0.276
γ_B	Portfolio adjustment cost	0.0001
Trade / goods markets		
n	Size of EM	0.2
ς	Prob. of price fixed (Calvo pricing)	0.85
η	Cross-country elasticity	2
σ	Domestic cross-good elasticity	6
Banking sector		
θ	Bank survival rate	0.97
δ_T	Bank capital injection share	0.004
$\kappa^e = \kappa^c$	Divertable fraction*	0.38
Capital producer		
ς	Capital adjustment cost	1.728
δ	Capital depreciation	0.0025
Monetary authority		
$\lambda_r^e = \lambda_r^c$	Monetary policy persistence	0.85
$\lambda_\pi^e = \lambda_\pi^c$	Taylor coefficient on inflation	1.2
$\lambda_y^e = \lambda_y^c$	Taylor coefficient on output gap	0.2
χ	Foreign reserve response to exchange rate*	0

*Notes: These parameters change across exercises.

3.3 Analysis

3.3.1 Parameterization

We take parameters values from the literature standard range. The model is parameterized to quarterly frequency. Table 3.3.1 reports the parameters used. The model is log-linearized to solve.

3.3.2 Absence of AE financial friction

We first investigate the effect of the currency of denomination of debt when there is no financial friction on the AE banking sector, i.e. $\kappa_t^c = 0$. Figure 3.3.1 plots the IRFs (% deviation from the steady-state) for the case of loans from global banks in foreign currency (original sin, OS: $ld = 1$) and local currency (original sin redux, OSR: $ld = 0$) in response to a 100 basis point monetary tightening shock in the AE.

The monetary tightening in AE causes the EM currency to depreciate. When the loans are denominated in local currency, EM GDP increases relative to the steady-state level for a few periods. This is the conventional trade channel of exchange rates at work - the increase is mainly because of the expenditure switching that increases EM exports and reduces import. The financial channel of exchange rate is largely muted. The EM banks' net worth reduces. On the AE side, the AE GDP reduces due to a sharp contraction in aggregate demand caused by the monetary tightening. This leads to a significant reduction in AE banks' net worth. However, since there is no financial friction in the AE banking sector, the lending rate over the policy rate doesn't change (AE spreads). As a result, the borrowing rate faced by EM banks is effectively unchanged, because the increase in AE interest rate is compensated by the expected appreciation of the EM currency subsequently.

When the loans are denominated in foreign currency, EM GDP drops substantially. Looking at the GDP components, EM net export increases more compared to local currency debt. This can be partly attributed to the higher depreciation of the currency. The reduction in GDP is mainly driven by the drop in EM investment. The currency depreciation harms the EM banks' net worth and therefore limits the capital investment. This illustrates the strong prevalence of the financial channel of exchange rates, which outweighs the trade channel of exchange rates. To summarize, in the absence of financial frictions on AE balance sheets, local currency debt insulates the EM economy from the financial channel by removing the exchange rate movements on the balance sheet of the financially constrained banking sector. This brings a more stable financial sector, which is consistent with policy prescriptions after the Asian financial crisis that advocated the development of local currency bond markets.

3.3.3 Presence of AE financial friction

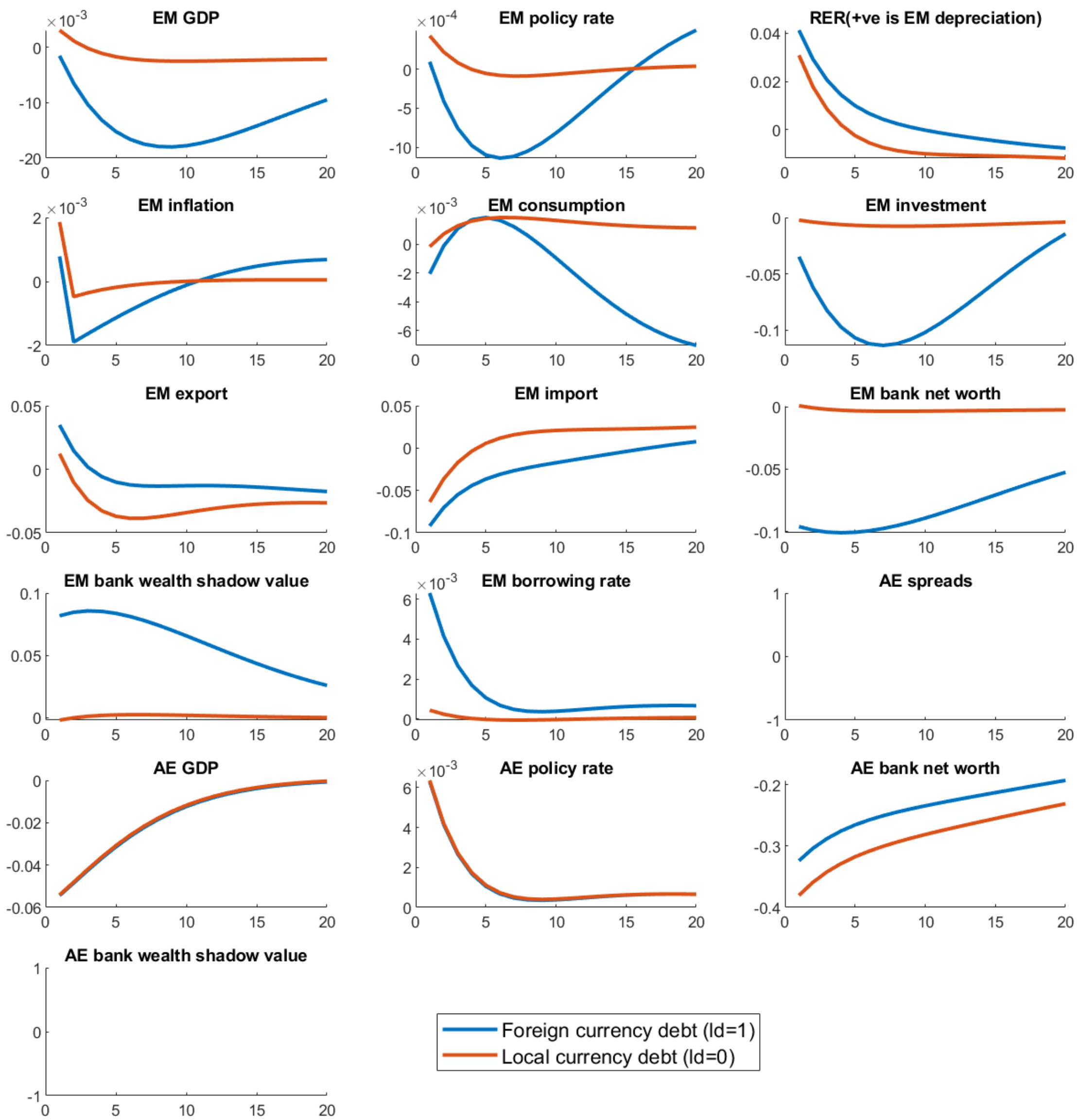
We now turn to the case when financial frictions are also present in the AE banking sector in addition to the EM banking sector. We set $\kappa_t^c = 0.38$, which is the same as Gertler and Karadi (2011). Figure 3.3.2 plots the impulse responses for three cases where there is a 100 basis point monetary tightening shock in the AE: 1) $ld = 0$ and when there is no AE financial friction (the case above), 2) $ld = 1$ (OS) and when there is AE financial friction, which we characterize as the "original sin" case and 3) $ld = 0$ (OSR) and when there is AE financial friction, which we characterize as the "original sin redux" case.

The blue line in Figure 3.3.2, which represents the "original sin" case, behaves similar to the blue line in Figure 3.3.1. It features strong reduction in EM GDP that is driven by a reduction in EM investment. This is because the exchange rate fluctuations affects the financially constrained EM banks.

More importantly, the IRFs of the "original sin redux" case behaves very differently from the case when there is no AE financial friction. The EM GDP drops significantly in this case, driven again by the dynamics of investment. Different from the case of OS, at least for the period of impact, EM banks net worth is mildly affected. The contraction of investment is due to the rise of lending rate offered by the AE banks. The unexpected EM currency depreciation erodes the local currency loan return for AE banks, as shown in the first period of "windchill",[5] which impairs the AE banks' net worth and therefore the lending rate to EM

[5] Carstens and Shin (2019) describe a loss in the local currency return as the "temperature effect" and there is

Figure 3.3.1: Advanced economy monetary tightening, absence of AE financial friction



banks. For the subsequent periods, the AE banks charge a higher than steady state lending rate. The high funding cost then affects the EM banks net worth, which creates dynamics similar to the original sin case ($ld = 1$). In other words, rather than a direct valuation change due to exchange rate fluctuations on EM bank balance sheets, the exchange rate fluctuations that is costly for AE bank balance sheets feeds back to the EM indirectly through a "price effect". The positive correlation between the EM financing cost (either in local or foreign currency) and EM currency depreciation driven by AE monetary shock period is consistent with the empirical findings in Hofmann et al. (2019a).[6]

The important message is that once we consider fully the external effect of local currency in a general equilibrium setting, the prescription of local currency bond markets may not be as ideal as one may have thought. One way or the other, the exchange rate mismatch problem remains, either on the lenders' or on borrowers' balance sheets.

3.3.4 Policy prescription 1: Domestic investor base

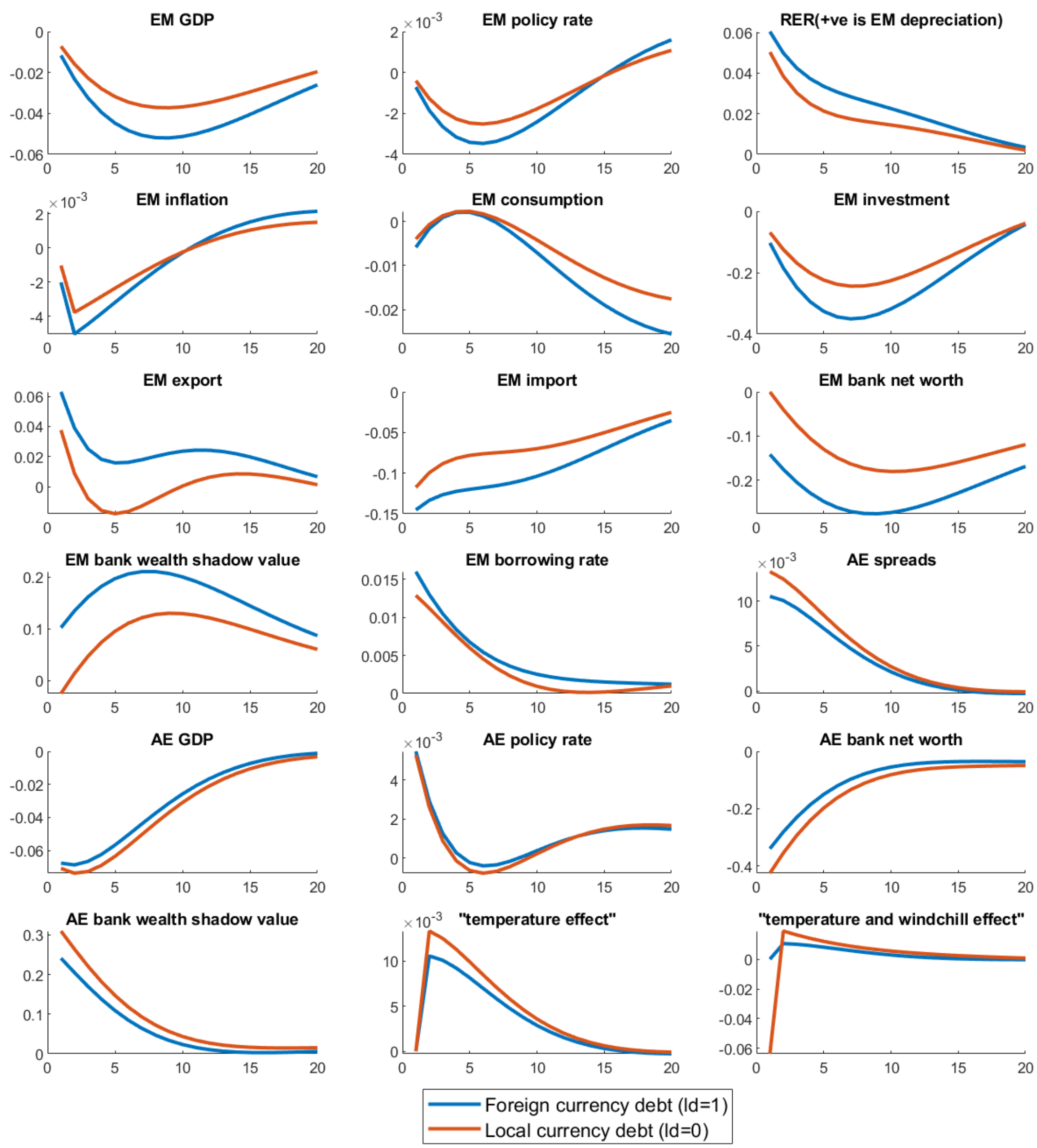
A notable observation is that the AE financial constraint is a restriction on the banking sector net worth, evaluated in the AE currency. Therefore, the exchange rate fluctuations affect the net worth when loans are denominated in EM currency. As hypothesized by Carstens and Shin (2019), this hints that increasing domestic investor base, who evaluates returns in local currency and therefore does not suffer from currency mismatches, can ease the friction and transmission of shocks.

In figure 3.3.3 we compare the effect of an AE monetary tightening shock (100 basis point) in the original sin redux case above to the original sin redux with 50% of the EM bank funds

an additional "windchill" effect if local currency depreciates at the same time, which double hits the AE investor who evaluates returns in foreign currency.

[6] In Hofmann et al. (2019a), the AE monetary shock is identified through high frequency identification on key FOMC announcement dates.

Figure 3.3.2: Advanced economy monetary tightening, with AE financial friction



Notes: The "temperature effect" is the ex-post nominal investment return over the risk-free rate of the currency of denomination. The "temperature and windchill effect" is the temperature effect plus ex-post change in nominal exchange rate.

sourced from domestic deposits ($\varphi_D = 1$). In both cases, the AE GDP and banks' net worth reduction are similar. However, the borrowing rate that the EM can obtain is much lower in the case with domestic deposit. There are two reasons for this difference. First, compared to the AE bank loan offer rate, the domestic deposit is less sensitive to a change in AE interest rate. Second, domestic deposits that sourced from EM households are not subject to the incentive constraint. The smaller increase in the borrowing cost, translate to a small reduction of EM banks' net worth and investment, resulting in a smaller drop in EM GDP.

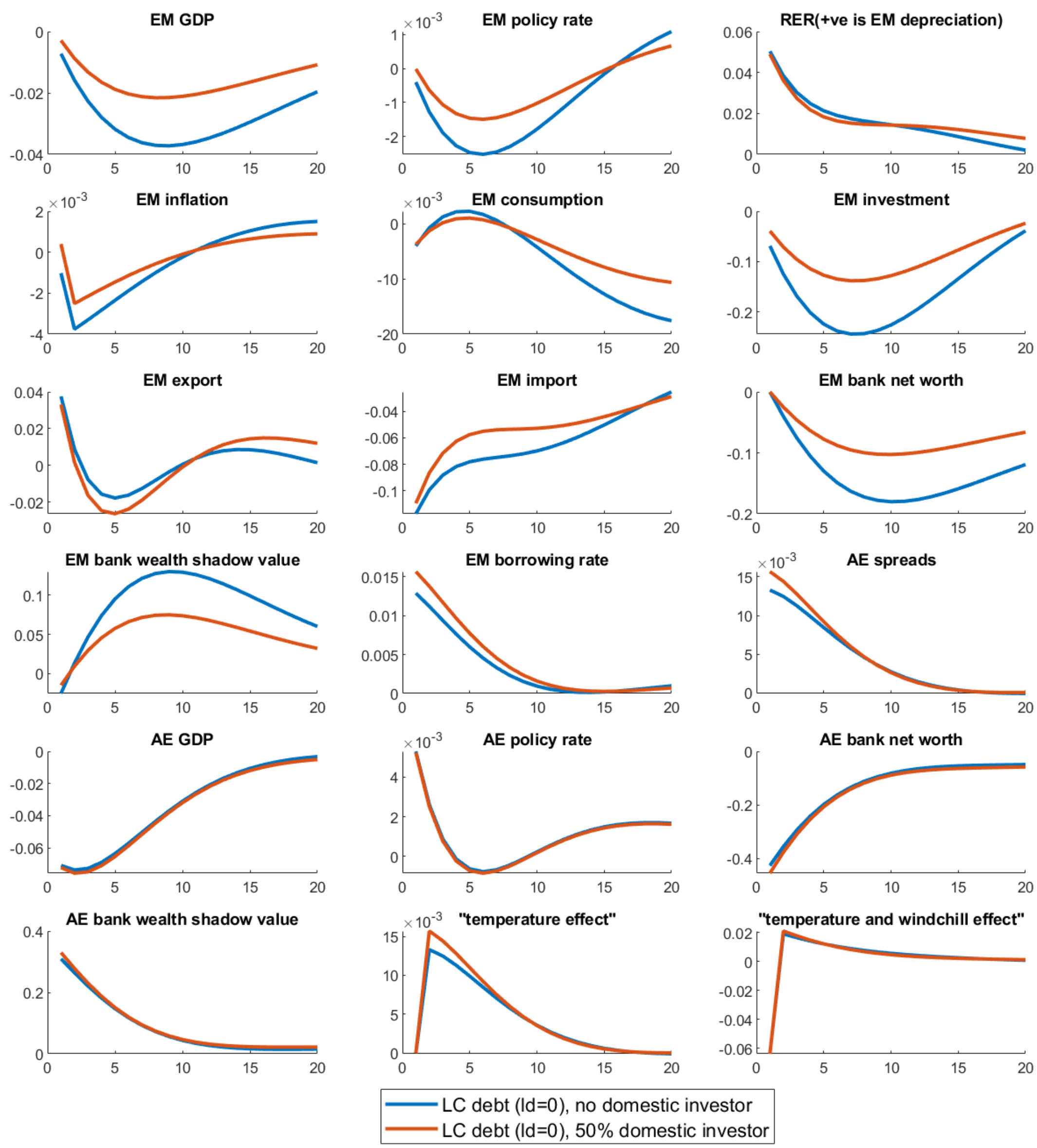
A large domestic investor base helps the economy to be less vulnerable to foreign shocks, but at the same, it increases the sensitivity to domestic shocks. Figure 3.3.4 shows how the economy responds to an EM tightening shock. The tightening appreciates the currency, leading to a higher than expected return for AE banks from EM loan investment. This leads to a lower AE lending rate for a few periods, as shown by the lower AE spreads. However, the overall EM borrowing rate is increasing because of the higher EM interest rate. This results in a higher drop in EM banks' net worth and investment compared to the case of no domestic deposit.

3.3.5 Policy prescription 2: FX intervention

Deepening the domestic investor base is a long process with involvement of institutional and structural changes. Potentially a more feasible alternative in the short run could come from the ability to stabilize exchange rate movements. We analyze the case of sterilized FX intervention in this subsection.

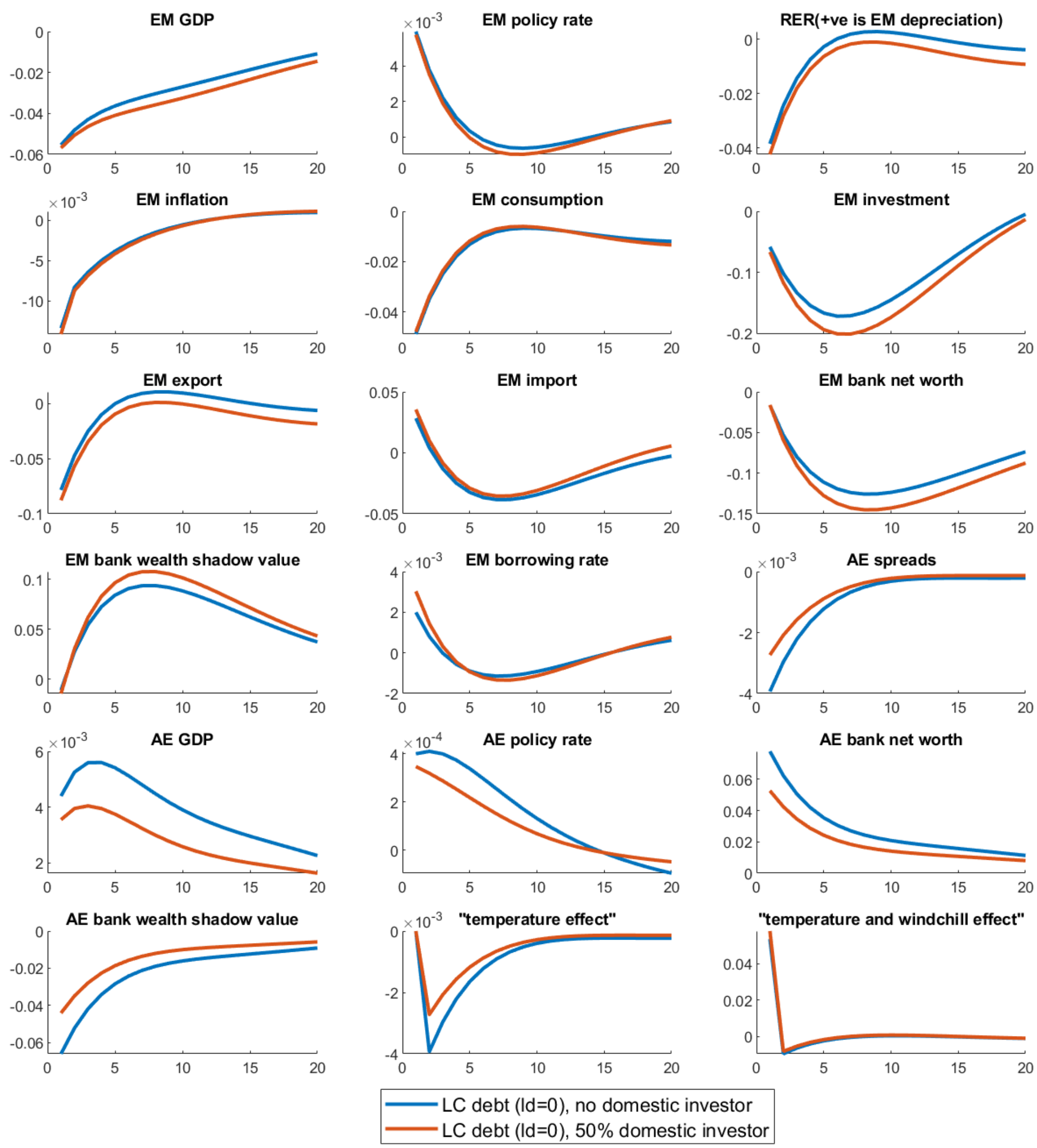
We consider two types of FX interventions. The case when the sterilization bonds go to the household ($\Psi = 0$) and when the sterilization bond go to the banking sector ($\Psi = 1$). Figure 3.3.5 shows the IRFs for the case of AE monetary tightening shock. When the intervention

Figure 3.3.3: Advanced economy monetary tightening, with domestic investor base



Notes: The "temperature effect" is the ex-post nominal investment return over the risk-free rate of the currency of denomination. The "temperature and windchill effect" is the temperature effect plus ex-post change in nominal exchange rate.

Figure 3.3.4: Emerging market economy monetary tightening, with domestic investor base



Notes: The "temperature effect" is the ex-post nominal investment return over the risk-free rate of the currency of denomination. The "temperature and windchill effect" is the temperature effect plus ex-post change in nominal exchange rate.

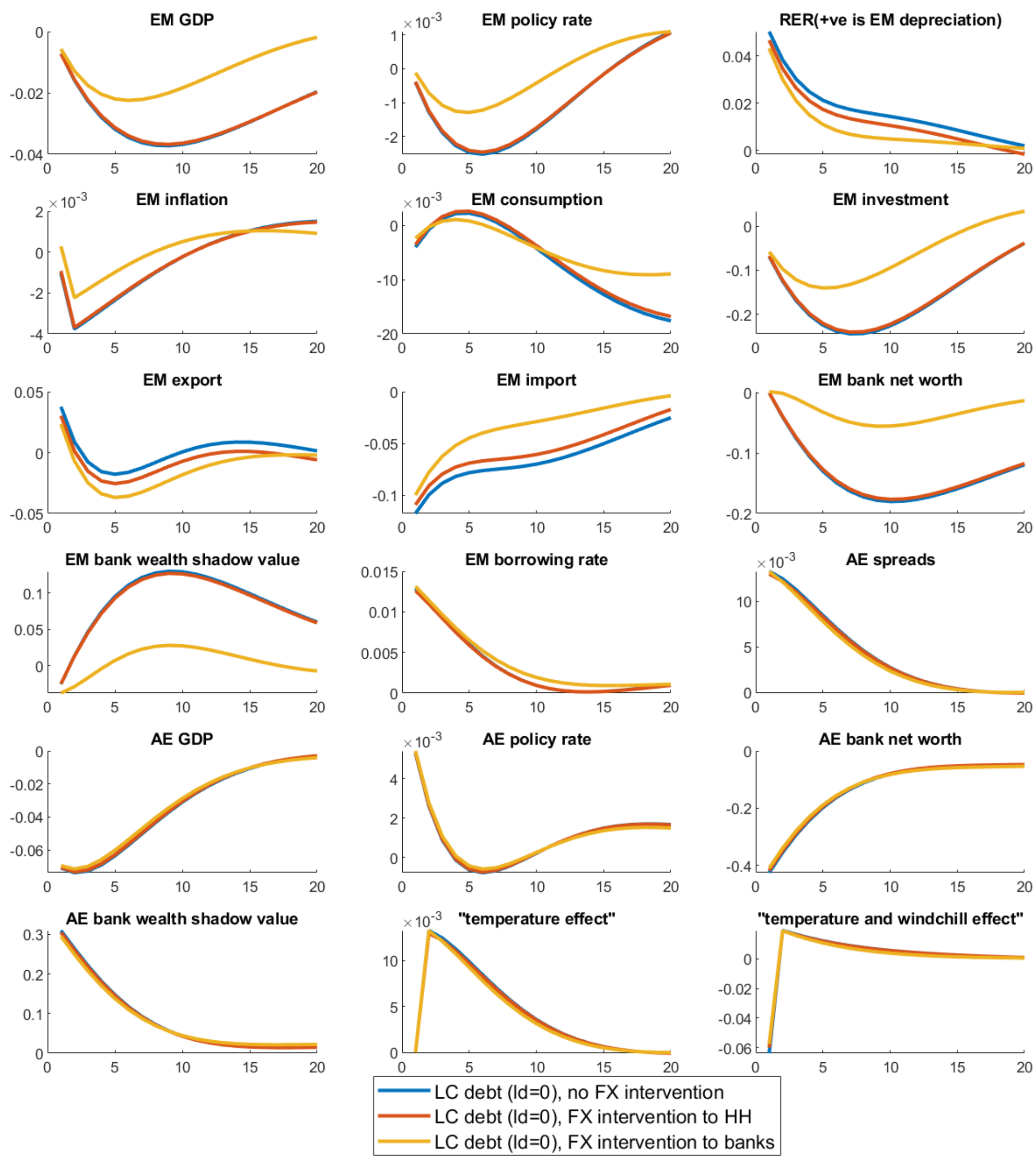
comes with sterilization bond going to the household sector, the intervention is almost ineffective. This is consistent with the finding of Backus and Kehoe (1989) in which FX intervention is ineffective in a frictionless portfolio market.[7]

The effect of intervention increases substantially when sterilization bonds go to the banking sector. The GDP reduction is significantly less. The intervention is successful in the sense that the equilibrium exchange rates depreciates less than the no intervention case. The less depreciated exchange rate helps with stablizing the net worth change in the AE bank but the effect is fairly limited. The reduction in AE banking net worth results in a higher EM borrowing rate. On the other hand, the FX intervention improves the EM banking balance sheets. The sterilized FX intervention involves selling foreign reserves and purchase of sterilization bond. This frees up resources for the banking sector to undertake more private lending and buffer the reduction of net worth. The FX intervention is effective here as it relaxes the more binding constraint when the AE tighten the monetary policy rate. The smaller reduction in banking net worth reduces the investment and GDP drop. This "debt limit channel" of FX intervention is also discussed in Chang and Velasco (2017), Chang (2018) and Hofmann et al. (2019b).

FX intervention is often considered as a possible solution to capital outflows. In the following exercise in Figure 3.3.6, we consider a capital outflow shock ϑ_t with a magnitude that is same as the steady-state EM borrowing rate (1.2%). The shock introduces a non-monetary return to AE assets relative to a loan to EM, inducing capital outflow. In response to the shock, the equilibrium EM borrowing rate increases, as AE banks require a higher monetary return to compensate. Again, in this scenario, the intervention that involves the household sector is almost ineffective. On the other hand, the FX intervention with purchase of sterilization bond from the banking sector significantly eases the banking sector constraint, as observed by the slower increase in the shadow value of wealth. This results in a smaller and flatter reduction

[7]The household portfolio market is not exactly frictionless in our model, but it has a very small portfolio adjustment cost.

Figure 3.3.5: Advanced economy monetary tightening, with FX intervention



Notes: The "temperature effect" is the ex-post nominal investment return over the risk-free rate of the currency of denomination. The "temperature and windchill effect" is the temperature effect plus ex-post change in nominal exchange rate.

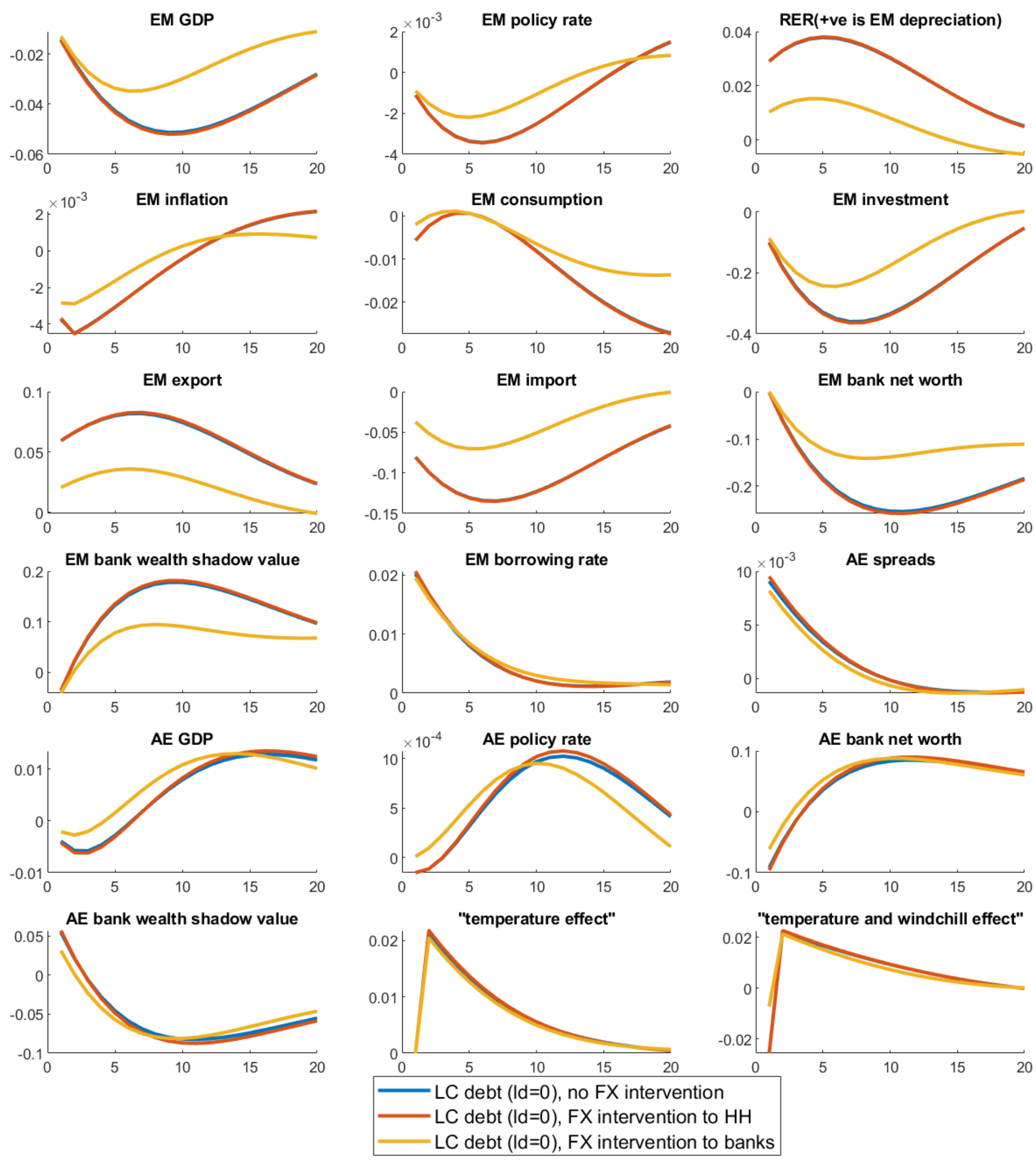
in banking net worth, therefore smaller reduction in EM investment and less depreciated currency. Such leaning against the wind of capital flow using FX intervention has been recently advocated by Diamond et al. (2020) and Cavallino (2019). In our model, the policy is effective because it stabilizes the credit creation ability of the banking system.

3.4 Conclusion

On the back of rapid growth in local currency debt markets over the last two decades, EMs have reduced their reliance on external foreign currency borrowing – the so-called "original sin". But this has not eliminated their financial vulnerability entirely. EMs still rely heavily on foreign sources of funding, albeit in local currency, as their bond markets have a less developed base of domestic institutional investors. This leaves them vulnerable to capital flow reversals on account of currency mismatches on the balance sheets of global lenders, and has given rise to the phenomenon of "original sin redux" (Carstens and Shin (2019)). This paper presents the first model-based evaluation of the original sin redux and the vulnerability of EMs to foreign and domestic shocks using a two country new keynesian DSGE model where financial frictions are present on both lenders' and borrowers' balance sheet.

The main takeaways from the analysis can be summarized as follows. First, while the original sin redux reduces the vulnerability of EMs to global shocks compared with original sin, it falls short of matching the benefits that ensue from a large domestic investor base. Second, while domestic investor base cushions the impact of external shocks, it increases the sensitivity of EM macroeconomic variables to domestic shocks. More generally, the ordering of the different regimes (OS, OSR or DD) depends on the nature of the shock, with DD proving to be the best alternative in the case of foreign shocks, and OSR and OS for foreign shocks. original sin redux does provide a weak improvement over original sin, regardless of the nature

Figure 3.3.6: Capital outflow shock, with FX intervention



Notes: The "temperature effect" is the ex-post nominal investment return over the risk-free rate of the currency of denomination. The "temperature and windchill effect" is the temperature effect plus ex-post change in nominal exchange rate.

of the shock. Third, foreign exchange intervention that eases constraints on the balance sheet of the affected financial institutions can mitigate the impact of external shocks, and thus proves to be a valuable addition to the policy toolkit of central banks.

The paper focuses on the simplest possible general equilibrium framework to highlight the role of frictions that give rise to differences across regimes. As such, it leaves open several avenues for future research and exploration. For instance, the regimes (OS, ORS and DD) are fixed exogenously throughout the analysis, and banks are not allowed to adjust the share of their funding in response to shocks. While this appears to be a restrictive assumption, there is a large body of evidence documenting that sources of funding (for both firms and banks) are fairly are sticky, especially at business cycle frequencies considered in this paper.[8] Nevertheless, extending the model to allow for endogenous switching between sourced of funding would be an interesting extension to establish the robustness of the results uncovered here.

Lastly, the focus of the paper is primarily positive, and we abstract from issues relating to optimal policy as well as the scope for coordination of policies across countries (as in Banerjee et al. (2016)). An extension to characterize optimal policy in the presence of two instruments (namely FX intervention and monetary policy) is likely to be particularly informative in the context of most EMs adopting monetary policy frameworks that employe additional tools and serve objectives beyond inflation targeting such as financial stability (BIS (2019)).

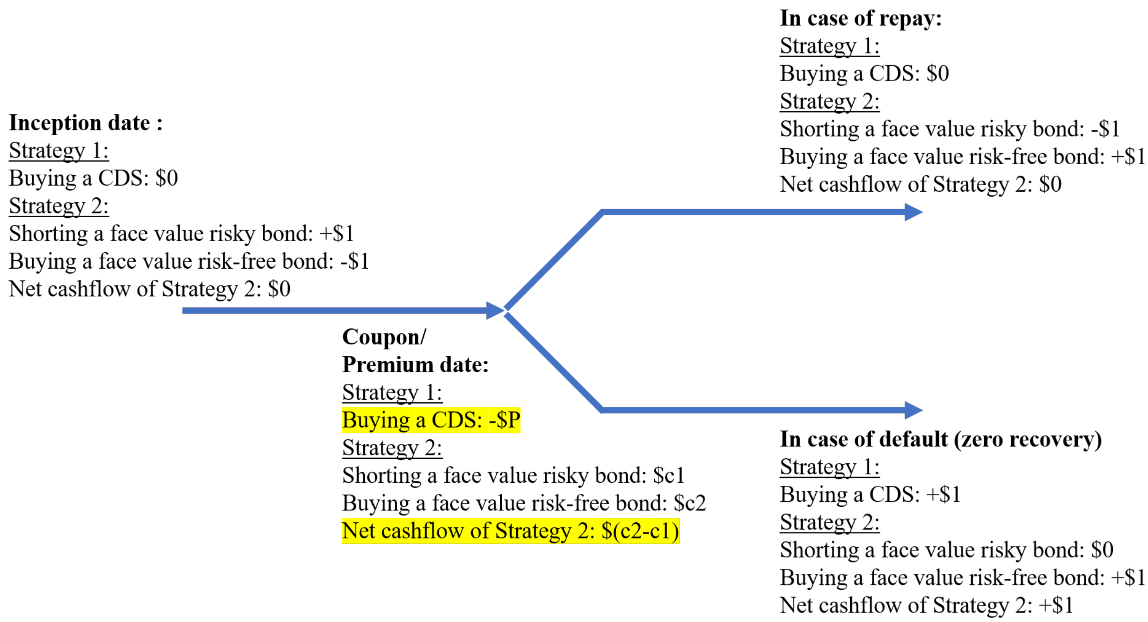
[8] See for instance see for instance Ivashina et al. (2015)Degryse et al. (2019), Khwaja and Mian (2008) and Jiménez et al. (2012), Paravisini (2008) and Paravisini et al. (2015)).

Appendix A

Appendix of Chapter 1

A.1 Equivalence between CDS and sovereign bond

Figure A.1.1: Cashflow chart of buying a CDS and shorting a sovereign bond with investing in risk free bond



Strategy 1, buying a CDS generates cashflow exactly the same as strategy 2, short selling a face value risky bond and buying a face value risk-free bond, regardless of repay or default. By no-arbitrage, \$P=\$(c2-c1), which says that the CDS premium is equal to the risky bond rate over the risk-free rate.

A.2 Construction of variables

Construction of default premium and risk premium variables

In this appendix, we describe in detail the decomposition of CDS premia and construction of each variable. Theoretically, risk premium is the additional return required by a risk-averse investor (or a constrained investor) compared to a risk-neutral investor. In this paper, we adopt two well-defined methods from the finance literature to measure the risk premium. Both methods infer the default probability from CDS spreads. There are a few advantages in using CDS spreads rather than the actual bond yield. First, the CDS market are often more liquid than the underlying bond market of the emerging countries. Second, the CDS spreads are not directly subject to interest rate risk, while the underlying fixed-rate bonds are. Finally, CDS are available in constant maturities (standard 1, 3, 5, 10 year). Both estimation methods rely on the assumption that risk-neutral investors only ask for a return that compensate the expected default probability. However, they are different in terms of how to infer the expected default probability.

Affine term structure decomposition. The first method relies on the term structure of sovereign CDS spreads to infer the expected default probability. The method and notation we discuss here follow closely Longstaff et al. (2011). We will be relying on taking expectations over the risk-neutral measure (related variables are denoted with superscript Q) and over the objective process (related variables are denoted with superscript P). Theoretically, the CDS spread of a CDS contract at time t with M-year maturity can be written as follows:

$$CDS_t(M) = \frac{2(1-R^Q)\int_t^{t+M} D(t,u) E_t^Q[\lambda_u e^{-\int_t^u (\lambda_s) ds}]du}{\sum_{j=1}^{2M} D(t,t+j/2)[E_t^Q e^{-\int_t^{t+j/2}\lambda_s ds}]},$$

where R^Q is the constant recovery rate (risk-neutral fractional recovery of the bond if there is a credit event), E^Q is the expectation under risk-neutral measure, r_t is the risk-free rate, λ_t denotes the risk-neutral arrival rate of a credit event, and $D(t,u)$ is the price of a default free zero coupon bond (issued at date t and maturing at date u). Intuitively, the numerator is the present value of the contingent payment by the protection seller upon a credit event. The denominator is the present value of a M-year semiannual annuity, which is the "insurance premium" that is paid by the protection buyer upon a credit event not having occurred.

Under the objective process, we assume the arrival rate of a credit event follows a log normal process:

$$dln\lambda_t = \kappa^P(\theta^P - ln\lambda_t)dt + \sigma_\lambda dB_t^P.$$

Similarly, under the risk-neutral process, we assume:

$$dln\lambda_t = \kappa^Q(\theta^Q - ln\lambda_t)dt + \sigma_\lambda dB_t^Q.$$

The two process are linked through the "market price of risk" in the following form:

$$\eta_t = \delta_0 + \delta_1 ln\lambda_t$$

This governs the change of probability distribution from P to Q. Specifically, the parameters are bridged by the following relationships: $\kappa^Q = \kappa^P + \delta_1\sigma_\lambda$ and $\kappa^Q\theta^Q = \kappa^P\theta^P - \delta_0\sigma_\lambda$. Therefore, when $\delta_0 = 0$ and $\delta_1 = 0$, there is no market price of risk and the two processes will be the same.

Analogously, we can compute the same CDS pricing with the expectation taking over the probability distribution P implied by the objective process:

$$CDS_t^P(M) = \frac{2(1-R^Q)\int_t^{t+M} D(t,u)E_t^P[\lambda_u e^{-\int_t^u(\lambda_s)ds}]du}{\sum_{j=1}^{2M} D(t,t+j/2)[E_t^P e^{-\int_t^{t+j/2}\lambda_s ds}]}.$$

This term, $CDS_t^P(M)$, is the hypothetical CDS spreads that an investor would require when they compute expectation using the objective process. That is, this is the CDS spread that corresponds to the physical default probability of the underlying asset, which is the default premium. To compute the risk premium, we take the difference between the market observed spread and the estimated hypothetical default premium. That is, $CDS_t(M) - CDS_t^P(M)$.

We estimate the $CDS_t^P(M)$ term by a maximum likelihood approach. We need to estimate κ^Q, κ^P, $\kappa^Q\theta^Q$, $\kappa^P\theta^P$ and σ_λ . δ_0 and δ_1 can be calculated through $\kappa^Q = \kappa^P + \delta_1\sigma_\lambda$ and $\kappa^Q\theta^Q = \kappa^P\theta^P - \delta_0\sigma_\lambda$. We make use of the term structure of CDS prices and the time series of the term structure to identify λ_t and the parameters (κ^Q, κ^P, $\kappa^Q\theta^Q$, $\kappa^P\theta^P$, σ_λ). Specifically, we have a term structure of one-year, three-year and five year CDS contracts. We assume the three-year CDS contract is priced perfectly and one-year and five-year are priced with mean zero normally distributed errors with standard deviation $\sigma_\varepsilon(1)$ and $\sigma_\varepsilon(5)$ respectively. The three-year CDS spreads is then inverted to infer λ_t. The recovery rate is assumed to be 0.25.

Computationally, we use Longstaff et al. (2011) programming code to conduct the maximum likelihood estimation and the decomposition. The data input for the code is the one-year, three-year, five year CDS spreads and the zero-coupon discount rate.

Credit rating decomposition. The second method relies on credit ratings to infer the expected default probability. The method and notation we discuss here follow closely Remolona et al. (2008). Credit rating agencies assign ratings to sovereigns. At the same time, they publish regularly average sovereign cumulative default rates by rating for various investment horizons T (denoted as $PD_t(T)$ for each time t). For example, in 2016, the 5-year default rate for a Moody's A rated sovereign is 1.16%. Assuming a hazard rate, we compute a Rating Implied Expected Loss for investment horizon T ($RIEL_t(T)$), which is defined as the recovery rate (RR) adjusted default intensity:

$$(1 - Pr_t(\text{default} < T) \times (1 - RR)) = (1 - PD_t(T) \times (1 - RR)) = e^{-T \times RIEL_t(T)}$$

Consistent with the assumption above, we assume a constant recovery rate of 25% throughout the exercise. For the example of observing a default rate of 1.16%, the formula above gives $(1-0.0116\times(1-0.25)) = e^{-5\times RIEL_t(5)} \Rightarrow RIEL_t(5) = 0.00175$. The $RIEL$ is then used as the default premium from credit rating decomposition, which is 17.5 basis points in this case. The risk premium is then computed as $CDS_t(T) - RIEL_t(T)$.

Throughout the exercise, we use Moody's credit rating and default rates from Moody's Investors Service reports to infer the $RIEL$. The reports are released annually (with some irregular semi-annual updates) and credit ratings can be changed in any given quarter. These give the time variation of the estimated $RIEL$.

Construction of external debt by currency type by sector

We construct the FC corporate external debt, the FC sovereign external debt, and the LC sovereign external debt data in two ways and the results are robust to the construct method. First, we follow Du and Schreger (2017) cleaning procedure closely, which rely on BIS International Debt Statistics (IDS), Locational Banking Statistics (LBS) and commercial data source. Second, BIS provide more transparent data than before so we also construct the data based on BIS data only with some mild assumptions.

Du and Schreger procedure. The procedure in brief is as follows:

(1) Obtain country aggregate outstanding bond and cross-border loan data from the BIS

(2) Obtain transaction level bond and loan data from Bloomberg (Du and Schreger (2017) use Thomson One instead)

(3) Identify the external loans and bonds in transaction level

- (3a) A loan deal is counted as external if at least one bookrunner of the deal is a foreign bank

- (3b) All bond issuances in international market are counted towards external debt

(4) Aggregate the Bloomberg data to country-level aggregate

(5) Split the aggregate level bond and loan data in (1) by the share by each sector (public, private) and by each currency from the aggregated Bloomberg data

(6) Obtain the sovereign debt held by foreign lenders in domestic market by national data source and Arslanalp and Tsuda (2014)

(7) Combine bond and loan values to construct the external debt variables

The aggregated Bloomberg data covers on average 80% of the BIS numbers. The BIS statistics take into account of adjustments such as additional offerings and buying back debts before maturity. It also combines information from a few other commercial databases so the aggregate numbers are more accurate. Therefore, splitting the BIS numbers with disaggregated data from Bloomberg gives a good measure of the share of debt by sector and by currency.

Using BIS data only. BIS actively improves the transparency of IDS and LBS. The recent version has more sectoral and currency split information. We construct the variables as follows.

For IDS:

(1a) IDS provides international bond amount denominated in USD and EUR; We count these debts towards FC

(1b) We count the debt from "Central bank," "General government," "Public banks," and "Public other financial institutions" as public debt. The rest are counted as private debt.

For LBS:

(2a) LBS provides loan amount denominated in USD, EUR, GBP, JPY, and CHF; We count these loans towards FC

(2b) LBS provides sectoral split by financial and non-financial breakdown, but not sovereign and coporate breakdown. We count all loans toward the private sector, which is consistent with the confidential version of LBS that the loan to public sector is negligible.[1]

(3) We obtain the sovereign debt held by foreign lenders in domestic market by national data source and Arslanalp and Tsuda (2014).

(4) We combine bond and loan values to construct the external debt variables

[1]BIS starts to report more detailed sectoral breakdown since 2013 but the detailed breakdown is restricted for central banks access only.

A.3 Summary statistics

Country		Brazil	Chile	China	Colombia	Croatia	Hungary
CDS	mean	195.2	78.4	80.1	164.8	230.0	242.9
	sd	102.0	45.8	45.5	72.1	143.3	160.8
	max	494.9	214.9	201.2	412.1	545.8	635.0
	min	75.8	13.2	11.0	81.5	15.5	15.0
	obs	48	48	48	48	48	41
CDS risk premium	mean	126.0	53.8	42.3	48.5	160.9	171.3
(Terms structure)	sd	97.7	37.4	31.3	70.7	113.6	152.1
	max	413.0	165.6	118.0	292.0	408.4	544.9
	min	13.3	0.7	-2.1	-32.1	-6.8	-40.7
CDS risk premium	mean	146.0	69.8	75.2	115.4	185.1	213.4
(Credit rating)	sd	106.1	50.0	43.5	77.7	147.4	151.0
	max	470.0	214.9	201.2	362.5	516.2	587.7
	min	-7.2	-18.3	11.0	0.7	-35.8	15.0
CDS default premium	mean	69.3	24.6	37.8	116.3	69.1	71.6
(Terms structure)	sd	4.5	8.5	15.0	1.5	30.1	8.8
	max	83.1	49.3	83.2	120.7	137.3	90.1
	min	62.6	12.5	13.1	113.6	22.3	55.7
CDS default premium	mean	49.2	8.6	4.9	49.4	44.9	29.5
(Credit rating)	sd	33.1	10.4	5.4	28.4	6.9	23.2
	max	116.3	37.9	12.7	105.6	56.1	74.8
	min	14.2	0.0	0.0	13.1	29.6	0.0
Corp FC debt to GDP	mean	9.4	25.2	3.8	7.6	43.4	32.4
	sd	2.7	4.2	1.1	3.9	7.4	12.6
	max	15.6	34.1	6.2	16.4	56.0	57.4
	min	6.1	17.6	1.8	4.0	28.2	16.7
	obs	48	48	48	48	48	41
Govt FC debt to GDP	mean	3.3	2.1	0.3	5.9	14.0	16.8
	sd	1.4	1.0	0.2	1.6	7.6	3.0
	max	7.3	4.6	0.6	8.4	27.5	21.5
	min	1.9	0.8	0.1	3.8	4.7	10.8
	obs	48	48	48	48	48	41
Govt LC debt to GDP	mean	4.4	0.4	0.2	3.0	0.0	12.1
	sd	2.5	0.4	0.2	2.1	0.0	2.8
	max	9.0	1.2	0.7	8.1	0.0	17.7
	min	0.0	0.0	0.0	0.6	0.0	7.1
	obs	48	48	48	48	48	41
Exchange rate	mean	2.3	553.4	7.0	2222.0	5.8	217.7
(LC per USD)	sd	0.6	65.9	0.8	394.9	0.6	35.3
	max	4.0	707.3	8.3	3149.5	7.2	293.7
obs=52	min	1.6	439.1	6.1	1768.2	4.6	149.8

Country		India	Indonesia	Korea	Malaysia	Mexico	Philippines
CDS	mean	171.9	210.3	84.8	99.1	122.4	174.4
	sd	37.2	106.5	71.2	58.2	61.6	88.6
	max	270.5	691.4	333.0	240.9	380.4	412.7
	min	123.0	110.3	-1.0	16.2	35.6	87.2
	obs	13	47	47	48	48	48
CDS risk premium	mean	104.3	140.6	57.1	32.7	81.5	51.1
(Terms structure)	sd	35.3	101.7	63.6	26.2	52.4	44.2
	max	198.0	601.8	280.8	111.4	301.5	189.0
	min	58.0	45.4	-27.1	-4.1	7.4	8.3
CDS risk premium	mean	146.5	141.2	77.7	90.9	109.2	101.4
(Credit rating)	sd	35.2	105.7	73.4	58.2	63.7	75.3
	max	239.8	595.3	333.0	237.6	369.7	307.0
	min	100.9	-4.4	-13.7	9.0	24.8	-3.7
CDS default premium	mean	67.7	69.7	27.6	66.4	40.9	123.3
(Terms structure)	sd	1.9	5.0	7.9	35.7	9.2	47.4
	max	72.4	89.6	54.9	173.0	78.9	271.0
	min	65.0	64.7	19.3	15.8	28.2	76.9
CDS default premium	mean	25.5	69.1	7.1	8.2	13.2	73.1
(Credit rating)	sd	2.9	41.2	5.7	4.4	7.6	38.6
	max	30.7	146.9	17.2	17.2	37.9	125.1
	min	22.1	22.1	0.0	3.2	10.0	13.1
Corp FC debt to GDP	mean	7.6	8.1	16.1	18.8	11.2	14.1
	sd	0.8	1.9	2.8	4.0	4.3	2.9
	max	9.4	12.3	22.2	29.9	21.0	23.6
	min	6.6	5.4	11.0	12.8	5.7	11.2
	obs	13	47	47	48	48	48
Govt FC debt to GDP	mean	0.1	3.2	3.0	5.3	4.2	12.3
	sd	0.0	1.5	0.4	1.2	0.7	3.5
	max	0.2	6.5	3.7	7.8	6.0	19.9
	min	0.1	1.0	2.2	3.1	3.4	8.5
	obs	13	47	47	48	48	48
Govt LC debt to GDP	mean	1.0	2.7	2.9	8.9	5.8	2.0
	sd	0.2	1.3	1.6	4.9	4.1	1.8
	max	1.2	5.7	4.7	17.3	12.0	4.6
	min	0.5	0.5	0.1	1.7	1.0	0.0
	obs	13	47	47	48	48	48
Exchange rate	mean	51.4	10332.0	1097.5	3.5	13.0	47.1
(LC per USD)	sd	8.8	1673.6	97.4	0.4	2.3	4.5
	max	68.0	14657.0	1377.1	4.5	20.6	56.4
obs=52	min	39.4	8587.0	920.7	3.0	10.3	40.9

Country		Poland	Russia	South Africa	Thailand	Turkey
CDS	mean	96.2	202.7	166.0	106.4	228.3
	sd	74.9	136.9	88.6	54.1	65.6
	max	295.8	741.2	393.6	255.3	408.7
	min	8.5	43.2	28.6	26.9	127.0
	obs	48	47	47	47	45
CDS risk premium	mean	74.2	118.4	102.8	68.3	56.1
(Terms structure)	sd	67.3	57.0	66.8	47.5	23.0
	max	256.0	293.6	261.0	196.2	94.7
	min	-3.3	40.2	0.0	0.1	19.1
CDS risk premium	mean	90.2	180.8	153.0	93.2	161.5
(Credit rating)	sd	73.8	140.3	91.3	57.8	69.9
	max	290.7	729.2	381.6	243.3	312.6
	min	8.5	3.2	2.7	-3.9	29.8
CDS default premium	mean	22.0	84.3	63.1	38.1	172.2
(Terms structure)	sd	7.8	82.8	22.4	7.0	50.6
	max	42.9	447.5	132.6	59.1	345.0
	min	11.8	2.3	28.5	26.9	100.0
CDS default premium	mean	6.0	21.9	13.0	13.2	66.8
(Credit rating)	sd	6.1	13.8	8.3	7.7	31.6
	max	13.2	51.5	37.9	37.9	116.3
	min	0.0	10.0	3.2	9.8	22.1
Corp FC debt to GDP	mean	10.5	9.2	8.6	10.2	16.1
	sd	2.5	1.8	2.1	2.4	3.2
	max	14.8	13.4	13.4	14.4	22.1
	min	5.7	6.3	4.7	6.4	9.8
	obs	48	47	47	47	45
Govt FC debt to GDP	mean	9.4	2.7	3.0	0.4	6.2
	sd	1.6	0.9	0.5	0.5	0.8
	max	12.1	4.7	4.3	1.9	7.9
	min	6.3	1.4	2.4	0.1	5.2
	obs	48	47	47	47	45
Govt LC debt to GDP	mean	8.7	0.6	6.6	2.2	3.7
	sd	2.6	0.6	4.7	1.7	0.9
	max	12.3	1.9	15.6	4.8	5.8
	min	3.5	0.0	0.2	0.1	2.0
	obs	48	47	47	47	40
Exchange rate	mean	3.2	35.2	8.8	34.4	1.8
(LC per USD)	sd	0.4	13.2	2.6	3.4	0.6
	max	4.2	72.9	15.5	41.4	3.5
obs=52	min	2.1	23.5	5.6	29.3	1.2

A.4 Robustness of baseline regression

We run regression (1.2, 1.3, 1.4) with additional country-specific controls to show the key findings are robust across specifications.

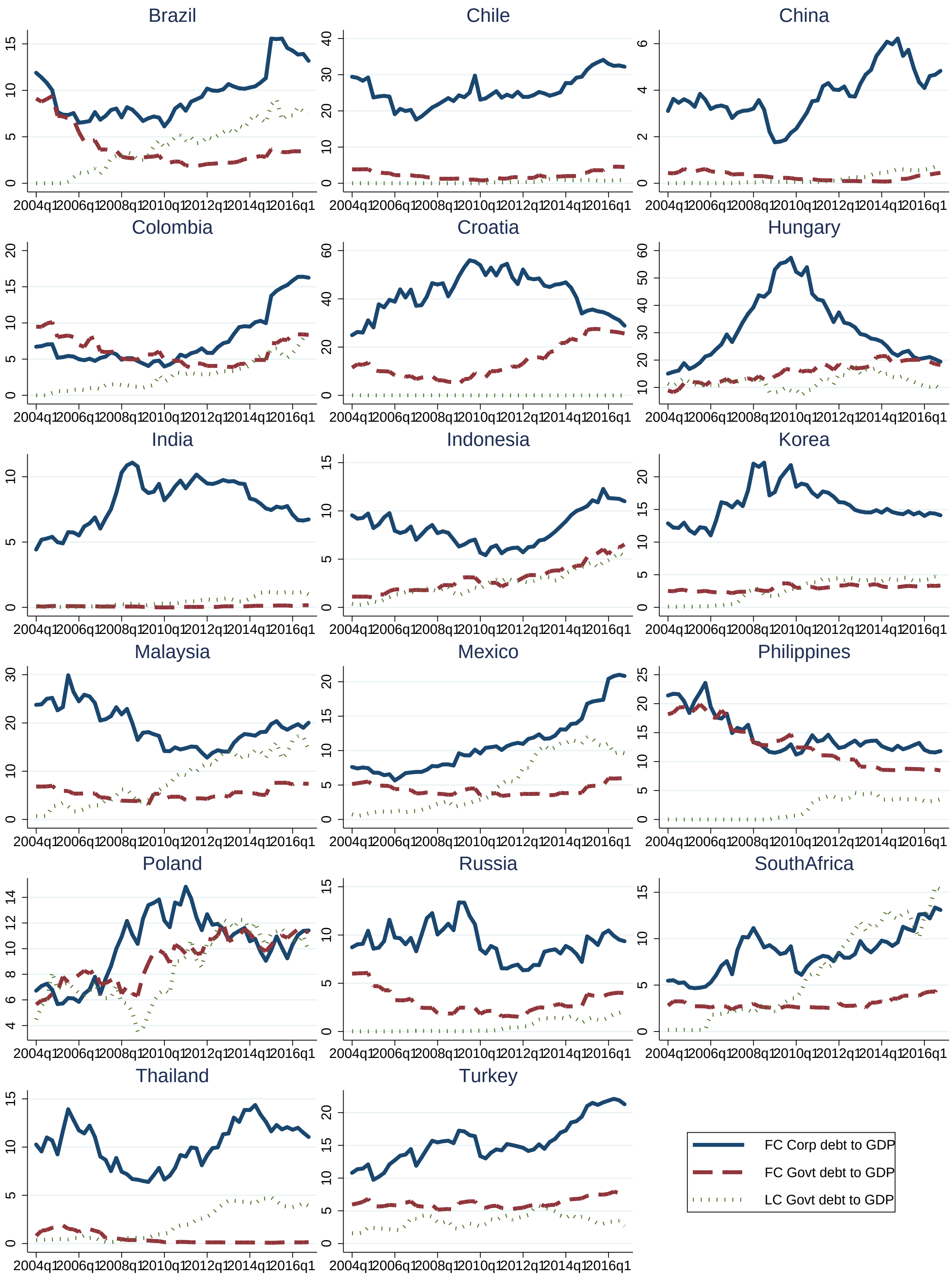
$$\begin{aligned}\text{Sovereign CDS}_{i,t} = \quad & \alpha_i + \beta_1(\frac{\text{FC Corp debt}}{\text{GDP}})_{i,t-1} + \beta_2(\frac{\text{FC Sovereign debt}}{\text{GDP}})_{i,t-1} \\ & + \beta_3(\frac{\text{LC Sovereign debt}}{\text{GDP}})_{i,t-1} + \beta_j CC_{j,t-1} + \mu GC_t + \varepsilon_{i,t}\end{aligned}$$

$$\begin{aligned}\text{Sovereign CDS}_{i,t}^{\text{Default premium}} = \quad & \eta_i + \gamma_1(\frac{\text{FC Corp debt}}{\text{GDP}})_{i,t-1} + \gamma_2(\frac{\text{FC Sovereign debt}}{\text{GDP}})_{i,t-1} \\ & + \gamma_3(\frac{\text{LC Sovereign debt}}{\text{GDP}})_{i,t-1} + \gamma_j CC_{j,t-1} + \omega GC_t + \nu_{i,t}\end{aligned}$$

$$\begin{aligned}\text{Sovereign CDS}_{i,t}^{\text{Risk premium}} = \quad & \chi_i + \delta_1(\frac{\text{FC Corp debt}}{\text{GDP}})_{i,t-1} + \delta_2(\frac{\text{FC Sovereign debt}}{\text{GDP}})_{i,t-1} \\ & + \delta_3(\frac{\text{LC Sovereign debt}}{\text{GDP}})_{i,t-1} + \delta_j CC_{j,t-1} + \theta GC_t + u_{i,t}\end{aligned}$$

where the additional country specific controls, CC_4, CC_5, CC_6 are year-on-year GDP growth, reserve to GDP and trade balance to GDP, which are obtained from IMF IFS dataset,

Figure A.3.1: Times-series of debt to GDP variables (%)



Appendix Table 1: Panel regression with components of USD sovereign CDS as dependent variables, robustness check

	USD sovereign CDS premium (bps)	USD sovereign CDS default premium (bps)		USD sovereign CDS risk premium (bps)	
		Term	Rating	Term	Rating
(%)	(1)	(2a)	(2b)	(3a)	(3b)
$\frac{\text{FC Corp debt}}{\text{GDP}}$	5.606***	0.454	-0.274	5.152***	5.881***
	(0.938)	(0.303)	(0.237)	(0.785)	(0.965)
$\frac{\text{FC Sovereign debt}}{\text{GDP}}$	11.078***	2.486***	2.258***	8.592***	8.820***
	(2.211)	(0.455)	(0.460)	(1.850)	(1.988)
$\frac{\text{LC Sovereign debt}}{\text{GDP}}$	2.389	0.727	0.705	1.662	1.684
	(2.064)	(0.495)	(0.532)	(1.734)	(1.673)
GDP growth	-2.075	-1.217	-0.464	-0.858	-1.611
	(3.129)	(0.787)	(0.379)	(2.470)	(2.910)
$\frac{\text{Reserve}}{\text{GDP}}$	-1.698*	-1.201**	-0.479	-0.497	-1.219
	(0.962)	(0.496)	(0.319)	(0.844)	(0.814)
$\frac{\text{Trade balance}}{\text{GDP}}$	2.964	0.932	4.277***	2.032	-1.313
	(2.512)	(1.461)	(1.569)	(3.049)	(3.032)
Observations	761	761	761	761	761
R^2 adjusted	0.640	0.732	0.662	0.597	0.620
Period	2004Q1-2016Q4				
Countries	17				
Global Controls	Yes				
Country FE	Yes				

Standard errors in parentheses are heteroskedasticity autocorrelation spatial correlation robust standard errors (Driscoll and Kraay (1998)) with a 4-quarter lag. * p<0.1, ** p<0.05, *** p<0.01. All the spread measure of the independent variables are 5-year tenor. Decomposition in column (2a) and column (3a) uses affine term structure model by Longstaff et al. (2011). Decomposition in column (2a) and column (3a) applies credit rating method by Remolona et al. (2008).

In the next regression, in addition to the year-on-year GDP growth, reserve to GDP, trade balance to GDP, we also control for country-specific commodity price index to see that our results are not affected by commodity price fluctuation. The price indices are obtained from the IMF IFS dataset. However, we don't have the data for China, India and Indonesia so these countries are dropped in the regression.

Appendix Table 2: Panel regression with components of USD sovereign CDS as dependent variables, robustness check with commodity price index

	USD sovereign CDS premium (bps)	USD sovereign CDS default premium (bps)		USD sovereign CDS risk premium (bps)	
		Term	Rating	Term	Rating
(%)	(1)	(2a)	(2b)	(3a)	(3b)
$\frac{\text{FC Corp debt}}{\text{GDP}}$	5.213***	0.245	-0.309	4.968***	5.522***
	(1.044)	(0.345)	(0.240)	(0.882)	(1.019)
$\frac{\text{FC Sovereign debt}}{\text{GDP}}$	11.334***	2.556***	2.901***	8.778***	8.433***
	(2.673)	(0.572)	(0.667)	(2.163)	(2.254)
$\frac{\text{LC Sovereign debt}}{\text{GDP}}$	0.218	0.093	1.550***	0.125	-1.332
	(2.326)	(1.045)	(0.546)	(1.668)	(2.120)
GDP growth	-1.258	-0.814	-0.330	-0.444	-0.928
	(2.371)	(0.589)	(0.312)	(1.922)	(2.231)
$\frac{\text{Reserve}}{\text{GDP}}$	-1.644	-1.288*	-0.548*	-0.356	-1.096
	(1.167)	(0.652)	(0.315)	(0.906)	(0.971)
$\frac{\text{Trade balance}}{\text{GDP}}$	-0.432	-0.051	3.822***	-0.382	-4.254
	(2.350)	(1.947)	(1.031)	(2.651)	(2.950)
Commodity price index	1.281***	0.561***	-0.095	0.720**	1.376***
	(0.380)	(0.137)	(0.130)	(0.326)	(0.298)
Observations	636	636	636	636	636
R^2 adjusted	0.658	0.740	0.690	0.624	0.640
Period	2004Q1-2016Q4				
Countries	13				
Global Controls	Yes				
Country FE	Yes				

Standard errors in parentheses are heteroskedasticity autocorrelation spatial correlation robust standard errors (Driscoll and Kraay (1998)) with a 4-quarter lag. * p<0.1, ** p<0.05, *** p<0.01. All the spread measure of the independent variables are 5-year tenor. Decomposition in column (2a) and column (3a) uses affine term structure model by Longstaff et al. (2011). Decomposition in column (2a) and column (3a) applies credit rating method by Remolona et al. (2008).

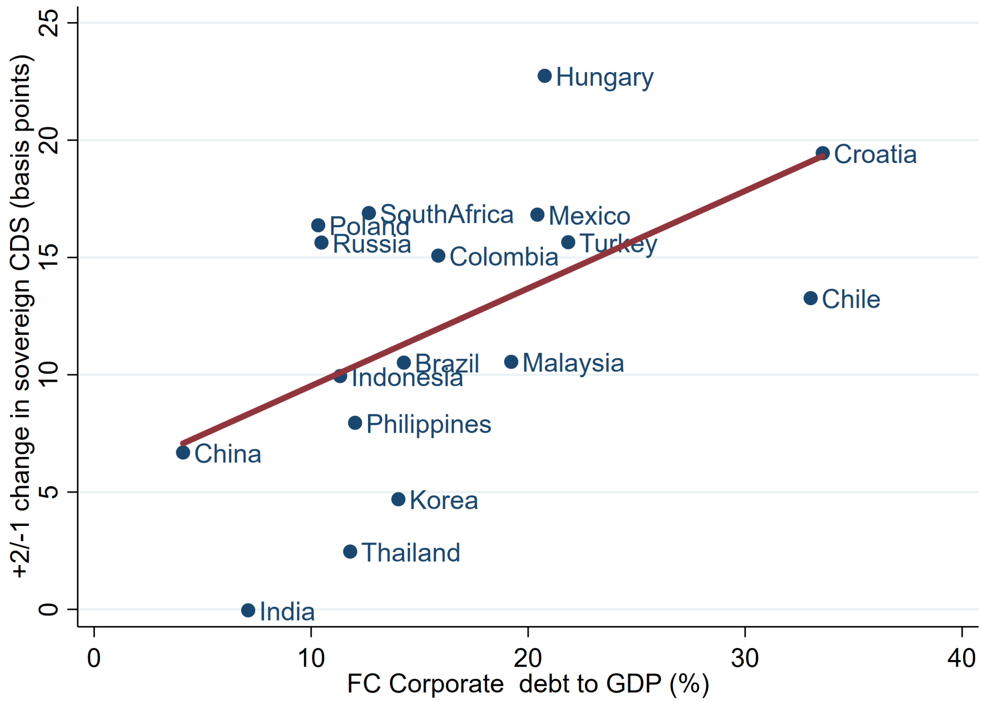
As in most sovereign default models, our model is slient about domestic credit. In the next regression, we further control for domestic credit to GDP to see that our results are not affected by this. However, we are only able to obtain domestic credit to GDP data for all sample countries from the World Bank, which only has annual data. We report our end-of-year regression with domestic credit to GDP, year-on-year GDP growth, reserve to GDP, trade balance to GDP and commodity price index. Our results are also robust to excluding commodity price index so to have the three countries added back to the sample.

Appendix Table 3: Panel regression with components of USD sovereign CDS as dependent variables, robustness check with domestic credit to GDP

	USD sovereign CDS premium (bps)	USD sovereign CDS default premium (bps)		USD sovereign CDS risk premium (bps)	
		Term	Rating	Term	Rating
(%)	(1)	(2a)	(2b)	(3a)	(3b)
$\frac{\text{FC Corp debt}}{\text{GDP}}$	4.541***	0.320	-0.323	4.221***	4.864***
	(0.836)	(0.408)	(0.319)	(1.095)	(0.793)
$\frac{\text{FC Sovereign debt}}{\text{GDP}}$	8.635***	1.907***	2.863***	6.727***	5.772**
	(2.630)	(0.592)	(0.643)	(2.155)	(2.065)
$\frac{\text{LC Sovereign debt}}{\text{GDP}}$	2.638	0.424	2.481***	2.214	0.158
	(3.994)	(1.624)	(0.664)	(2.604)	(3.651)
GDP growth	1.461	0.757	-0.699	0.704	2.161
	(2.858)	(0.755)	(0.565)	(2.194)	(2.632)
$\frac{\text{Reserve}}{\text{GDP}}$	0.191	-0.575	-0.457*	0.766	0.649
	(1.807)	(1.018)	(0.216)	(1.285)	(1.668)
$\frac{\text{Trade balance}}{\text{GDP}}$	2.805	2.204	3.785	0.601	-0.980
	(6.837)	(4.200)	(2.215)	(4.102)	(8.396)
Commodity price index	2.162***	0.973***	-0.067	1.188**	2.228***
	(0.317)	(0.185)	(0.111)	(0.400)	(0.278)
$\frac{\text{Domestic credit}}{\text{GDP}}$	1.145	-0.093	-0.106	1.238	1.251
	(1.804)	(0.634)	(0.210)	(1.389)	(1.732)
Observations	157	157	157	157	157
R^2 adjusted	0.681	0.740	0.690	0.624	0.657
Period	2004Q1-2016Q4				
Countries	13				
Global Controls	Yes				
Country FE	Yes				

Standard errors in parentheses are heteroskedasticity autocorrelation spatial correlation robust standard errors (Driscoll and Kraay (1998)) with a 4-quarter lag. * p<0.1, ** p<0.05, *** p<0.01. All the spread measure of the independent variables are 5-year tenor. Decomposition in column (2a) and column (3a) uses affine term structure model by Longstaff et al. (2011). Decomposition in column (2a) and column (3a) applies credit rating method by Remolona et al. (2008).

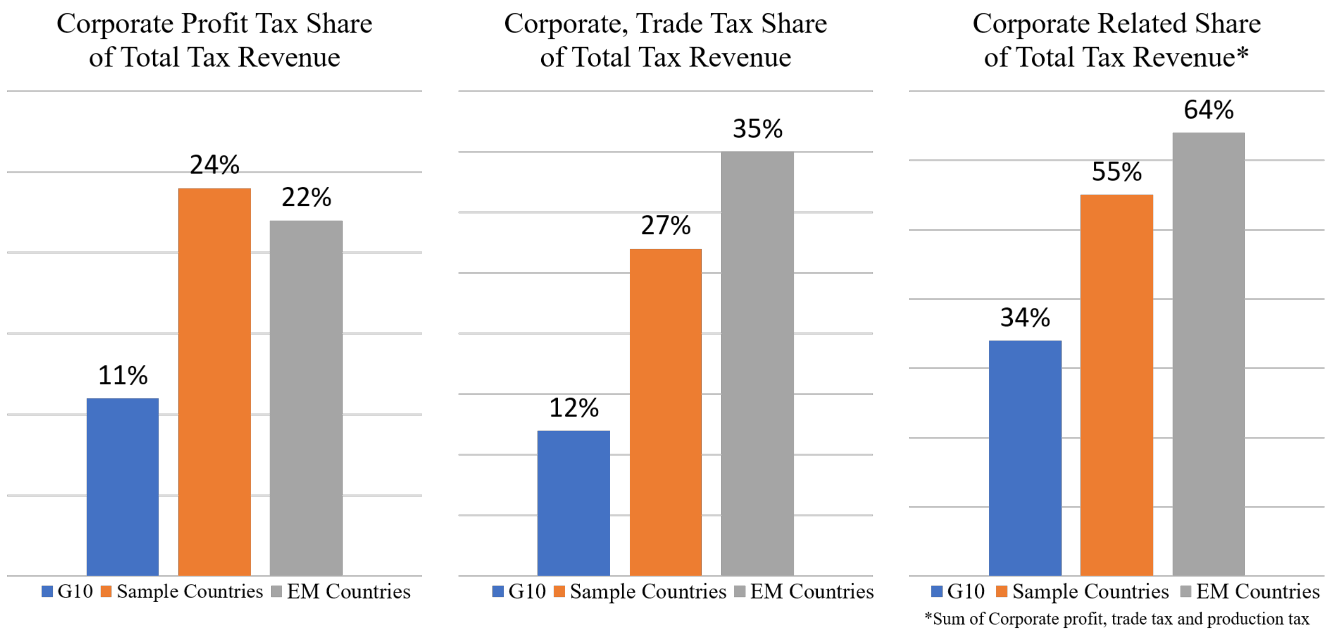
Figure A.5.1: Positive relationship of change of sovereign CDS and FC corporate debt to GDP on Brexit referendum day



A.5 Scatterplot for a representative event date

We plot the unconditional relationship of FC corporate debt to GDP against a three-day change in sovereign CDS over the Brexit referendum on June 23rd, 2016 (one day before and two days after). On this date, the VIX index increased by 50%. The CDS spreads increase by an average of 10 basis points with the country with more FC corporate debt to GDP tending to have a larger increase. We think of the dramatic increase in VIX as a proxy of an increase in investor risk appetite and investors evaluate the riskiness of a country by looking at the FC corporate debt to GDP as a pricing factor.

Figure A.6.1: Corporate tax share



A.6 Corporate tax as a share of total tax

We provide summary statistics for the corporate tax share of total tax revenue below. The source is IMF World Revenue Longitudinal Dataset period from 2004-2014. The statistics indicates higher reliance on corporate tax revenue in emerging countries than advanced countries. The share is also high as we count in corporate profit tax, trade tax and production tax, which are taxes that are related to corporate activities. We run a regression of change in these sub-component of tax revenue on FC corporate debt to GDP and interacting with change of exchange rate. The coefficient of the interacted term are significantly negative, indicating a local currency depreciation reduces these tax revenues and more so if corporate debt is high.

A.7 USD Safety Premium

In this section, we provide empirical evidence that USD, the major FC in our sample emerging countries debt profile, appreciates when lender SDF is high, supporting the relationship assumed in the model section. We follow the approach developed by Maggiori (2013) to document this "USD Safety Premium" for each of our sample country.

Consider a two country world: a EM country (home) and the US (foreign). We denote the foreign variable with *. By no-arbitrage condition, there exist two SDF, one for each country, such that:

$$1 = E_t[M_{t+1}R_{t+1}] \text{ , } 1 = E_t[M^*_{t+1}R^*_{t+1}]$$

where Λ_{t+1} is the home SDF and R_{t+1} is the home asset return. Exchange rate S_t is denoted as home currency per USD.

If assets are traded internationally and no arbitrage condition holds. Then there exist two SDFs such that:[2]

$$M_{t+1} = M^*_{t+1}\frac{S_t}{S_{t+1}}$$

Assuming the variables are all jointly log-normally distributed, then the expected excess return of US investment converted to home currency and home investment is:

$$0 = E_t M^*_{t+1}(R^*_{t+1} - R_{t+1}\frac{S_t}{S_{t+1}})$$

[2]Home and US agents agree on the prices of all assets that they can trade. Under complete markets, the span of assets covers the entire state space so that agents agree on all possible prices. Under this condition, the SDF of each country is unique and obeys the relationship. However, if markets are not complete agents need only agree on the prices of assets that can actually be traded. For each country there exists an infinite set of valid SDFs. The relationship does not need to hold between any two arbitrary SDFs. However, the equation can be considered a denition for SDFs in one country given a choice of SDF in the other country. To simplify the exposition, we assume here that markets are complete.

$$E_t(r^*_{t+1} - \Delta s_{t+1} - r_{t+1}) + \frac{1}{2}var_t(r^*_{t+1}) - \frac{1}{2}var_t(\Delta s_{t+1} + r_{t+1}) =$$
$$-cov_t(m^*_{t+1}, r^*_{t+1}) - cov_t(m^*_{t+1}, \Delta s_{t+1}) + cov_t(m^*_{t+1}, r_{t+1})$$

In the case when r_{t+1} and r^*_{t+1} are risk free rates that are known at time t, we have:

$$r_{t+1} \; - r^*_{t+1} + E_t(\Delta s_{t+1}) + \frac{1}{2}var_t(\Delta s_{t+1}) = cov_t(m^*_{t+1}, \Delta s_{t+1}) \equiv \$SP_t \;\; .$$

The USD is safe if it appreciates in bad times. Those scenarios are characterized by high marginal utility growth (i.e., a high SDF case). Therefore, a positive $cov_t(m^*_{t+1},\Delta s_{t+1})$ is evidence of the safety property of USD. Maggiori (2013) documents a positive $cov_t(m^*_{t+1}, \Delta s_{t+1})$ both conditionally and unconditionally for the US against a basket of rest of the world countries. In this paper, $cov_t(m^*_{t+1},\Delta s_{t+1}) > 0$ will be consistent with our reduced form SDF with a positive γ.

We estimate the USD safety premium ($\$SP_t$) in two ways. First, we document an ex-ante $\$SP_t$. Second, following an approach developed in Maggiori (2013), we compute an ex-post $\widetilde{\$SP_t}$ with a two-stage estimation, based on the realized value. We use the data at quarterly frequency with one-year investment horizon. Following Du et al. (2018a) and Engel and Wu (2018), the (one-year) interest rate swap rates are treated as the risk free rate. We obtain the one-year exchange rate expectation from survey forecast from Bloomberg.[3] The sample period is 2001Q2-2017Q4 where the starting date is constrained by the availability of exchange rate forecast data.

For the ex ante $\$SP_t$, notice that if we want to show $\$SP_t > 0$, it is sufficient to show that $DUIP_t \equiv r_{t+1} - r^*_{t+1} + E_t(\Delta s_{t+1}) > 0$ because $\frac{1}{2}var_t(\Delta s_{t+1})$ is always positive by the definition of variance. Therefore, without estimating the conditional variance of exchange rate, we provide evidence of an ex-ante UIP deviation that biased towards an excess return if investing in home currency.

[3] We take the median forecast as the expectation.

Table A.7.1 below reports the mean value of the term $DUIP_t \equiv r_{t+1} - r^*_{t+1} + E_t(\Delta s_{t+1})$ where the home country is one of the sample countries and the foreign country is the US. We can see that all countries exhibit a UIP deviation that is biased toward an excess return of investing in EM countries. The simple cross-country average is around 0.038 (3.8%). This provides evidence that there is a positive USD safety premium.

Table A.7.1: Deviation of UIP with Bloomberg forecast data

Country	mean $DUIP_t$	Country	mean $DUIP_t$
Brazil	0.058	Malaysia	0.037
Chile	0.0018	Mexico	0.059
China	0.018	Philippines	0.029
Colombia	0.021	Poland	0.022
Croatia	NA	Russia	0.061
Hungary	0.010	South Africa	0.026
India	0.074	Thailand	0.018
Indonesia	0.072	Turkey	0.073
Korea	0.035		

For the ex-post $\widetilde{\$SP_t}$, we follow one of the approaches by Maggiori (2013) with a two-stage estimation.[4] Formally, define $\widetilde{\$SP_t} \equiv r_{t+1} - r^*_{t+1} + \Delta s_{t+1} + \frac{1}{2}\widetilde{var_t}(\Delta s_{t+1})$, where Δs_{t+1} is the observed ex-post realization. The term $\widetilde{var_t}(\Delta s_{t+1})$ is an estimate of the conditional variance from the following first stage regression using ex-post data:

$$\Delta s_{t+1} = \alpha_e Y^e_t + \varepsilon^e_{t+1}$$

where $Y^e_t = [1, r^*_{t+1} - r_{t+1}, \Delta s_t]$.

The estimated residuals, $\hat{\varepsilon}^e_{t+1}$, are used to compute $\widetilde{var_t}(\Delta s_{t+1}) = (\hat{\varepsilon}^e_{t+1})^2$. Table A.7.2 below reports the mean value of $\widetilde{\$SP_t}$ where the home country is one of the sample countries and the foreign country is the US. Again we see that all countries exhibit a positive USD safety

[4] See equation (11) of Maggiori (2013)

premium.

Table A.7.2: USD Safety Premium as in Maggiori (2013) for the sample countries

Country	mean $\$\widetilde{SP_t}$	Country	mean $\$\widetilde{SP_t}$
Brazil	0.096	Malaysia	0.001
Chile	0.026	Mexico	0.006
China	0.004	Philippines	0.034
Colombia	0.025	Poland	0.041
Croatia	0.002	Russia	0.003
Hungary	0.053	South Africa	0.049
India	0.015	Thailand	0.016
Indonesia	0.044	Turkey	0.014
Korea	0.021		

To conclude, from both ex-ante and ex-post aspects, we find that there is a positive USD safety premium. This supports the reduced form relationship in the modeling section which assumes that the FC appreciates when lender's SDF is high.

A.8 Emerging market bond performance and dollar index

In footnote 43, we decribe a story where EM market specialized investor performance is worse when USD appreciates. We provide evidence below that both BAML EM Corporate Index and BAML US Corp BBB Index are very negatively correlated to dollar index (-0.5 and -0.45). Investors who invest in these high yield corporates are likely to provide funding and being the marginal pricer of the emerging market sovereigns.

Figure A.8.1: Strong negative relationship of EM corporate index and dollar index

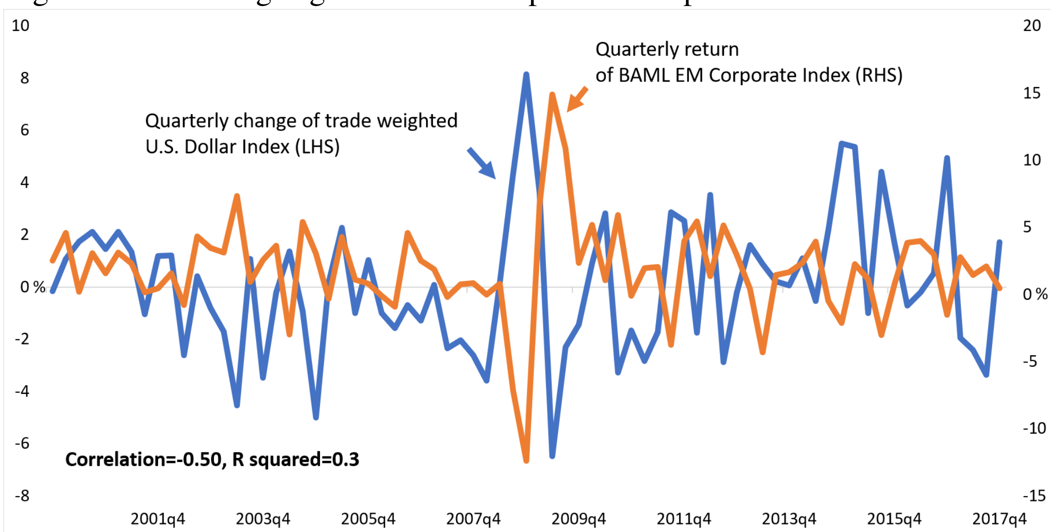
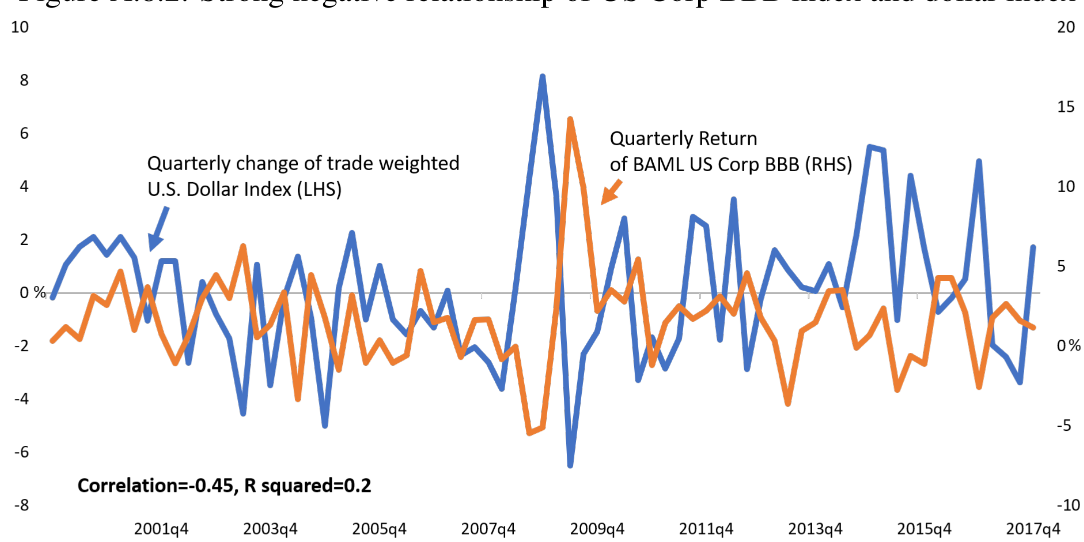


Figure A.8.2: Strong negative relationship of US Corp BBB index and dollar index



A.9 Numerical Algorithm

Recursive equilibrium definition

To compute the model solution, we first discretize the shock processes (z,S,V) and choice variables (B,k,b). The three exogenous shocks are "tauchenize" to 11, 21 and 31 grid points respectively. The choice variables are discretized to 41 grid points each. We then solve the model by using a two loop algorithm for each of the two sector. For each sector, we first iterate the value function in an inner loop and iterate the bond price schedule in an outer loop. Convergence in each sector is defined as both value function difference and bond price difference are smaller their the tolerance level of 1×10^{-5}. The algorithm is common in the literature but we extend it to a two sector setup. The model is solved with the following algorithm:

1) Start with initial guesses for corporate bond price $q_0(k',b';X)$ and enter$U_0^E(k,b;X)$, we iterate until $U^E(k,b;X)$ converges.

2) Once the value function $U^E(k,b;X)$ converges, compute the default set by comparing $U^E(k,b;X)$ to $U^E(k,0;X)-\varepsilon$

3) Update the corporate bond price schedule using the default set according the pricing equation and the old bond price schedule with a (0.5,0.5) weight.

4) Iterate step 1) to 3) until value function and bond price schedule converge.

5) Compute a tax revenue schedule for the sovereign from the converged entrepreneur policy function.

6) Given the tax revenue schedule, start with initial guesses for sovereign bond price $Q_0(k',b';X)$ and enter $W_0^G(k,b;X)$; We iterate until $W^G(k,b;X)$ converges.

7) Once the value functions converge $W^G(B,k,b;X)$, compute the default set by comparing $W^G(B,k,b;X)$ to $U^E(0,k,b;X)-V$

8) Update the sovereign bond price schedule using the default set according the pricing equation and the old bond price schedule with a (0.5,0.5) weight.

9) Iterate step 6) to 8) until value function and bond price schedule converge.

A.10 Testable predictions

In this section, we verify two testable predictions from the model

Prediction 1. Upon an exchange rate change, a country with a higher corporate FC debt to GDP has a larger change in default premium.

Prediction 2. Holding debt level constant, an increase in capital stock or investment decreases default premium. Similarly, holding capital stock or investment constant, an increase in corporate debt is associated with an increase in default premium.

We test these predictions by augmenting the baseline regression in eq (1.3) in two ways. First, we add exchange shocks identified through high frequency FOMC surprise and interact exchange rate shocks with corporate FC debt to GDP. Second, we control for investment to GDP and capital stock to GDP. We perform the following regressions:

$$\begin{aligned}\text{Sovereign CDS}_{i,t}^{\text{Default premium}} &= \alpha_i + \beta_1 \Delta S_{t-1} + \beta_2 \Delta S_{t-1} \left(\frac{\text{FC Corp debt}}{\text{GDP}}\right)_{i,t-1} \\ +\beta_3 \left(\frac{\text{FC Corp debt}}{\text{GDP}}\right)_{i,t-1} + \beta_4 \left(\frac{\text{FC Sovereign debt}}{\text{GDP}}\right)_{i,t-1} &+ \beta_5 \left(\frac{\text{LC Sovereign debt}}{\text{GDP}}\right)_{i,t-1} + \mu GC_t + \varepsilon_{i,t}\end{aligned}$$

$$\begin{aligned}\text{Sovereign CDS}_{i,t}^{\text{Default premium}} &= \eta_i + \gamma_1 \left(\frac{\text{Invesment}}{\text{GDP}}\right)_{i,t-1} \\ +\gamma_2 \left(\frac{\text{FC Corp debt}}{\text{GDP}}\right)_{i,t-1} + \gamma_3 \left(\frac{\text{FC Sovereign debt}}{\text{GDP}}\right)_{i,t-1} &+ \gamma_4 \left(\frac{\text{LC Sovereign debt}}{\text{GDP}}\right)_{i,t-1} + \omega GC_t + \nu_{i,t}\end{aligned}$$

$$\begin{aligned}\text{Sovereign CDS}_{i,t}^{\text{Default premium}} &= \chi_i + \delta_1 \left(\frac{\text{Capital stock}}{\text{GDP}}\right)_{i,t-1} \\ +\delta_2 \left(\frac{\text{FC Corp debt}}{\text{GDP}}\right)_{i,t-1} + \delta_3 \left(\frac{\text{FC Sovereign debt}}{\text{GDP}}\right)_{i,t-1} &+ \delta_4 \left(\frac{\text{LC Sovereign debt}}{\text{GDP}}\right)_{i,t-1} + \theta GC_t + u_{i,t}\end{aligned}$$

To ease endogenity between default risk and exchange rate, we identified the exchange rate shock as LC per USD exchange rate change over one day window of FOMC meeting dates.[5] Because, there are no capital stock data available in quarterly frequency, we use the cumulative sum of investment as a related series to interpolate the annual capital stock to quarterly frequency.[6]

[5]When multiple meetings occur in the same quarter, we aggregate the shock to quarter frequency, as in Gertler and Karadi (2015).

[6]Cubic spline interpolation is applied.

Table A.10.1: Testing model predictions with modified baseline regression

	Default premium	Default premium	Default premium
ΔS_{t-1}	-1.2643**		
	(0.6079)		
$\Delta S_{t-1}(\frac{\text{FC Corp debt}}{\text{GDP}})_{i,t-1}$	0.0418*		
	(0.0235)		
$(\frac{\text{Invesment}}{\text{GDP}})_{i,t-1}$		-1.5825**	
		(0.7618)	
$(\frac{\text{Capital stock}}{\text{GDP}})_{i,t-1}$			-8.3391**
			(3.4326)
$\frac{\text{FC Corp debt}}{\text{GDP}}$	-0.0756	0.5562**	0.4418*
	(0.2938)	(0.2560)	(0.2599)
$\frac{\text{FC Sovereign debt}}{\text{GDP}}$	4.0306***	2.9119***	2.5224***
	(0.6834)	(0.5685)	(0.4863)
$\frac{\text{LC Sovereign debt}}{\text{GDP}}$	0.6981*	0.4059	0.6768
	(0.3779)	(0.4035)	(0.4265)
Observations	713	769	769
Period		2004Q1-2016Q4	
Countries		17	
Global Controls		Yes	
Country FE		Yes	

Notes: Standard errors in parentheses are heteroskedasticity autocorrelation spatial correlation robuststandard errors (Driscoll and Kraay (1998)) with a 4-quarter lag. * p<0.1, ** p<0.05, *** p<0.01.

Appendix B

Appendix of Chapter 2

B.1 Derivation of Model of Liquidity Returns

Consider first the problem of the home-country investor. As in Krishnamurthy and Vissing-Jorgensen (2012), Nagel (2016) and Engel (2016), we take a very simple approach to modeling the liquidity service of some assets, by including them in the utility function. In particular, we assume home households maximize:

$$E_0 \left\{ \sum_{t=0}^{\infty} \beta^t \left[u(c_t) + v\left(\frac{M_{H,t}}{P_t}, \frac{B_{H,t}}{P_t}, \frac{S_t B^*_{H,t}}{P_t} \right) \right] \right\} \tag{B.1}$$

There are six assets in the world economy:

M_t- home country money

M_t^* - foreign country money

B_t - home country government bonds

B_t^* - foreign country government bonds

B_t^m- home country "market" bonds

B_t^{*m} - foreign country "market" bonds

The H subscript in the asset holdings refers to home country holdings of each asset, while F will denote foreign country holdings. c_t (c_t^*) is home (foreign) country consumption.

The utility function for the home household shows that it may get liquidity services from home money, home government bonds and foreign government bonds. Below we will specify that holdings of each of these assets must be weakly positive. We will assume that the supplies of the assets and the parameterization of the utility function is such that the home household will always hold home money and government bonds and get liquidity services from those assets, but it may hold a zero amount of foreign government bonds in equilibrium. The utility function $v(.)$ is assumed to be strictly concave, but Inada conditions do not hold for the foreign government bond, so its holdings may be zero. An example of such a utility function, which we will use illustratively below is:

$$v\left(\frac{M_{H,t}}{P_t}, \frac{B_{H,t}}{P_t}, \frac{S_t B^*_{H,t}}{P_t}\right) = \frac{1}{1-\gamma}\left[\left(\frac{M_{H,t}}{P_t}\right)^{\frac{\varepsilon-1}{\varepsilon}} + \left(\frac{\kappa B_{H,t}}{P_t}\right)^{\frac{\varepsilon-1}{\varepsilon}} + \left(\frac{\eta S_t B^*_{H,t}}{P_t} + \mu\right)^{\frac{\varepsilon-1}{\varepsilon}}\right]^{\frac{(1-\gamma)\varepsilon}{\varepsilon-1}} \tag{B.2}$$

where we assume $\varepsilon > 1$, $\gamma > 0$, $0 < \kappa < 1$, $0 < \eta < 1$, $\mu \geq 0$.

This specification is a slight generalization of that of Nagel (2016) because we assume that there are two non-money assets that might deliver liquidity services. In addition, Nagel assumes that the liquidity from money and domestic government bonds are perfect substitutes (though bonds provide less liquidity per currency unit), while we allow imperfect substitution.

The period-by-period budget constraint is given by

$$P_t c_t + M_{H,t} + B_{H,t} + B^m_{H,t} + S_t B^*_{H,t} + S_t B^{*m}_{H,t}$$
$$= P_t y_t + M_{H,t-1} + (1+i_{t-1}) B_{H,t-1} + \left(1+i^m_{t-1}\right) B^m_{H,t-1} + S_t \left(1+i^*_{t-1}\right) B^*_{H,t-1} + S_t \left(1+i^{*m}_{t-1}\right) B^{*m}_{H,t-1} \tag{B.3}$$

Households maximize B.1 subject to B.3, and to the constraints $M_{H,t} \geq 0$, $B_{H,t} \geq 0$ and $B^*_{H,t} \geq 0$. These latter constraints mean that households are unable to issue securities with the same liquidity properties as government securities. We will assume, for convenience, that as in the New Keynesian model in the paper, goods prices in each currency are known one period in advance. The first-order conditions are given by:

$$-\frac{1}{P_t} u'(c_t) + \frac{1}{P_{t+1}} \beta E_t u'(c_{t+1}) + \frac{1}{P_t} v_M \left(\frac{M_{H,t}}{P_t}, \frac{B_{H,t}}{P_t}, \frac{S_t B^*_{H,t}}{P_t} \right) \leq 0 \tag{B.4}$$

$$-\frac{1}{P_t} u'(c_t) + \frac{1+i_t}{P_{t+1}} \beta E_t u'(c_{t+1}) + \frac{1}{P_t} v_B \left(\frac{M_{H,t}}{P_t}, \frac{B_{H,t}}{P_t}, \frac{S_t B^*_{H,t}}{P_t} \right) \leq 0 \tag{B.5}$$

$$-\frac{1}{P_t}u'(c_t)+\frac{1+i_t^m}{P_{t+1}}\beta E_t u'(c_{t+1})=0 \tag{B.6}$$

$$-\frac{S_t}{P_t}u'(c_t)+\frac{1+i_t^*}{P_{t+1}}\beta E_t S_{t+1}u'(c_{t+1})+\frac{S_t}{P_t}v_{B^*}\left(\frac{M_{H,t}}{P_t},\frac{B_{H,t}}{P_t},\frac{S_tB_{H,t}^*}{P_t}\right)\leq 0 \tag{B.7}$$

$$-\frac{S_t}{P_t}u'(c_t)+\frac{1+i_t^{*m}}{P_{t+1}}\beta E_t S_{t+1}u'(c_{t+1})=0 \tag{B.8}$$

The foreign household's problem is symmetric. For convenience, we assume they have the same utility function for consumption as home households. The utility function for liquidity is symmetric to the home household's, with foreign assets taking the place of home assets. In the example we will use later:

$$v^*\left(\frac{M_{F,t}^*}{P_t^*},\frac{B_{F,t}^*}{P_t^*},\frac{S_t^{-1}B_{F,t}}{P_t^*}\right)=\frac{1}{1-\gamma}\left[\left(\frac{M_{F,t}^*}{P_t^*}\right)^{\frac{\varepsilon-1}{\varepsilon}}+\left(\frac{\kappa B_{F,t}^*}{P_t^*}\right)^{\frac{\varepsilon-1}{\varepsilon}}+\left(\frac{\eta S_t^{-1}B_{F,t}}{P_t^*}+\mu\right)^{\frac{\varepsilon-1}{\varepsilon}}\right]^{\frac{(1-\gamma)\varepsilon}{\varepsilon-1}} \tag{B.9}$$

.

The first-order conditions for the foreign household are:

$$-\frac{1}{P_t^*}u'(c_t^*)+\frac{1}{P_{t+1}^*}\beta E_t u'\left(c_{t+1}^*\right)+\frac{1}{P_t^*}v_{M^*}^*\left(\frac{M_{F,t}^*}{P_t^*},\frac{B_{F,t}^*}{P_t^*},\frac{S_t^{-1}B_{F,t}}{P_t^*}\right)\leq 0 \tag{B.10}$$

$$-\frac{1}{P_t^*}u'(c_t^*)+\frac{1+i_t^*}{P_{t+1}^*}\beta E_t u'\left(c_{t+1}^*\right)+\frac{1}{P_t^*}v_{B^*}^*\left(\frac{M_{F,t}^*}{P_t^*},\frac{B_{F,t}^*}{P_t^*},\frac{S_t^{-1}B_{F,t}}{P_t^*}\right)\leq 0 \tag{B.11}$$

$$-\frac{1}{P_t^*}u'\left(c_t^*\right)+\frac{1+i_t^{*m}}{P_{t+1}^*}\beta E_t u'\left(c_{t+1}^*\right)=0 \tag{B.12}$$

$$-\frac{S_t^{-1}}{P_t^*}u'\left(c_t^*\right)+\frac{1+i_t}{P_{t+1}^*}\beta E_t S_{t+1}^{-1}u'\left(c_{t+1}^*\right)+\frac{S_t^{-1}}{P_t^*}v_B^*\left(\frac{M_{F,t}^*}{P_t^*},\frac{B_{F,t}^*}{P_t^*},\frac{S_t^{-1}B_{F,t}}{P_t^*}\right)\leq 0 \tag{B.13}$$

$$-\frac{S_t^{-1}}{P_t^*}u'\left(c_t^*\right)+\frac{1+i_t^{m}}{P_{t+1}^*}\beta E_t S_{t+1}^{-1}u'\left(c_{t+1}^*\right)=0 \tag{B.14}$$

Equations B.6 and B.8 imply the relationship:

$(1+i_t^m)E_t u'\left(c_{t+1}\right)=(1+i_t^{*m})E_t\frac{S_{t+1}}{S_t}u'\left(c_{t+1}\right)=0.$

If we maintain the assumption of rational expectations and no market frictions, then the assumption that the conditional distribution of exchange rates and consumption is jointly log-normal, we can derive

$i_t^{*m}+E_t s_{t+1}-s_t-i_t^m=-\frac{1}{2}var_t\left(s_{t+1}\right)-cov_t\left(m_{t+1},s_{t+1}\right)$ where $m_{t+1}=\ln\left(\frac{u'(c_{t+1})}{P_{t+1}}\right)$. If markets are complete, we have $s_{t+1}-s_t=m_{t+1}^*-m_{t+1}$, where $m_{t+1}^*=\ln\left(\frac{u'\left(c_{t+1}^*\right)}{P_{t+1}^*}\right)$. Using this relationship, we can write

$$i_t^{*m}+E_t s_{t+1}-s_t-i_t^m=r_t \tag{B.15}$$

where $r_t=\frac{1}{2}\left(var_t\left(m_{t+1}\right)-var_t\left(m_{t+1}^*\right)\right)$. As noted in the text, we do not insist that r_t be interpreted as a time-varying risk premium. It may arise for other reasons as well, such as financial market or expectational frictions, or from the presence of noise traders. While we derived B.15 from B.6 and B.8, it is straightforward to check that equations B.12 and B.14

imply the same relationship.[1]

Assume equations B.4 and B.5 hold with equality, so that the home agent holds positive amounts of home money and home government bonds. B.6 implies:

$$\frac{1}{P_{t+1}}\beta E_t u'(c_{t+1}) = \frac{1}{(1+i_t^m)P_t}u'(c_t). \tag{B.16}$$

Substitute this into B.5, and cancel terms to get:

$$\frac{1+i_t}{1+i_t^m} + \frac{v_B\left(\frac{M_{H,t}}{P_t}, \frac{B_{H,t}}{P_t}, \frac{S_t B^*_{H,t}}{P_t}\right)}{u'(c_t)} = 1 \tag{B.17}$$

.

Similarly, substituting B.16 into B.4 gives us:

$$\frac{1}{1+i_t^m} + \frac{v_M\left(\frac{M_{H,t}}{P_t}, \frac{B_{H,t}}{P_t}, \frac{S_t B^*_{H,t}}{P_t}\right)}{u'(c_t)} = 1$$

.

Rearranging these two equations, we find:

$$i_t^m - i_t = \frac{v_B\left(\frac{M_{H,t}}{P_t}, \frac{B_{H,t}}{P_t}, \frac{S_t B^*_{H,t}}{P_t}\right)}{v_M\left(\frac{M_{H,t}}{P_t}, \frac{B_{H,t}}{P_t}, \frac{S_t B^*_{H,t}}{P_t}\right) - v_B\left(\frac{M_{H,t}}{P_t}, \frac{B_{H,t}}{P_t}, \frac{S_t B^*_{H,t}}{P_t}\right)} i_t. \tag{B.18}$$

The model in the text approximates this equation around a steady state in which , to arrive at

$i_t^m - i_t = \alpha i_t$

We will have $\alpha > 0$ if $v_M > v_B$ in the steady state, so the liquidity value of money exceeds that of home government bonds. Taking the analogous set of relationships for the foreign

[1] These relationships are well-known in the literature. See the survey of Engel (2014) for example.

country, and assuming $\alpha=\frac{\bar{v}_B}{\bar{v}_M-\bar{v}_B}=\frac{\bar{v}^*_{B^*}}{\bar{v}^*_{M^*}-\bar{v}^*_{B^*}}$ (the overbar indicates the functions are evaluated at the steady state levels of the assets) we find:

$$(i^m_t-i_t)-(i^{m*}_t-i^*_t)=\alpha\left(i_t-i^*_t\right).$$

If we had added a shock to liquidity preferences as in Engel (2016), we would then, using (A.44) arrive exactly at the model given in the text, in which

$$i^*_t+E_t s_{t+1}-s_t-i_t=\eta_t+r_t,\text{where}\eta_t\equiv(i^m_t-i_t)-(i^{m*}_t-i^*_t)=\alpha\left(i_t-i^*_t\right)+v_t.$$

Note that if the home household holds the foreign government bond, we have:

$$\frac{1+i^*_t}{1+i^m_t}E_t\left(\frac{S_{t+1}}{S_t}\right)+\frac{v_{B^*}\left(\frac{M_{H,t}}{P_t},\frac{B_{H,t}}{P_t},\frac{S_tB^*_{H,t}}{P_t}\right)}{u'(c_t)}=1.$$

Together with equation B.17, we find:

$$\left(1+i^*_t\right)E_t\left(\frac{S_{t+1}}{S_t}\right)-\left(1+i_t\right)=\left(1+i^m_t\right)\frac{v_B\left(\frac{M_{H,t}}{P_t},\frac{B_{H,t}}{P_t},\frac{S_tB^*_{H,t}}{P_t}\right)-v_{B^*}\left(\frac{M_{H,t}}{P_t},\frac{B_{H,t}}{P_t},\frac{S_tB^*_{H,t}}{P_t}\right)}{u'(c_t)}$$

Our model implies that if home households hold both government bonds, the difference in the expected rates of return reflects the difference in the liquidity services that the two bonds provide to home households. If the foreign government bond pays a higher monetary return, it must provide a lower liquidity return to the home household in equilibrium.

For the utility function given in B.2, we can derive that the liquidity premium from the right-hand-side of equation B.18 is given by:

$$\frac{v_B\left(\frac{M_{H,t}}{P_t},\frac{B_{H,t}}{P_t},\frac{S_tB^*_{H,t}}{P_t}\right)}{v_M\left(\frac{M_{H,t}}{P_t},\frac{B_{H,t}}{P_t},\frac{S_tB^*_{H,t}}{P_t}\right)-v_B\left(\frac{M_{H,t}}{P_t},\frac{B_{H,t}}{P_t},\frac{S_tB^*_{H,t}}{P_t}\right)}i_t=\frac{\left(M_{H,t}\right)^{\frac{1}{\varepsilon}}\kappa^{\frac{\varepsilon-1}{\varepsilon}}}{\left(B_{H,t}\right)^{\frac{1}{\varepsilon}}-\left(M_{H,t}\right)^{\frac{1}{\varepsilon}}\kappa^{\frac{\varepsilon-1}{\varepsilon}}}i_t.$$

As $\varepsilon\to\infty$, so the liquidity services provided by government bonds are simply a diminished service identical to that provided by money, the liquidity return goes to $\frac{\kappa}{1-\kappa}i_t$.

B.2 Data source

Table B.2.1: Generic data source table

Data	Data source
Spot Exchange rates	Datastream (DS)
1Y Forward rates	Datastream (DS)
1M Forward rates	Datastream (DS)
1Y Government bond yield	Datastream (DS), Bloomberg (BBG), central banks
1M Government bond yield	Datastream (DS), Bloomberg (BBG), central banks
1Y Interest Rate Swap	Bloomberg (BBG)
1Y Credit Default Swap	Bloomberg (BBG), Markit (MK)
1M LIBOR rates	Datastream (DS)
Consumer Price Index	IMF IFS
Unemployment rates	IMF IFS, FRED for New Zealand
Gold price	FRED
VIX index	FRED
General Govt Debt to GDP	BIS Credit to the non-financial sector dataset
Central bank policy rates	IMF IFS, Norges bank for Norway
Bloomberg exchange rate forecasts	Bloomberg (BBG)

Table B.2.2: Specific data ticker table

All the variables are created by filling the missing value in the order reported. For exchange rates and forward rates, we do a trilateral cross to get the non-US related exchange rates. For example, the AUD per CAD exchange rate is constructed by $log(S_{USD/CAD}) - log(S_{(USD/AUD)}$. Germany government yield, debt to GDP and CDS are used for EUR.

Data	AUD	CAD	EUR	JPY
Spot Exchange rates	AUSTDO$	CNDOLL$	USEURSP	JAPAYE$
1Y Forward rates	USAUDYF	USCADYF	USEURYF	USJPYYF
1M Forward rates	USAUD1F	USCAD1F	USEUR1F	USJPY1F
1Y Government bond yield	BBG:GTAUD1Y Govt BBG: C1271Y INDEX	DS:CNTBB1Y BBG: C1011Y INDEX	BBG:GTDEM1Y Govt BBG: C9101Y INDEX	BBG:GTJPY1Y Govt BBG: C1051Y INDEX
1M Government bond yield	DS:TRAU1MT BBG: AUTE1MYL Index	DS:TRCN1MT BBG: FMSTTB1M Index	DS:TRBD1MT BBG: GETB1M Index	DS:TRJP1MT
1Y Interest Rate Swap	BBG: ADSWAP1Q CURNCY ADSWAP1 CURNCY	BBG:CDSW1 CURNCY	BBG: EUSW1V3 CURNCY EUSA1 CURNCY	BBG:JYSW1 CURNCY
1Y Credit Default Swap	BBG:AUSTLA CDS USD SR 1Y D14 Corp, MK:QS973P	BBG:CANPAC CDS USD SR 1Y D14 Corp, MK:27CBJG	BBG:GERMAN CDS USD SR 1Y D14 Corp, MK:3AB549	BBG:JGB CDS USD SR 1Y D14 Corp, MK:4B818G
1M LIBOR rates	ECAUD1M	ECCAD1M	ECEUR1M	EUJAP1M
General Govt Debt to GDP	Q:AU:G:A:N:770:A	Q:CA:G:A:N:770:A	Q:DE:G:A:N:770:A	Q:JP:G:A:N:770:A
Bloomberg exchange rate forecasts	FCUSAUQ "XYY" Index	FCUSCAQ "XYY" Index	FCUSEUQ "XYY" Index	FCUSJPQ "XYY" Index

*See the data appendix of Du et al. (2018a) for the detail of the construction, available at: https://sites.google.com/site/wenxindu/data/govt-cip?authuser=0

Data	NZD	NOK	SEK
Spot Exchange rates	NZDOLL$	NORKRO$	SWEKRO$
1Y Forward rates	USNZDYF	USNOKYF	USSEKYF
1M Forward rates	USNZD1F	-	USSEK1F
1Y Government bond yield	BBG:GTNZD1Y Govt DS:NZGBY1Y BBG: C2501Y INDEX	BBG:ST3XY Index BBG: C2661Y INDEX	Sveriges Riksbank website, Treasury bills SE12M BBG:BV010259 Index BBG: C2591Y INDEX
1M Government bond yield	DS:TRNZ1MT BBG: NDTB1M Curncy	-	DS:TRSD1MT
1Y Interest Rate Swap	BBG:NDSWAP1 CURNCY	BBG:NKSW1 CURNCY	BBG:SKSW1 CURNCY
1Y Credit Default Swap	BBG:NZ CDS USD SR 1Y D14 Corp, MK:6B5178	BBG:NORWAY CDS USD SR 1Y D14 Corp, MK:6CFB55	BBG:SWED CDS USD SR 1Y D14 Corp, MK:8F7220
1M LIBOR rates	ECNZD1M	ECNOR1M	ECSWE1M
General Govt Debt to GDP	Q:NZ:G:A:N:770:A	Q:NO:G:A:N:770:A	Q:SE:G:A:N:770:A
Bloomberg exchange rate forecasts	FCUSNZQ "XYY" Index	FCUSNOQ "XYY" Index	FCUSSEQ "XYY" Index

Data	CHF	GBP	USD
Spot Exchange rates	SWISSF$	USDOLLR	-
1Y Forward rates	USCHFYF	USGBPYF	-
1M Forward rates	USCHF1F	USGBP1F	-
1Y Government bond yield	Swiss National Bank, spot interest rate for 1Y govt bond BBG: C2561Y INDEX	BBG:GTGBP1Y Govt	BBG: GB12 Govt FRED BBG: C0821Y INDEX
1M Government bond yield	DS:TRSW1MT	DS:TRUK1MT BBG: UKGTB1M Index	DS:TRUS1MT BBG: GB1M Index
1Y Interest Rate Swap	BBG:SFSW1V3 CURNCY BBG:SFSW1 CURNCY	BBG:BPSW1V3 CURNCY BBG:BPSW1 CURNCY	BBG:USSW1 CURNCY
1Y Credit Default Swap	BBG:SWISS CDS USD SR 1Y D14 Corp, MK:HPBCIO	BBG:UK CDS USD SR 1Y D14 Corp, MK:9A17DE	BBG:US CDS USD SR 1Y D14 Corp, MK:9A3AAA
1M LIBOR rates	ECSWF1M	ECUKP1M	ECUSD1M
General Govt Debt to GDP	Q:CH:G:A:N:770:A	Q:GB:G:A:N:770:A	Q:US:G:A:N:770:A
Bloomberg exchange rate forecasts	FCUSCHQ "XYY" Index	FCUSGBQ "XYY" Index	X={1,2,3,4} Y=year

Table B.2.3: Data period

Data	AUD	CAD	EUR	JPY	NZD	NOK	SEK	CHF	GBP	USD
Spot Exchange rates	99M1-18M1	99M1-18M1	99M1-18M1	99M1-18M1	99M1-18M1	99M1-18M1	99M1-18M1	99M1-18M1	99M1-18M1	99M1-18M1
1Y Forward rates	99M1-18M1	99M1-18M1	99M1-18M1	99M1-18M1	99M1-18M1	99M1-18M1	99M1-18M1	99M1-18M1	99M1-18M1	99M1-18M1
1M Forward rates	99M1-18M1	99M1-18M1	99M1-18M1	99M1-18M1	99M1-18M1	99M1-18M1	99M1-18M1	99M1-18M1	99M1-18M1	99M1-18M1
1Y Government bond yield	99M11-18M1	99M1-18M1	99M11-18M1	99M11-18M1	99M1-18M1	99M1-18M1	99M1-18M1	99M1-18M1	99M11-18M1	99M1-18M1
1M Government bond yield	99M1-13M3*	99M1-18M1	10M11-18M1	12M8-18M1	99M1-18M1	NA	99M1-18M1	09M1-18M1	99M1-18M1	99M1-18M1
1Y Interest Rate Swap	99M1-18M1	01M1-18M1	99M1-18M1	99M1-18M1	99M1-18M1	99M1-18M1	99M1-18M1	99M1-18M1	99M1-18M1	99M1-18M1
1Y Credit Default Swap	08M3-18M1	09M4-18M1*	08M1-18M1	08M1-18M1	08M2-18M1**	08M1-18M1	08M1-18M1	09M1-18M1	09M1-18M1	09M1-18M1
1M LIBOR rates	99M1-18M1	99M1-18M1	99M1-18M1	99M1-18M1	99M1-18M1	99M1-18M1	99M1-18M1	99M1-18M1	99M1-18M1	99M1-18M1
Consumer Price Index	99Q1-17Q4	99M1-18M1	99M1-18M1	99M1-18M1	99Q1-17Q4	99M1-18M1	99M1-18M1	99M1-18M1	99M1-18M1	99M1-18M1
Unemployment rates	99M1-18M1	99M1-18M1	99M1-18M1	99M1-18M1	99Q1-17Q4	99M1-18M1	99M1-18M1	99M1-18M1	99M1-18M1	99M1-18M1
Gold price	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
VIX	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
General Govt Debt to GDP	99Q1-17Q4	99Q1-17Q4	00Q1-17Q4	99Q1-17Q4	99Q1-17Q4	99Q1-17Q4	99Q1-17Q4	99Q1-17Q4	99Q1-17Q4	99Q1-17Q4
Central bank policy rates	99M1-18M1	99M1-17M7	99M1-15M3	NA	99M3-18M1	99M1-18M1	02M7-17M6	00M1-18M1	99M1-16M8	99M1-17M4
Bloomberg exchange rate forecasts	06Q1-17Q4	06Q1-17Q4	06Q1-17Q4	06Q1-17Q4	06Q1-17Q4	06Q1-17Q4	06Q1-17Q4	06Q1-17Q4	06Q1-17Q4	NA

*there are multiple missing values in different months **there are missing values at 2008m3-m4

B.3 Summary statistics

All the summary statistics scaled by 100 to improve visibility. For example, i of 4.06 represents 4.06% annualized interest rate. Interest rates and forward rates reported are with 1-year tenor.

	AUD					**CAD**				
	Obs	Mean	SD	Min	Max	Obs	Mean	SD	Min	Max
s (ln(S))	2052	-0.7022	1.5554	-4.671	1.091	2052	-0.7807	1.5499	-4.799	0.933
Δs (%)	2052	-0.0657	3.0878	-13.335	25.511	2052	-0.0435	2.9058	-13.775	21.062
q (ln(Q))	2052	-0.7345	1.5707	-4.766	1.018	2052	-0.7791	1.5681	-4.855	0.962
i^R (%)	2052	1.9442	1.5960	-2.489	6.076	2052	0.0470	1.6446	-4.146	5.848
Δi^R (%)	2052	0.0013	0.2357	-1.279	1.408	2052	-0.0003	0.2021	-1.226	1.034
$f-s$ (%)	2052	2.1930	1.7595	-2.474	7.001	2052	-0.0033	1.8152	-5.420	6.112
$\tilde{\eta}$ (%)	2052	0.2488	0.3070	-0.990	1.605	2052	-0.0502	0.3008	-1.576	1.126
$\Delta\tilde{\eta}$ (%)	2052	0.0008	0.1725	-1.256	1.207	2052	0.0007	0.1432	-1.308	1.156
τ (%)	2029	0.1580	0.2037	-0.381	1.123	1845	0.0770	0.2021	-0.528	1.252
l^R (%)	1121	0.0314	0.1163	-0.264	0.603	530	0.0322	0.1368	-0.474	0.381
λ (%)	1121	0.0853	0.3060	-1.027	1.304	530	-0.0272	0.3185	-1.280	0.642
$\hat{\eta}$ (%)	2029	0.0901	0.3009	-1.109	1.303	1845	-0.1169	0.3048	-1.510	0.603
i (%)	228	4.0617	1.4967	1.502	6.682	228	2.3542	1.6275	0.409	6.062
IRS (%)	228	4.4784	1.6936	1.637	7.984	205	2.2344	1.3400	0.461	5.720
Govt debt to GDP (%)	76	18.9197	9.0569	8.100	37.500	76	64.7149	7.5029	48.800	80.300

	EUR					**JPY**				
	Obs	Mean	SD	Min	Max	Obs	Mean	SD	Min	Max
s (ln(S))	2052	-1.2008	1.5229	-5.128	0.541	2052	4.1758	0.8535	2.378	5.513
Δs (%)	2052	0.0129	2.5820	-15.628	17.877	2052	0.0272	3.7519	-25.511	14.005
q (ln(Q))	2052	-1.1907	1.5421	-5.165	0.581	2052	4.2362	0.8590	2.338	5.595
i^R (%)	2052	-0.6449	1.5885	-4.241	4.642	2052	-2.4247	1.9632	-6.993	0.973
Δi^R (%)	2052	-0.0020	0.1883	-1.212	1.135	2052	0.0126	0.2052	-1.376	1.279
$f-s$ (%)	2052	-0.7570	1.7470	-4.810	4.826	2052	-2.7403	2.0239	-7.911	1.069
$\tilde{\eta}$ (%)	2052	-0.1121	0.2893	-1.497	1.071	2052	-0.3157	0.3010	-2.026	0.982
$\Delta\tilde{\eta}$ (%)	2052	0.0001	0.1381	-1.259	1.723	2052	-0.0008	0.1619	-1.353	2.464
τ (%)	2029	-0.1032	0.2149	-1.340	0.451	2029	-0.0890	0.2343	-0.959	0.743
l^R (%)	1177	-0.0400	0.1169	-0.726	0.513	1184	0.0210	0.1191	-0.703	0.512
λ (%)	1177	0.0293	0.3150	-1.444	1.521	1184	-0.1862	0.3071	-1.890	0.658
$\hat{\eta}$ (%)	2029	-0.0100	0.3118	-1.310	1.385	2029	-0.2285	0.2853	-1.784	0.539
i (%)	228	1.7316	1.7475	-0.919	5.043	228	0.1298	0.2253	-0.328	0.782
IRS (%)	228	2.0567	1.7446	-0.329	5.381	228	0.2583	0.2718	-0.140	1.081
Govt debt to GDP (%)	73	68.4822	6.9507	57.200	81.100	76	159.23	31.082	95.700	201.50

	NZD					NOK				
	Obs	Mean	SD	Min	Max	Obs	Mean	SD	Min	Max
s (ln(S))	2052	-0.5271	1.5634	-4.558	1.297	2052	1.1395	1.5287	-3.063	2.639
Δs (%)	2052	-0.0971	3.3520	-14.005	21.551	2052	0.0671	2.8650	-15.512	20.633
q (ln(Q))	2052	-0.5587	1.5787	-4.650	1.238	2052	1.1310	1.5486	-3.156	2.634
i^R (%)	2052	2.2993	1.5487	-2.206	6.957	2052	0.8790	1.8196	-4.090	6.993
Δi^R (%)	2052	0.0012	0.2579	-1.217	1.388	2052	-0.0078	0.2229	-1.408	1.083
$f-s$ (%)	2052	2.6107	1.7379	-2.157	7.911	2052	0.8600	2.0219	-4.660	7.268
$\tilde{\eta}$ (%)	2052	0.3113	0.3896	-1.379	2.001	2052	-0.0190	0.3524	-2.142	1.513
$\Delta\tilde{\eta}$ (%)	2052	0.0018	0.2379	-1.420	1.366	2052	-0.0017	0.1873	-2.464	0.994
τ (%)	2029	0.1424	0.2328	-0.545	1.365	2029	-0.1095	0.1901	-1.101	0.532
l^R (%)	1073	0.0857	0.1387	-0.248	0.817	1054	-0.0923	0.1333	-0.846	0.126
λ (%)	1073	0.0873	0.3512	-0.909	1.890	1054	0.0169	0.3631	-1.807	1.630
$\hat{\eta}$ (%)	2029	0.1691	0.4290	-1.292	1.784	2029	0.0878	0.3519	-1.602	1.752
i (%)	228	4.3813	1.7397	1.773	7.739	228	3.1031	2.0423	0.419	7.018
IRS (%)	228	4.8693	2.0617	1.985	8.853	228	3.5178	2.1694	0.779	7.695
Govt debt to GDP (%)	76	26.9570	5.7796	15.600	36.800	76	36.2771	7.5183	22.700	51.900

	SEK					CHF				
	Obs	Mean	SD	Min	Max	Obs	Mean	SD	Min	Max
s (ln(S))	2052	1.2677	1.5173	-2.897	2.752	2052	-0.8396	1.5517	-4.879	0.990
Δs (%)	2052	0.0610	2.7145	-9.570	18.786	2052	-0.1483	2.9065	-19.718	11.893
q (ln(Q))	2052	1.2761	1.5349	-2.939	2.817	2052	-0.8329	1.5769	-4.933	1.101
i^R (%)	2052	-0.4376	1.6605	-4.723	4.672	2052	-1.5843	1.5653	-5.656	3.556
Δi^R (%)	2052	-0.0042	0.2018	-1.388	0.978	2052	0.0046	0.1997	-1.372	0.926
$f-s$ (%)	2052	-0.4171	1.8478	-5.328	4.760	2052	-1.9686	1.6655	-6.185	3.662
$\tilde{\eta}$ (%)	2052	0.0205	0.3461	-1.473	1.576	2052	-0.3843	0.3382	-2.057	0.676
$\Delta\tilde{\eta}$ (%)	2052	0.0010	0.1652	-1.245	1.762	2052	-0.0014	0.1766	-1.244	2.189
τ (%)	2029	-0.0894	0.1750	-1.164	0.636	2029	-0.0589	0.2067	-0.925	0.668
l^R (%)	1129	-0.0195	0.1165	-0.423	0.589	905	-0.0136	0.1262	-0.416	0.846
λ (%)	1129	0.1797	0.3249	-1.515	1.540	905	-0.3814	0.2741	-1.630	0.860
$\hat{\eta}$ (%)	2029	0.1099	0.3304	-1.370	1.379	2029	-0.3284	0.2796	-1.752	0.479
i (%)	228	1.9181	1.7212	-0.909	4.684	228	0.8861	1.2324	-0.984	3.827
IRS (%)	228	2.3506	1.7635	-0.560	5.458	228	0.9260	1.3310	-1.055	4.030
Govt debt to GDP (%)	76	44.7232	6.8896	35.000	65.733	76	37.5618	7.4843	29.000	48.733

	GBP					USD				
	Obs	Mean	SD	Min	Max	Obs	Mean	SD	Min	Max
s (ln(S))	2052	-1.5305	1.4984	-5.513	-0.034	2052	-1.0022	1.5424	-4.897	0.731
Δs (%)	2052	0.1283	2.9243	-14.482	19.718	2052	0.0580	3.1381	-17.865	13.209
q (ln(Q))	2052	-1.5332	1.5196	-5.595	-0.028	2052	-1.0142	1.5623	-5.114	0.761
i^R (%)	2052	0.3190	1.7716	-4.241	6.068	2052	-0.3970	1.8370	-5.299	5.930
Δi^R (%)	2052	-0.0081	0.2145	-1.286	1.187	2052	0.0027	0.2067	-1.228	1.217
$f - s$ (%)	2052	0.4246	1.9223	-4.440	6.384	2052	-0.2021	2.0335	-6.144	7.129
$\tilde{\eta}$ (%)	2052	0.1057	0.3061	-1.091	1.619	2052	0.1949	0.3381	-1.161	2.142
$\Delta\tilde{\eta}$ (%)	2052	0.0006	0.1769	-1.366	2.123	2052	-0.0011	0.1670	-1.336	1.409
τ (%)	2029	-0.0312	0.1957	-1.365	0.988	2029	0.1109	0.1845	-0.387	1.217
l^R (%)	995	0.0305	0.1315	-0.461	0.663	940	-0.0221	0.1480	-0.641	0.423
λ (%)	995	0.1345	0.3218	-0.728	1.807	940	0.0018	0.3078	-1.428	1.478
$\hat{\eta}$ (%)	2029	0.1362	0.3043	-1.052	1.602	2029	0.0801	0.3160	-1.282	1.486
i (%)	228	2.5990	2.1680	-0.003	6.195	228	1.9546	1.9134	0.086	6.057
IRS (%)	228	3.0572	2.2969	0.310	6.830	228	2.3655	2.1001	0.261	7.500
Govt debt to GDP (%)	73	59.1850	22.260	33.700	87.900	76	72.226	19.277	46.900	98.700

B.4 Supplmentary Appendix A

Liquidity and Exchange Rates: An Empirical Investigation

Charles Engel and Steve Pak Yeung Wu
May 16, 2020

Supplementary Appendix A

Robustness

1. Uncovered Interest Parity regression (Fama regression) over the sample

UIP regression: $\Delta s_t = \alpha + \beta(i_t^m - i_t^{m*}) + \varepsilon_t$

where the change of exchange rate and interest rates (1m-LIBOR) are rate at monthly rates

Currency pair	beta	upper 95% CI	lower 95% CI	Currency pair	beta	upper 95% CI	lower 95% CI
AUD-USD	-0.8	2.9	-4.6	JPY-NZD	3.4	7.2	-0.3
CAD-USD	0.6	5.8	-4.7	NOK-NZD	1.1	3.8	-1.6
CHF-USD	-1.5	2.1	-5.1	AUD-NOK	0.0	2.6	-2.6
EUR-USD	-1.1	2.5	-4.7	CAD-NOK	-1.1	2.0	-4.1
GBP-USD	0.9	4.5	-2.7	CHF-NOK	0.5	3.4	-2.4
JPY-USD	0.4	2.6	-1.8	EUR-NOK	0.1	3.1	-2.8
NOK-USD	0.2	3.1	-2.7	GBP-NOK	0.2	2.9	-2.6
NZD-USD	0.6	4.7	-3.6	JPY-NOK	1.1	4.0	-1.9
SEK-USD	-0.8	2.3	-3.8	AUD-JPY	3.9	8.9	-1.1
AUD-SEK	0.9	5.4	-3.6	CAD-JPY	0.2	4.0	-3.6
CAD-SEK	-2.1	1.9	-6.0	CHF-JPY	-0.3	4.7	-5.3
CHF-SEK	0.6	4.8	-3.7	EUR-JPY	1.2	4.7	-2.4
EUR-SEK	-1.2	2.9	-5.2	GBP-JPY	1.4	4.1	-1.3
GBP-SEK	-0.5	2.7	-3.7	AUD-GBP	-0.3	3.6	-4.2
JPY-SEK	2.1	6.0	-1.8	CAD-GBP	3.6	7.9	-0.7
NOK-SEK	-0.6	2.1	-3.4	CHF-GBP	-0.3	2.9	-3.5
NZD-SEK	2.7	6.1	-0.7	EUR-GBP	-0.4	3.7	-4.6
AUD-NZD	1.2	4.6	-2.1	AUD-EUR	-1.2	3.8	-6.2
CAD-NZD	1.4	5.3	-2.5	CAD-EUR	-2.4	2.9	-7.7
CHF-NZD	3.0	6.8	-0.8	CHF-EUR	-1.6	2.4	-5.6
EUR-NZD	4.9	9.4	0.5	AUD-CHF	0.4	6.0	-5.2
GBP-NZD	1.1	6.5	-4.3	CAD-CHF	-3.3	2.5	-9.2
				AUD-CAD	-0.3	3.3	-3.9

Data period 1999M1-2018M1.

2. Correlation of central bank policy rate and 1-year government bond rate

In our model, the monetary authority controls the policy rate, which is the one-period government bond. In the data, we use 1-year government bond rate as the baseline measure. In the table below, we provide evidence that the central bank policy rates obtained from the IMF IFS dataset are highly correlated with the 1-year government bond rate.

Currency	Correlation
AUD	0.96
CAD	0.98
EUR	0.96
NOK	0.96
NZD	0.97
SEK	0.92
GBP	0.98
USD	0.99

Interest rates are end of period rates. JPY policy rate is not available in the IMF IFS dataset. The NOK data is directly obtained from the Norges Bank. Data period 1999M1-2018M1.

3. Baseline regression with survey-based exchange rate risk premium

In the baseline empirical regression, we regress the change of nominal exchange rate on lagged real exchange rate, change of liquidity return, change of government bond interest rate differential, lagged liquidity return and lagged government bond interest rate differential. r_t , which is the unmodelled stochastic deviation from uncovered interest party in the model, is left as the residual in the empirical regression. We remain agnostic about the source of this deviation and it can potentially include the foreign exchange risk premium. As we discussed in the main text, it is challenging for the existing exchange rate risk premium models to deliver a positive correlation between z_t and η_t , after controlling for interest rate differential. In this section, we address the concern about leaving out the foreign exchange risk premium by constructing a measure of it and control for it. We define a measure of foreign exchange risk premium, rp_t , as $rp_t \equiv s^e_{t,t+1} - f_{t,t+1}$ where $s^e_{t,t+1}$ is the exchange rate expectation. We make use of the Bloomberg exchange rate forecast function, which provides survey of commercial and investment banks exchange rate forecasts. These are collections of quarter-end exchange rate prediction which starts around 13 months before the target date. Depending on the currency, there are roughly 10-30 providers for each of these forecasts and we take the median forecast as a measure exchange rate expectation.[1]

The regression specification becomes:

$$\Delta s_{j,t} = \alpha_j + \beta_1 q_{j,t-1} + \beta_2 \left(\Delta \tilde{\eta}_{j,t} \right) + \beta_3 \left(\Delta i^R_{j,t} \right) + \beta_4 \tilde{\eta}_{j,t-1} + \beta_5 i^R_{j,t-1} + \beta_6 \left(\Delta rp_{j,t} \right) + \beta_7 rp_{j,t-1} + u_{j,t}$$

The regression results are presented in the table below. Controlling for the foreign exchange risk premium, the coefficient estimates on $\Delta \tilde{\eta}_{j,t}$ are still negatively significant, except for JPY, which is still estimated with the right sign but insignificant. Therefore, the main findings of the importance of treasury liquidity premium in explaining exchange rates is robust to this extension. The R-squared also improves. However, introducing foreign exchange risk premium put some restrictions to our analysis. First, the exchange rate forecast survey from Bloomberg are forecasts for quarter-end values. It limits our regression frequency to quarter. Second, the survey started since 2006Q1, which limits the start date of our regression. Finally, it is well-known that the forward rate at time t ($f_{t,t+1}$) is highly correlated with the spot exchange rate (0.9999 in our sample). In this case, if the exchange rate forecast survey is a noisy forecast, then the risk premium measure could be creating a serious endogeneity issue by explaining the exchange rates with exchange rates. We provide evidence here that our results are not affected inclusion of foreign exchange risk premium but conduct the main analysis without including it.

[1] These forecasts are all dollar – foreign currency exchange rates. We do a trilateral cross to get the non-US related exchange rates.

Regression with survey-based exchange rate risk premium:

$$\Delta s_{j,t} = \alpha_j + \beta_1 q_{j,t-1} + \beta_2\left(\Delta\tilde{\eta}_{j,t}\right) + \beta_3\left(\Delta i^R_{j,t}\right) + \beta_4\tilde{\eta}_{j,t-1} + \beta_5 i^R_{j,t-1} + \beta_6\left(\Delta rp_{j,t}\right) + \beta_7 rp_{j,t-1} + u_{j,t}$$

	$q_{j,t-1}$	$\Delta\tilde{\eta}_{j,t}$	$\Delta i^R_{j,t}$	$\tilde{\eta}_{j,t-1}$	$i^R_{j,t-1}$	$\Delta rp_{j,t}$	$rp_{j,t-1}$	constant	N	R2 within	R2_within (without risk premium terms)
AUD	-0.0810***	-3.2019***	-7.2446***	1.9757**	-0.9909***	-0.7240***	-0.1381*	0.0321***	423	0.5841	0.3336
	(0.0017)	(1.1717)	(0.7584)	(0.9502)	(0.2404)	(0.0785)	(0.0728)	(0.0061)			
CAD	-0.0757***	-5.2150***	-6.8789***	2.3662***	-0.1648	-0.6541***	-0.2372***	0.0167***	423	0.5461	0.3520
	(0.0017)	(1.0421)	(0.7699)	(0.8088)	(0.2145)	(0.0752)	(0.0677)	(0.0046)			
EUR	-0.0711***	-3.8245***	-5.5451***	1.2964	-0.2829	-0.7112***	-0.2678***	-0.0073	423	0.5169	0.3235
	(0.0017)	(0.9630)	(0.7555)	(0.9012)	(0.2364)	(0.0729)	(0.0647)	(0.0050)			
JPY	-0.1294***	-1.0737	-7.3340***	5.6438***	-0.1854	-0.8431***	-0.3667***	0.6430***	423	0.6876	0.4810
	(0.0033)	(1.4832)	(0.9227)	(1.2031)	(0.2767)	(0.0937)	(0.0861)	(0.0176)			
NZD	-0.0818***	-4.1683***	-6.4873***	3.2502***	0.2991	-0.7201***	-0.3097***	0.0104	423	0.5810	0.3019
	(0.0017)	(1.2306)	(0.8348)	(0.9537)	(0.2605)	(0.0779)	(0.0685)	(0.0073)			
NOK	-0.0687***	-3.9244***	-6.5149***	2.5133**	-0.4699**	-0.6709***	-0.1742**	0.1401***	423	0.5699	0.3707
	(0.0018)	(1.1091)	(0.7903)	(0.9764)	(0.2384)	(0.0776)	(0.0682)	(0.0062)			
SEK	-0.0906***	-4.8318***	-6.1171***	0.7765	-0.2802	-0.5881***	-0.2216***	0.1805***	423	0.4535	0.2863
	(0.0019)	(1.1674)	(0.8301)	(1.0055)	(0.2424)	(0.0817)	(0.0725)	(0.0061)			
CHF	-0.0343***	-3.3066***	-3.9437***	1.9309*	0.2254	-0.8664***	-0.2494***	0.0231***	423	0.5202	0.2135
	(0.0019)	(1.1732)	(0.7775)	(1.0563)	(0.2140)	(0.0800)	(0.0761)	(0.0076)			
GBP	-0.0321***	-2.9451***	-6.6417***	1.8615**	0.1727	-0.7825***	-0.3663***	-0.0090**	423	0.6050	0.3765
	(0.0014)	(1.0694)	(0.7329)	(0.8766)	(0.2269)	(0.0732)	(0.0665)	(0.0043)			
USD	-0.0734***	-6.4576***	-5.9744***	-0.4047	0.0073	-0.6595***	-0.1193	-0.1457***	423	0.5482	0.3979
	(0.0018)	(1.2682)	(0.9046)	(1.1204)	(0.2800)	(0.0911)	(0.0798)	(0.0069)			

The table reports the OLS estimates of the coefficient of the panel fixed effect regression listed above. The 10 currencies used are Australian Dollar (AUD), Canadian Dollar (CAD), Euro (EUR), Japanese Yen (JPY), New Zealand Dollar (NZD), Norwegian Krone (NOK), Swedish Krona (SEK), Swiss Franc (CHF), British Pound (GBP) and United States Dollar (USD). Each row represents a regression estimation using the column (1) currency as the home currency and the other 9 currencies as foreign currency j. $s_{j,t}$ is the nominal exchange rate between home and foreign country j, defined as home currency price of foreign currency, $q_{j,t}$ is the real exchange rate. $rp_{j,t}$ is the measure of foreign exchange risk premium, $\tilde{\eta}_{j,t}$ is the measure of the government bond liquidity. $i^R_{j,t}$ is the home minus foreign interest rates. Δ is a difference operator. The sample period is 2006Q1-2017Q4. Germany government interest rate is used for EUR case. Standard errors in parentheses are standard errors adjusted for cross-sectional correlation. *, **, and *** indicate that the alternative model significantly different from zero at 10%, 5%, and 1% significance level, respectively, based on standard normal critical values for the two-sided test. *, **, and *** for $q_{j,t}$ is based on critical values from distribution for Augmented Dickey Fuller test with a constant.

4. Regression tables in the main text with all coefficients reported

Full table of Table 1A

Estimation result of $\Delta s_{j,t} = \alpha_j + \beta_1 q_{j,t-1} + \beta_2(\Delta\tilde{\eta}_{j,t}) + \beta_3(\Delta i^R_{j,t}) + \beta_4(\tilde{\eta}_{j,t-1}) + \beta_5(i^R_{j,t-1}) + u_{j,t}$

	$q_{j,t-1}$	$\Delta\tilde{\eta}_{j,t}$	$\Delta i^R_{j,t}$	$\tilde{\eta}_{j,t-1}$	$i^R_{j,t-1}$	constant	N	R2_within
AUD	-0.0284***	-5.2710***	-5.7441***	0.2859	-0.2746***	0.0117***	2052	0.1891
	(0.0071)	(0.7181)	(0.5356)	(0.4313)	(0.1047)	(0.0040)		
CAD	-0.0267***	-4.6086***	-5.4603***	0.5648	-0.2635***	0.0070***	2052	0.1723
	(0.0062)	(0.6238)	(0.4910)	(0.3827)	(0.0968)	(0.0025)		
EUR	-0.0203***	-4.6406***	-5.0187***	-0.0199	-0.1843**	-0.0043**	2052	0.1434
	(0.0059)	(0.5179)	(0.4103)	(0.3109)	(0.0891)	(0.0021)		
JPY	-0.0400***	-4.3863***	-6.3171***	2.1844***	-0.1223	0.1973***	2052	0.1692
	(0.0102)	(0.9532)	(0.7367)	(0.5770)	(0.1220)	(0.0476)		
NZD	-0.0276***	-6.2906***	-6.0200***	0.1755	-0.1178	0.0127**	2052	0.1955
	(0.0082)	(0.7275)	(0.6082)	(0.4340)	(0.1216)	(0.0059)		
NOK	-0.0190***	-4.0106***	-4.8711***	0.6109	-0.1815*	0.0395***	2052	0.1537
	(0.0068)	(0.6138)	(0.4877)	(0.3915)	(0.0940)	(0.0139)		
SEK	-0.0226***	-4.5193***	-4.5991***	-0.3225	-0.1193	0.0460***	2052	0.1315
	(0.0062)	(0.5796)	(0.4631)	(0.3558)	(0.0968)	(0.0131)		
CHF	-0.0129**	-2.3197***	-2.7587***	0.6843	-0.2153**	0.0016	2052	0.0509
	(0.0065)	(0.7129)	(0.5557)	(0.4265)	(0.1006)	(0.0032)		
GBP	-0.0227***	-3.3495***	-5.2385***	0.8066**	-0.3468***	-0.0076**	2052	0.1283
	(0.0067)	(0.6655)	(0.5212)	(0.4103)	(0.0986)	(0.0033)		
USD	-0.0113*	-6.4388***	-4.7717***	-1.1849***	-0.0761	-0.0212	2052	0.1689
	(0.0068)	(0.7198)	(0.5691)	(0.4373)	(0.1045)	(0.0143)		

The table reports the OLS estimates of the coefficient of the panel fixed effect regression listed above. The 10 currencies used are Australian Dollar (AUD), Canadian Dollar (CAD), Euro (EUR), Japanese Yen (JPY), New Zealand Dollar (NZD), Norwegian Krone (NOK), Swedish Krona (SEK), Swiss Franc (CHF), British Pound (GBP) and United States Dollar (USD). Each row represents a regression estimation using the first column currency as the home currency and the other 9 currencies as foreign currency j. $s_{j,t}$ is the nominal exchange rate between home and foreign country j, defined as home currency price of foreign currency, $q_{j,t}$ is the real exchange rate. $\tilde{\eta}_{j,t}$ is a measure of the treasury liquidity, $i^R_{j,t}$ is the home minus foreign interest rates. Δ is a difference operator. The sample period is 1999M1-2018M1.

Standard errors in parentheses are standard errors adjusted for cross-sectional correlation. *, **, and *** indicate that the alternative model significantly different from zero at 10%, 5%, and 1% significance level, respectively, based on standard normal critical values for the two-sided test.

Full table of Table 1B

Estimation result of $\Delta s_{j,t} = \alpha_j + \beta_1 q_{j,t-1} + \beta_2(\Delta i^R_{j,t}) + \beta_3(i^R_{j,t-1}) + u_{j,t}$

	$q_{j,t-1}$	$\Delta i^R_{j,t}$	$i^R_{j,t-1}$	constant	N	R2_within
AUD	-0.0316***	-4.0715***	-0.2823***	0.0128***	2052	0.1134
	(0.0074)	(0.5134)	(0.1087)	(0.0042)		
CAD	-0.0276***	-4.5353***	-0.2493**	0.0058**	2052	0.1166
	(0.0064)	(0.4682)	(0.0985)	(0.0023)		
EUR	-0.0226***	-3.8297***	-0.1958**	-0.0046**	2052	0.0895
	(0.0060)	(0.3850)	(0.0909)	(0.0021)		
JPY	-0.0340***	-5.3243***	-0.1493	0.1581***	2052	0.1000
	(0.0105)	(0.7255)	(0.1294)	(0.0486)		
NZD	-0.0308***	-2.6695***	-0.0946	0.0135**	2052	0.0563
	(0.0093)	(0.5950)	(0.1333)	(0.0065)		
NOK	-0.0177**	-3.4970***	-0.1255	0.0353**	2052	0.0820
	(0.0070)	(0.4693)	(0.0951)	(0.0141)		
SEK	-0.0267***	-3.2092***	-0.1359	0.0548***	2052	0.0711
	(0.0063)	(0.4350)	(0.0983)	(0.0132)		
CHF	-0.0097	-2.0012***	-0.2245**	-0.0026	2052	0.0239
	(0.0061)	(0.5164)	(0.1026)	(0.0023)		
GBP	-0.0225***	-3.7205***	-0.3344***	-0.0081**	2052	0.0856
	(0.0068)	(0.4902)	(0.0994)	(0.0033)		
USD	-0.0141*	-3.6842***	-0.1376	-0.0288*	2052	0.0684
	(0.0075)	(0.5813)	(0.1122)	(0.0157)		

The table reports the OLS estimates of the coefficient of the panel fixed effect regression listed above. The 10 currencies used are Australian Dollar (AUD), Canadian Dollar (CAD), Euro (EUR), Japanese Yen (JPY), New Zealand Dollar (NZD), Norwegian Krone (NOK), Swedish Krona (SEK), Swiss Franc (CHF), British Pound (GBP) and United States Dollar (USD). Each row represents a regression estimation using the first column currency as the home currency and the other 9 currencies as foreign currency j. $s_{j,t}$ is the nominal exchange rate between home and foreign country j, defined as home currency price of foreign currency, $q_{j,t}$ is the real exchange rate. $\tilde{\eta}_{j,t}$ is a measure of the treasury liquidity, $i^R_{j,t}$ is the home minus foreign interest rates. Δ is a difference operator. The sample period is 1999M1-2018M1.

Standard errors in parentheses are standard errors adjusted for cross-sectional correlation. *, **, and *** indicate that the alternative model significantly different from zero at 10%, 5%, and 1% significance level, respectively, based on standard normal critical values for the two-sided test.

Full table of Table 1C 1999M1-2007M12

Estimation result of $\Delta s_{j,t} = \alpha_j + \beta_1 q_{j,t-1} + \beta_2(\Delta\tilde{\eta}_{j,t}) + \beta_3(\Delta i^R_{j,t}) + \beta_4(\tilde{\eta}_{j,t-1}) + \beta_5(i^R_{j,t-1}) + u_{j,t}$

	$q_{j,t-1}$	$\Delta\tilde{\eta}_{j,t}$	$\Delta i^R_{j,t}$	$\tilde{\eta}_{j,t-1}$	$i^R_{j,t-1}$	constant	N	R2_within
AUD	-0.0442**	-3.7828***	-3.3832***	-0.2771	-0.1394	0.0169**	972	0.0860
	(0.0172)	(1.2048)	(0.7835)	(0.7478)	(0.1697)	(0.0070)		
CAD	-0.0343**	-2.7138**	-3.2586***	-0.1023	-0.3389**	0.0083	972	0.0899
	(0.0157)	(1.0860)	(0.7449)	(0.6405)	(0.1582)	(0.0053)		
EUR	-0.0220	-2.8935***	-2.1521***	-0.3512	-0.2072	-0.0046	972	0.0463
	(0.0137)	(0.8520)	(0.5495)	(0.5668)	(0.1302)	(0.0030)		
JPY	-0.0477**	-1.1698	-1.6902*	0.7050	0.1013	0.2400**	972	0.0413
	(0.0198)	(1.3160)	(0.8907)	(0.8468)	(0.1821)	(0.0980)		
NZD	-0.0515***	-4.4680***	-3.5879***	-0.9822	-0.1811	0.0320***	972	0.0987
	(0.0173)	(1.1189)	(0.8693)	(0.6770)	(0.1675)	(0.0103)		
NOK	-0.0260*	-3.5820***	-2.7345***	-0.0776	-0.0880	0.0502*	972	0.0890
	(0.0154)	(0.9969)	(0.6348)	(0.6635)	(0.1318)	(0.0303)		
SEK	-0.0418***	-2.9760***	-2.3355***	-1.9765***	-0.0035	0.0849***	972	0.0743
	(0.0140)	(0.9147)	(0.6098)	(0.5870)	(0.1375)	(0.0301)		
CHF	-0.0265*	-1.1317	-1.1283*	-0.2191	-0.2178	0.0047	972	0.0262
	(0.0148)	(1.0144)	(0.6531)	(0.6819)	(0.1401)	(0.0071)		
GBP	-0.0356***	-4.1039***	-3.0239***	0.0960	-0.2111*	-0.0169**	972	0.0988
	(0.0130)	(0.8843)	(0.5724)	(0.5987)	(0.1252)	(0.0075)		
USD	-0.0017	-3.9766***	-2.0088***	-1.3819*	-0.1937	0.0013	972	0.0791
	(0.0121)	(1.1134)	(0.7022)	(0.7433)	(0.1497)	(0.0258)		

The table reports the OLS estimates of the coefficient of the panel fixed effect regression listed above. The 10 currencies used are Australian Dollar (AUD), Canadian Dollar (CAD), Euro (EUR), Japanese Yen (JPY), New Zealand Dollar (NZD), Norwegian Krone (NOK), Swedish Krona (SEK), Swiss Franc (CHF), British Pound (GBP) and United States Dollar (USD). Each row represents a regression estimation using the first column currency as the home currency and the other 9 currencies as foreign currency j. $s_{j,t}$ is the nominal exchange rate between home and foreign country j, defined as home currency price of foreign currency, $q_{j,t}$ is the real exchange rate. $\tilde{\eta}_{j,t}$ is a measure of the treasury liquidity, $i^R_{j,t}$ is the home minus foreign interest rates. Δ is a difference operator. The sample period is 1999M1-2007M12.

Standard errors in parentheses are standard errors adjusted for cross-sectional correlation. *, **, and *** indicate that the alternative model significantly different from zero at 10%, 5%, and 1% significance level, respectively, based on standard normal critical values for the two-sided test.

Full table of Table 1C 2008M1-2018M1

Estimation result of $\Delta s_{j,t} = \alpha_j + \beta_1 q_{j,t-1} + \beta_2(\Delta\tilde{\eta}_{j,t}) + \beta_3(\Delta i^R_{j,t}) + \beta_4(\tilde{\eta}_{j,t-1}) + \beta_5(i^R_{j,t-1}) + u_{j,t}$

	$q_{j,t-1}$	$\Delta\tilde{\eta}_{j,t}$	$\Delta i^R_{j,t}$	$\tilde{\eta}_{j,t-1}$	$i^R_{j,t-1}$	constant	N	R2_within
AUD	-0.0479***	-6.0254***	-7.4325***	0.1386	-0.4157**	0.0154**	1080	0.2958
	(0.0135)	(0.8766)	(0.7380)	(0.6054)	(0.2106)	(0.0071)		
CAD	-0.0421***	-5.7275***	-7.6665***	0.0651	0.1196	0.0049*	1080	0.2921
	(0.0108)	(0.7300)	(0.6477)	(0.4992)	(0.1707)	(0.0030)		
EUR	-0.0379***	-5.2961***	-7.3637***	-0.2554	-0.1148	-0.0116***	1080	0.2587
	(0.0103)	(0.6488)	(0.6024)	(0.4536)	(0.1839)	(0.0038)		
JPY	-0.0594***	-5.7308***	-11.1782***	2.0933**	-0.1388	0.2808***	1080	0.3300
	(0.0176)	(1.2351)	(1.1239)	(0.8886)	(0.2941)	(0.0798)		
NZD	-0.0538***	-6.9225***	-8.0179***	0.3942	0.1117	0.0093	1080	0.3205
	(0.0139)	(0.9474)	(0.8704)	(0.6478)	(0.2404)	(0.0092)		
NOK	-0.0331***	-4.8783***	-8.0136***	0.8544	-0.1418	0.0652***	1080	0.2584
	(0.0111)	(0.7696)	(0.7390)	(0.5510)	(0.1948)	(0.0220)		
SEK	-0.0493***	-5.6023***	-6.5534***	-0.0884	-0.0153	0.0962***	1080	0.2276
	(0.0112)	(0.7307)	(0.6968)	(0.4909)	(0.1970)	(0.0222)		
CHF	-0.0252**	-2.8630***	-4.0887***	0.3166	0.1736	-0.0015	1080	0.0918
	(0.0128)	(1.0104)	(0.9266)	(0.7260)	(0.2240)	(0.0057)		
GBP	-0.0461***	-3.4219***	-7.8212***	0.7905	-0.2768	-0.0182***	1080	0.2086
	(0.0144)	(0.9195)	(0.8551)	(0.6344)	(0.2411)	(0.0064)		
USD	-0.0470***	-7.1136***	-9.5402***	-0.8047	0.0188	-0.0901***	1080	0.3262
	(0.0127)	(0.8594)	(0.8147)	(0.5847)	(0.2209)	(0.0253)		

The table reports the OLS estimates of the coefficient of the panel fixed effect regression listed above. The 10 currencies used are Australian Dollar (AUD), Canadian Dollar (CAD), Euro (EUR), Japanese Yen (JPY), New Zealand Dollar (NZD), Norwegian Krone (NOK), Swedish Krona (SEK), Swiss Franc (CHF), British Pound (GBP) and United States Dollar (USD). Each row represents a regression estimation using the first column currency as the home currency and the other 9 currencies as foreign currency j. $s_{j,t}$ is the nominal exchange rate between home and foreign country j, defined as home currency price of foreign currency, $q_{j,t}$ is the real exchange rate. $\tilde{\eta}_{j,t}$ is a measure of the treasury liquidity, $i^R_{j,t}$ is the home minus foreign interest rates. Δ is a difference operator. The sample period is 2008M1-2018M1.

Standard errors in parentheses are standard errors adjusted for cross-sectional correlation. *, **, and *** indicate that the alternative model significantly different from zero at 10%, 5%, and 1% significance level, respectively, based on standard normal critical values for the two-sided test.

Full table of Table 1D (excluding 2007-2009)

Estimation result of $\Delta s_{j,t} = \alpha_j + \beta_1 q_{j,t-1} + \beta_2(\Delta\tilde{\eta}_{j,t}) + \beta_3(\Delta i^R_{j,t}) + \beta_4(\tilde{\eta}_{j,t-1}) + \beta_5(i^R_{j,t-1}) + u_{j,t}$

	$q_{j,t-1}$	$\Delta\tilde{\eta}_{j,t}$	$\Delta i^R_{j,t}$	$\tilde{\eta}_{j,t-1}$	$i^R_{j,t-1}$	constant	N	R2_within
AUD	-0.0229***	-5.0274***	-4.9028***	0.1657	-0.2888***	0.0104***	1719	0.1274
	(0.0070)	(0.9224)	(0.6239)	(0.4966)	(0.1066)	(0.0040)		
CAD	-0.0225***	-4.7266***	-4.6251***	0.3536	-0.3178***	0.0064***	1719	0.1266
	(0.0060)	(0.7771)	(0.5477)	(0.4220)	(0.0941)	(0.0025)		
EUR	-0.0173***	-5.1489***	-3.7518***	-0.4207	-0.1907**	-0.0046**	1719	0.0899
	(0.0059)	(0.7045)	(0.4968)	(0.3700)	(0.0949)	(0.0022)		
JPY	-0.0350***	-2.2265*	-3.4653***	1.9718***	-0.1089	0.1732***	1719	0.0576
	(0.0101)	(1.2139)	(0.8794)	(0.6179)	(0.1219)	(0.0472)		
NZD	-0.0226***	-5.8416***	-4.4753***	-0.4604	-0.1456	0.0116**	1719	0.1083
	(0.0082)	(0.9511)	(0.7274)	(0.5488)	(0.1246)	(0.0058)		
NOK	-0.0146**	-4.1858***	-4.1295***	0.4507	-0.2002**	0.0307**	1719	0.1068
	(0.0070)	(0.8479)	(0.5888)	(0.4758)	(0.1011)	(0.0147)		
SEK	-0.0179***	-4.1802***	-3.3752***	-0.4311	-0.1521	0.0359***	1719	0.0782
	(0.0061)	(0.7760)	(0.5545)	(0.4102)	(0.1013)	(0.0130)		
CHF	-0.0081	-2.1892**	-0.8891	0.0452	-0.2529**	-0.0029	1719	0.0207
	(0.0063)	(0.8846)	(0.6284)	(0.4648)	(0.0996)	(0.0034)		
GBP	-0.0161**	-4.7377***	-3.9819***	0.1791	-0.2829***	-0.0060**	1719	0.0820
	(0.0065)	(0.8639)	(0.5979)	(0.4671)	(0.0972)	(0.0031)		
USD	-0.0080	-7.1290***	-4.3299***	-1.3807***	-0.1094	-0.0138	1719	0.1254
	(0.0069)	(0.9607)	(0.6697)	(0.4872)	(0.1061)	(0.0146)		

The table reports the OLS estimates of the coefficient of the panel fixed effect regression listed above. The 10 currencies used are Australian Dollar (AUD), Canadian Dollar (CAD), Euro (EUR), Japanese Yen (JPY), New Zealand Dollar (NZD), Norwegian Krone (NOK), Swedish Krona (SEK), Swiss Franc (CHF), British Pound (GBP) and United States Dollar (USD). Each row represents a regression estimation using the first column currency as the home currency and the other 9 currencies as foreign currency j. $s_{j,t}$ is the nominal exchange rate between home and foreign country j, defined as home currency price of foreign currency, $q_{j,t}$ is the real exchange rate. $\tilde{\eta}_{j,t}$ is a measure of the treasury liquidity, $i^R_{j,t}$ is the home minus foreign interest rates. Δ is a difference operator. The sample period is 1999M1-2018M1 but excludes data from 2007-2009.

Standard errors in parentheses are standard errors adjusted for cross-sectional correlation. *, **, and *** indicate that the alternative model significantly different from zero at 10%, 5%, and 1% significance level, respectively, based on standard normal critical values for the two-sided test.

Full table of Table 1E (excluding U.S. dollar)

Estimation result of $\Delta s_{j,t} = \alpha_j + \beta_1 q_{j,t-1} + \beta_2(\Delta\tilde{\eta}_{j,t}) + \beta_3(\Delta i^R_{j,t}) + \beta_4(\tilde{\eta}_{j,t-1}) + \beta_5(i^R_{j,t-1}) + u_{j,t}$

	$q_{j,t-1}$	$\Delta\tilde{\eta}_{j,t}$	$\Delta i^R_{j,t}$	$\tilde{\eta}_{j,t-1}$	$i^R_{j,t-1}$	constant	N	R2_within
AUD	-0.0322***	-4.7984***	-5.6396***	0.5626	-0.2767**	-0.0544***	1824	0.1843
	(0.0077)	(0.7149)	(0.5278)	(0.4410)	(0.1079)	(0.0132)		
CAD	-0.0325***	-4.3134***	-5.4166***	0.9654**	-0.3029***	-0.0590***	1824	0.1779
	(0.0072)	(0.6501)	(0.5027)	(0.4068)	(0.1032)	(0.0132)		
EUR	-0.0261***	-4.3161***	-4.9467***	0.3973	-0.2206**	-0.0582***	1824	0.1413
	(0.0063)	(0.5333)	(0.4095)	(0.3276)	(0.0916)	(0.0139)		
JPY	-0.0441***	-4.7844***	-6.6379***	2.4014***	-0.0940	0.1236***	1824	0.1801
	(0.0113)	(1.0061)	(0.7713)	(0.6233)	(0.1287)	(0.0297)		
NZD	-0.0333***	-5.9481***	-5.9658***	0.3598	-0.1308	-0.0538***	1824	0.1942
	(0.0087)	(0.7216)	(0.6017)	(0.4318)	(0.1252)	(0.0134)		
NOK	-0.0230***	-3.4899***	-4.9305***	0.8936**	-0.2366**	-0.0001	1824	0.1533
	(0.0072)	(0.6049)	(0.4810)	(0.3868)	(0.0954)	(0.0016)		
SEK	-0.0292***	-4.0158***	-4.5171***	0.1306	-0.1701*	0.0455***	1824	0.1249
	(0.0064)	(0.5704)	(0.4522)	(0.3508)	(0.0977)	(0.0099)		
CHF	-0.0153**	-1.8779***	-2.7105***	0.9696**	-0.2059*	-0.0294	1824	0.0491
	(0.0073)	(0.7056)	(0.5466)	(0.4380)	(0.1085)	(0.0182)		
GBP	-0.0243***	-3.4335***	-5.4040***	1.1084***	-0.3789***	-0.0592***	1824	0.1358
	(0.0073)	(0.7056)	(0.5466)	(0.4380)	(0.1085)	(0.0182)		

The table reports the OLS estimates of the coefficient of the panel fixed effect regression listed above. The 9 currencies used are Australian Dollar (AUD), Canadian Dollar (CAD), Euro (EUR), Japanese Yen (JPY), New Zealand Dollar (NZD), Norwegian Krone (NOK), Swedish Krona (SEK), Swiss Franc (CHF) and British Pound (GBP). We exclude United States Dollar (USD) from all the regressions. Each row represents a regression estimation using the first column currency as the home currency and the other 8 currencies as foreign currency j. $s_{j,t}$ is the nominal exchange rate between home and foreign country j, defined as home currency price of foreign currency, $q_{j,t}$ is the real exchange rate. $\tilde{\eta}_{j,t}$ is a measure of the treasury liquidity, $i^R_{j,t}$ is the home minus foreign interest rates. Δ is a difference operator. The sample period is 1999M1-2018M1.

Standard errors in parentheses are standard errors adjusted for cross-sectional correlation. *, **, and *** indicate that the alternative model significantly different from zero at 10%, 5%, and 1% significance level, respectively, based on standard normal critical values for the two-sided test.

Full table of Table 1F

Estimation result of $\Delta s_{j,t} = \alpha_j + \beta_1 q_{j,t-1} + \beta_2(\Delta\tilde{\eta}_{j,t}) + \beta_3(\Delta i^R_{j,t}) + \beta_4(\tilde{\eta}_{j,t-1}) + \beta_5(i^R_{j,t-1}) + u_{j,t}$

	$q_{j,t-1}$	$\Delta\tilde{\eta}_{j,t}$	$\Delta i^R_{j,t}$	$\tilde{\eta}_{j,t-1}$	$i^R_{j,t-1}$	constant	N	R2_within
AUD	-0.0543**	-7.2292	-22.9042	-11.0936	-2.9609	0.0104	360	0.0535
	(0.0259)	(10.5997)	(14.9001)	(12.0581)	(3.0581)	(0.0100)		
CAD	-0.0299***	-12.7346***	-29.1263***	-9.5571**	0.2082	0.0033	1228	0.0564
	(0.0099)	(4.6383)	(7.2838)	(4.8155)	(1.8784)	(0.0031)		
EUR	-0.0826***	-18.6085**	-20.0382**	-18.8645***	2.2468	-0.0213***	609	0.0870
	(0.0167)	(7.4739)	(9.0270)	(7.3184)	(2.7402)	(0.0050)		
JPY	-0.1023***	-23.3412**	-11.6606	-1.2668	-6.9507**	0.4741***	462	0.1397
	(0.0237)	(10.1332)	(11.6918)	(12.1462)	(3.4989)	(0.1084)		
NZD	-0.0331***	-18.7123***	-28.5861***	-11.9830**	0.9539	0.0072	1228	0.0632
	(0.0103)	(4.8520)	(6.9774)	(5.2982)	(1.5912)	(0.0070)		
SEK	-0.0332***	-14.9686***	-17.2230***	-11.1691***	-0.0599	0.0645***	1228	0.0460
	(0.0085)	(3.8834)	(5.6090)	(4.1247)	(1.2472)	(0.0177)		
CHF	-0.0572***	-10.8859	9.7523	-15.8180*	12.1774***	-0.0080*	731	0.0631
	(0.0138)	(8.9118)	(8.5222)	(9.0595)	(3.4159)	(0.0045)		
GBP	-0.0221*	-8.1728*	-19.2894***	-8.4952*	-1.0091	-0.0118**	1228	0.0305
	(0.0115)	(4.9056)	(7.0342)	(4.9864)	(1.6876)	(0.0055)		
USD	-0.0254***	-17.1716***	-15.1574**	-16.5361***	1.1967	-0.0464**	1228	0.0617
	(0.0088)	(3.9433)	(6.1518)	(3.9614)	(1.4326)	(0.0182)		

The table reports the OLS estimates of the coefficient of the panel fixed effect regression listed above. The 10 currencies used are Australian Dollar (AUD), Canadian Dollar (CAD), Euro (EUR), Japanese Yen (JPY), New Zealand Dollar (NZD), Norwegian Krone (NOK), Swedish Krona (SEK), Swiss Franc (CHF), British Pound (GBP) and United States Dollar (USD). Each row represents a regression estimation using the first column currency as the home currency and the other 9 currencies as foreign currency j. $s_{j,t}$ is the nominal exchange rate between home and foreign country j, defined as home currency price of foreign currency, $q_{j,t}$ is the real exchange rate. $\tilde{\eta}_{j,t}$ is a measure of the treasury liquidity, $i^R_{j,t}$ is the home minus foreign interest rates. Δ is a difference operator. The sample period is 1999M1-2018M1.

Standard errors in parentheses are standard errors adjusted for cross-sectional correlation. *, **, and *** indicate that the alternative model significantly different from zero at 10%, 5%, and 1% significance level, respectively, based on standard normal critical values for the two-sided test.

Full table of Table 1G

Estimation result of $\Delta s_{j,t} = \alpha_j + \beta_1 q_{j,t-1} + \beta_2 \Delta\hat{\eta}_{j,t} + \beta_3 \Delta i^R_{j,t} + \beta_4 \hat{\eta}_{j,t-1} + \beta_5 i^R_{j,t-1} + u_{j,t}$

	$q_{j,t-1}$	$\Delta\hat{\eta}_{j,t}$	$\Delta i^R_{j,t}$	$\hat{\eta}_{j,t-1}$	$i^R_{j,t-1}$	constant	N	R2_within
AUD	-0.0280***	-5.8403***	-5.6436***	0.3729	-0.2797**	0.0118***	2028	0.1925
	(0.0071)	(0.7792)	(0.5336)	(0.4037)	(0.1104)	(0.0041)		
CAD	-0.0292***	-3.6792***	-6.2239***	0.6596*	-0.2702**	0.0063**	1836	0.1780
	(0.0068)	(0.7446)	(0.5409)	(0.3722)	(0.1123)	(0.0025)		
EUR	-0.0208***	-3.5247***	-5.0296***	0.1062	-0.1604*	-0.0041*	2028	0.1199
	(0.0059)	(0.5774)	(0.4158)	(0.2963)	(0.0941)	(0.0021)		
JPY	-0.0379***	-4.1970***	-6.1899***	1.7952***	-0.2840**	0.1792***	2028	0.1433
	(0.0102)	(1.0210)	(0.7619)	(0.5391)	(0.1352)	(0.0473)		
NZD	-0.0286***	-6.0615***	-5.8825***	0.2684	-0.1196	0.0130**	2028	0.1689
	(0.0086)	(0.8071)	(0.6286)	(0.4018)	(0.1295)	(0.0061)		
NOK	-0.0177***	-2.8878***	-4.3967***	0.4004	-0.1699*	0.0358**	2028	0.1213
	(0.0069)	(0.6514)	(0.4989)	(0.3779)	(0.1021)	(0.0139)		
SEK	-0.0235***	-4.2018***	-4.4555***	-0.2478	-0.0883	0.0484***	2028	0.1128
	(0.0063)	(0.6442)	(0.4750)	(0.3446)	(0.1043)	(0.0130)		
CHF	-0.0101*	-3.1277***	-3.0788***	0.5760	-0.2172**	-0.0003	2028	0.0509
	(0.0061)	(0.7759)	(0.5552)	(0.3918)	(0.1080)	(0.0025)		
GBP	-0.0204***	-4.0860***	-5.3545***	0.5586	-0.3377***	-0.0075**	2028	0.1336
	(0.0067)	(0.7353)	(0.5244)	(0.3895)	(0.1054)	(0.0033)		
USD	-0.0139*	-6.0432***	-4.7403***	-1.1631***	-0.0296	-0.0289*	2028	0.1341
	(0.0071)	(0.8433)	(0.5988)	(0.4303)	(0.1141)	(0.0148)		

The table reports the OLS estimates of the coefficient of the panel fixed effect regression listed above. The 10 currencies used are Australian Dollar (AUD), Canadian Dollar (CAD), Euro (EUR), Japanese Yen (JPY), New Zealand Dollar (NZD), Norwegian Krone (NOK), Swedish Krona (SEK), Swiss Franc (CHF), British Pound (GBP) and United States Dollar (USD). Each row represents a regression estimation using the first column currency as the home currency and the other 9 currencies as foreign currency j. $s_{j,t}$ is the nominal exchange rate between home and foreign country j, defined as home currency price of foreign currency, $q_{j,t}$ is the real exchange rate, $\hat{\eta}_{j,t}$ is a measure of the treasury liquidity, $i^R_{j,t}$ is the home minus foreign interest rates. Δ is a difference operator. The sample period is 1999M1-2018M1.

Standard errors in parentheses are standard errors adjusted for cross-sectional correlation. *, **, and *** indicate that the alternative model significantly different from zero at 10%, 5%, and 1% significance level, respectively, based on standard normal critical values for the two-sided test.

Full table of Table 2A, full sample, no default risk

Estimation result of $\Delta s_{j,t} = \alpha_j + \beta_1 q_{j,t-1} + \beta_2 \Delta\lambda_{j,t} + \beta_3 \Delta\tau_{j,t} + \beta_4 \Delta l^R_{j,t} + \beta_5 \Delta i^R_{j,t} + \beta_6 \lambda_{j,t-1} + \beta_7 \tau_{j,t-1} + \beta_8 l^R_{j,t-1} + \beta_9 i^R_{j,t-1} + u_{j,t}$

	$q_{j,t-1}$	$\Delta\lambda_{j,t}$	$\Delta\tau_{j,t}$	$\Delta i^R_{j,t}$	$\lambda_{j,t-1}$	$\tau_{j,t-1}$	$i^R_{j,t-1}$	constant	N	R2_within
AUD	-0.0274***	-6.1475***	-2.9797**	-5.8688***	0.3472	-0.1402	-0.2849**	0.0118***	2028	0.1995
	(0.0072)	(0.7910)	(1.2262)	(0.5366)	(0.4285)	(0.7619)	(0.1109)	(0.0041)		
CAD	-0.0286***	-4.6021***	-5.2004***	-6.1767***	0.6082	-0.0500	-0.2890***	0.0061**	1836	0.2065
	(0.0068)	(0.7235)	(1.1252)	(0.5272)	(0.4023)	(0.7135)	(0.1105)	(0.0025)		
EUR	-0.0190***	-4.6613***	-4.9050***	-5.0429***	-0.0460	-0.3667	-0.1720*	-0.0047**	2028	0.1471
	(0.0059)	(0.5684)	(0.8672)	(0.4086)	(0.3126)	(0.5340)	(0.0911)	(0.0022)		
JPY	-0.0399***	-4.1648***	-4.9939***	-6.4133***	2.1716***	2.0497**	-0.1430	0.1959***	2028	0.1731
	(0.0101)	(1.0016)	(1.5866)	(0.7452)	(0.5782)	(0.9608)	(0.1340)	(0.0476)		
NZD	-0.0288***	-6.6165***	-5.7714***	-6.2660***	0.2044	-0.5417	-0.1606	0.0144**	2028	0.2014
	(0.0078)	(0.7968)	(1.2968)	(0.6124)	(0.4329)	(0.7811)	(0.1266)	(0.0057)		
NOK	-0.0190***	-3.8436***	-5.0816***	-4.9048***	0.5818	0.7234	-0.1754*	0.0397***	2028	0.1574
	(0.0068)	(0.6526)	(1.0437)	(0.4876)	(0.3978)	(0.6896)	(0.0987)	(0.0142)		
SEK	-0.0215***	-4.4583***	-5.0234***	-4.5856***	-0.2974	-0.6584	-0.1246	0.0430***	2028	0.1328
	(0.0063)	(0.6435)	(0.9849)	(0.4676)	(0.3630)	(0.6360)	(0.1030)	(0.0135)		
CHF	-0.0126*	-3.0442***	-1.1689	-3.0433***	0.6559	0.6751	-0.1920*	0.0017	2028	0.0545
	(0.0065)	(0.7725)	(1.1966)	(0.5521)	(0.4222)	(0.7477)	(0.1075)	(0.0034)		
GBP	-0.0218***	-4.1890***	-1.4009	-5.5283***	0.7676*	0.6448	-0.3340***	-0.0074**	2028	0.1373
	(0.0068)	(0.7457)	(1.1224)	(0.5252)	(0.4169)	(0.6977)	(0.1065)	(0.0033)		
USD	-0.0119*	-6.3166***	-6.7369***	-4.7912***	-1.2687***	-0.8782	-0.0583	-0.0231	2028	0.1708
	(0.0070)	(0.8213)	(1.1889)	(0.5794)	(0.4454)	(0.7188)	(0.1109)	(0.0148)		

The table reports the OLS estimates of the coefficient of the panel fixed effect regression listed above. The 10 currencies used are Australian Dollar (AUD), Canadian Dollar (CAD), Euro (EUR), Japanese Yen (JPY), New Zealand Dollar (NZD), Norwegian Krone (NOK), Swedish Krona (SEK), Swiss Franc (CHF), British Pound (GBP) and United States Dollar (USD). Each row represents a regression estimation using the first column currency as the home currency and the other 9 currencies as foreign currency j. $s_{j,t}$ is the nominal exchange rate between home and foreign country j, defined as home currency price of foreign currency, $q_{j,t}$ is the real exchange rate. $\tau_{j,t}$ is a measure of currency derivative friction, $l^R_{j,t}$ is a measure of home minus foreign default risk, $\lambda_{j,t}$ is a measure of the treasury liquidity after adjusting for derivative market friction and default risk, $i^R_{j,t}$ is the home minus foreign interest rates. Δ is a difference operator. The sample period is 1999M1-2018M1.

Standard errors in parentheses are standard errors adjusted for cross-sectional correlation. *, **, and *** indicate that the alternative model significantly different from zero at 10%, 5%, and 1% significance level, respectively, based on standard normal critical values for the two-sided test.

Full table of Table 2A, post 2008, with default risk

Estimation result of $\Delta s_{j,t} = \alpha_j + \beta_1 q_{j,t-1} + \beta_2 \Delta\lambda_{j,t} + \beta_3 \Delta\tau_{j,t} + \beta_4 \Delta l^R_{j,t} + \beta_5 \Delta i^R_{j,t} + \beta_6 \lambda_{j,t-1} + \beta_7 \tau_{j,t-1} + \beta_8 l^R_{j,t-1} + \beta_9 i^R_{j,t-1} + u_{j,t}$

	$q_{j,t-1}$	$\Delta\lambda_{j,t}$	$\Delta\tau_{j,t}$	$\Delta l^R_{j,t}$	$\Delta i^R_{j,t}$	$\lambda_{j,t-1}$	$\tau_{j,t-1}$	$l^R_{j,t-1}$	$i^R_{j,t-1}$	constant	N	R2_within
AUD	-0.0509***	-7.0027***	-3.1133**	14.3663***	-7.1490***	-0.3463	-0.4152	0.0981	-0.3792*	0.0155**	955	0.2878
	(0.0156)	(1.1219)	(1.5396)	(2.3547)	(0.8016)	(0.6623)	(1.1959)	(1.4170)	(0.2130)	(0.0074)		
CAD	-0.0313***	-8.8567***	-6.8906***	8.3213***	-8.9747***	-0.6043	-3.5155***	-0.6392	0.3944	-0.0009	399	0.3046
	(0.0118)	(1.5154)	(1.7969)	(2.5681)	(1.1122)	(0.8526)	(1.0528)	(1.5427)	(0.2489)	(0.0035)		
EUR	-0.0475***	-6.0993***	-3.9164***	8.2139***	-7.8031***	-0.0617	-0.6728	2.1319**	-0.0555	-0.0159***	966	0.2593
	(0.0108)	(0.7990)	(0.9455)	(1.6760)	(0.6197)	(0.4729)	(0.7124)	(1.0462)	(0.1759)	(0.0042)		
JPY	-0.0638***	-6.7890***	-4.4253**	10.1977***	-11.2335***	2.1124***	2.9840**	-0.2255	-0.0562	0.3035***	966	0.3391
	(0.0177)	(1.3763)	(1.8491)	(3.1745)	(1.1307)	(0.8119)	(1.4166)	(1.9881)	(0.2783)	(0.0799)		
NZD	-0.0548***	-7.7871***	-5.8429***	12.2542***	-7.9726***	0.7042	0.4257	0.0068	0.2191	0.0068	943	0.3138
	(0.0137)	(1.1415)	(1.4849)	(2.5075)	(0.9040)	(0.6976)	(1.2209)	(1.4197)	(0.2471)	(0.0091)		
NOK	-0.0419***	-5.1123***	-5.7420***	4.0843**	-7.8885***	0.6108	0.6935	1.4966	-0.1149	0.0821***	966	0.2600
	(0.0112)	(0.8095)	(1.2013)	(1.9590)	(0.7317)	(0.5327)	(0.8996)	(1.2677)	(0.1930)	(0.0224)		
SEK	-0.0490***	-5.5565***	-4.1789***	7.4308***	-6.1245***	0.0541	-1.0151	0.0312	-0.0316	0.0931***	966	0.2049
	(0.0113)	(0.8854)	(1.1469)	(1.9029)	(0.7209)	(0.5102)	(0.8522)	(1.1411)	(0.1903)	(0.0228)		
CHF	-0.0237*	-3.2384**	-1.1997	5.6024**	-0.9718	-0.4007	0.1134	1.7805	0.1994	-0.0042	888	0.0310
	(0.0124)	(1.4895)	(1.8080)	(2.6065)	(1.0721)	(0.7699)	(1.1614)	(1.4636)	(0.2318)	(0.0055)		
GBP	-0.0493***	-6.1288***	-0.4453	5.6119**	-8.9524***	0.4706	2.0941**	0.9179	-0.0648	-0.0190***	966	0.2294
	(0.0137)	(1.1158)	(1.4105)	(2.3529)	(0.8780)	(0.6577)	(1.0347)	(1.4854)	(0.2365)	(0.0063)		
USD	-0.0560***	-8.9086***	-3.2019**	12.5574***	-10.1507***	-0.9368	0.4045	1.0582	0.1366	-0.1104***	813	0.3756
	(0.0138)	(1.1126)	(1.2482)	(2.1570)	(0.8834)	(0.6296)	(0.9356)	(1.3704)	(0.2270)	(0.0275)		

The table reports the OLS estimates of the coefficient of the panel fixed effect regression listed above. The 10 currencies used are Australian Dollar (AUD), Canadian Dollar (CAD), Euro (EUR), Japanese Yen (JPY), New Zealand Dollar (NZD), Norwegian Krone (NOK), Swedish Krona (SEK), Swiss Franc (CHF), British Pound (GBP) and United States Dollar (USD). Each row represents a regression estimation using the first column currency as the home currency and the other 9 currencies as foreign currency j. $s_{j,t}$ is the nominal exchange rate between home and foreign country j, defined as home currency price of foreign currency, $q_{j,t}$ is the real exchange rate. $\tau_{j,t}$ is a measure of currency derivative friction, $l^R_{j,t}$ is a measure of home minus foreign default risk, $\lambda_{j,t}$ is a measure of the treasury liquidity after adjusting for derivative market friction and default risk, $i^R_{j,t}$ is the home minus foreign interest rates. Δ is a difference operator. The sample period is 2008M1-2018M1.

Standard errors in parentheses are standard errors adjusted for cross-sectional correlation. *, **, and *** indicate that the alternative model significantly different from zero at 10%, 5%, and 1% significance level, respectively, based on standard normal critical values for the two-sided test.

Full table of Table 2B for $\lambda_{j,t}$

Estimation result of $\Delta s_{j,t} = \alpha_j + \beta_1 q_{j,t-1} + \beta_2 \Delta\lambda_{j,t} + \beta_3 \Delta i^R_{j,t} + \beta_4 \lambda_{j,t-1} + \beta_5 i^R_{j,t-1} + u_{j,t}$

	$q_{j,t-1}$	$\Delta\lambda_{j,t}$	$\Delta i^R_{j,t}$	$\lambda_{j,t-1}$	$i^R_{j,t-1}$	constant	N	R2_within
AUD	-0.0543***	-4.3320***	-6.2922***	0.0266	-0.3915*	0.0162**	955	0.2080
	(0.0159)	(1.0848)	(0.8438)	(0.5792)	(0.2295)	(0.0077)		
CAD	-0.0359***	-3.6265***	-7.9490***	0.9625	0.4427*	0.0038	399	0.2396
	(0.0125)	(1.3326)	(1.1357)	(0.7107)	(0.2646)	(0.0035)		
EUR	-0.0422***	-3.1217***	-7.5554***	0.6824*	-0.0301	-0.0131***	966	0.2146
	(0.0106)	(0.7396)	(0.6290)	(0.4144)	(0.1847)	(0.0037)		
JPY	-0.0688***	-4.8998***	-10.7149***	1.7353***	-0.3464	0.3143***	966	0.2779
	(0.0182)	(1.3625)	(1.1784)	(0.6549)	(0.2943)	(0.0823)		
NZD	-0.0543***	-4.9252***	-6.8331***	0.9805	0.2785	0.0059	943	0.2225
	(0.0160)	(1.1290)	(0.9642)	(0.6664)	(0.2692)	(0.0100)		
NOK	-0.0355***	-4.1387***	-7.1490***	0.8489*	-0.0853	0.0668***	966	0.2111
	(0.0112)	(0.7748)	(0.7501)	(0.4503)	(0.2030)	(0.0220)		
SEK	-0.0514***	-4.0382***	-5.8983***	0.1242	0.0492	0.1002***	966	0.1613
	(0.0112)	(0.8195)	(0.7262)	(0.4638)	(0.1975)	(0.0223)		
CHF	-0.0212*	-1.7916	-0.7941	-0.0116	0.1872	-0.0033	888	0.0180
	(0.0118)	(1.3227)	(1.0637)	(0.6511)	(0.2334)	(0.0037)		
GBP	-0.0454***	-5.0370***	-8.1277***	0.1534	-0.1255	-0.0196***	966	0.2098
	(0.0134)	(1.0264)	(0.8637)	(0.5511)	(0.2391)	(0.0062)		
USD	-0.0595***	-5.1253***	-9.8593***	-0.7254	0.1777	-0.1159***	813	0.2804
	(0.0163)	(1.1080)	(0.9587)	(0.6271)	(0.2570)	(0.0322)		

The table reports the OLS estimates of the coefficient of the panel fixed effect regression listed above. The 10 currencies used are Australian Dollar (AUD), Canadian Dollar (CAD), Euro (EUR), Japanese Yen (JPY), New Zealand Dollar (NZD), Norwegian Krone (NOK), Swedish Krona (SEK), Swiss Franc (CHF), British Pound (GBP) and United States Dollar (USD). Each row represents a regression estimation using the first column currency as the home currency and the other 9 currencies as foreign currency j. $s_{j,t}$ is the nominal exchange rate between home and foreign country j, defined as home currency price of foreign currency, $q_{j,t}$ is the real exchange rate. $\tau_{j,t}$ is a measure of currency derivative friction, $l^R_{j,t}$ is a measure of home minus foreign default risk, $\lambda_{j,t}$ is a measure of the treasury liquidity after adjusting for derivative market friction and default risk, $i^R_{j,t}$ is the home minus foreign interest rates. Δ is a difference operator. The sample period is 2008M1-2018M1. Regressions involving default risk $\hat{l}^R_{j,t}$ are only estimated through 2008M1-2018M1 period.

Standard errors in parentheses are standard errors adjusted for cross-sectional correlation. *, **, and *** indicate that the alternative model significantly different from zero at 10%, 5%, and 1% significance level, respectively, based on standard normal critical values for the two-sided test.

Full table of Table 2B for $\tau_{j,t}$

Estimation result of $\Delta s_{j,t} = \alpha_j + \beta_1 q_{j,t-1} + \beta_2 \Delta\tau_{j,t} + \beta_3 \Delta i^R_{j,t} + \beta_4 \tau_{j,t-1} + \beta_5 i^R_{j,t-1} + u_{j,t}$

	$q_{j,t-1}$	$\Delta\tau_{j,t}$	$\Delta i^R_{j,t}$	$\tau_{j,t-1}$	$i^R_{j,t-1}$	constant	N	R2_within
AUD	-0.0312***	-1.4191	-4.1932***	-0.2277	-0.2925**	0.0130***	2028	0.1160
	(0.0075)	(1.2782)	(0.5169)	(0.7500)	(0.1146)	(0.0043)		
CAD	-0.0286***	-4.3619***	-5.3167***	-0.6401	-0.2864***	0.0049**	1836	0.1703
	(0.0068)	(1.1244)	(0.4978)	(0.6464)	(0.1095)	(0.0024)		
EUR	-0.0207***	-3.1629***	-3.6498***	-0.3955	-0.1949**	-0.0051**	2028	0.1036
	(0.0059)	(0.8745)	(0.3745)	(0.4824)	(0.0911)	(0.0022)		
JPY	-0.0339***	-5.8142***	-5.5937***	0.6695	-0.1067	0.1598***	2028	0.1283
	(0.0103)	(1.6352)	(0.7067)	(0.9127)	(0.1352)	(0.0482)		
NZD	-0.0307***	-4.0584***	-2.8848***	-0.3508	-0.1083	0.0139**	2028	0.0762
	(0.0088)	(1.4135)	(0.5836)	(0.7794)	(0.1357)	(0.0063)		
NOK	-0.0176**	-3.0231***	-3.6394***	0.1943	-0.1224	0.0355**	2028	0.0958
	(0.0070)	(1.0557)	(0.4664)	(0.6613)	(0.0976)	(0.0144)		
SEK	-0.0244***	-4.3694***	-3.2657***	-0.5796	-0.1616	0.0491***	2028	0.0859
	(0.0064)	(0.9940)	(0.4275)	(0.6035)	(0.1013)	(0.0136)		
CHF	-0.0112*	-1.4794	-2.0211***	0.4119	-0.1921*	-0.0015	2028	0.0279
	(0.0063)	(1.2040)	(0.5085)	(0.7012)	(0.1057)	(0.0028)		
GBP	-0.0219***	-0.6742	-3.7763***	-0.2472	-0.3444***	-0.0081**	2028	0.0877
	(0.0070)	(1.1406)	(0.4907)	(0.6729)	(0.1063)	(0.0033)		
USD	-0.0126*	-6.1304***	-3.7428***	-0.6531	-0.1663	-0.0246	2028	0.1006
	(0.0075)	(1.2345)	(0.5663)	(0.6949)	(0.1139)	(0.0160)		

The table reports the OLS estimates of the coefficient of the panel fixed effect regression listed above. The 10 currencies used are Australian Dollar (AUD), Canadian Dollar (CAD), Euro (EUR), Japanese Yen (JPY), New Zealand Dollar (NZD), Norwegian Krone (NOK), Swedish Krona (SEK), Swiss Franc (CHF), British Pound (GBP) and United States Dollar (USD). Each row represents a regression estimation using the first column currency as the home currency and the other 9 currencies as foreign currency j. $s_{j,t}$ is the nominal exchange rate between home and foreign country j, defined as home currency price of foreign currency, $q_{j,t}$ is the real exchange rate. $\tau_{j,t}$ is a measure of currency derivative friction, $l^R_{j,t}$ is a measure of home minus foreign default risk, $\lambda_{j,t}$ is a measure of the treasury liquidity after adjusting for derivative market friction and default risk, $i^R_{j,t}$ is the home minus foreign interest rates. Δ is a difference operator. The sample period is 1999M1-2018M1. Regressions involving default risk $\hat{l}^R_{j,t}$ are only estimated through 2008M1-2018M1 period.

Standard errors in parentheses are standard errors adjusted for cross-sectional correlation. *, **, and *** indicate that the alternative model significantly different from zero at 10%, 5%, and 1% significance level, respectively, based on standard normal critical values for the two-sided test.

Full table of Table 2B for $l_{j,t}^{R}$

Estimation result of $\Delta s_{j,t} = \alpha_j + \beta_1 q_{j,t-1} + \beta_2 \Delta l_{j,t}^{R} + \beta_3 \Delta i_{j,t}^{R} + \beta_4 l_{j,t-1}^{R} + \beta_5 i_{j,t-1}^{R} + u_{j,t}$

	$q_{j,t-1}$	$\Delta l_{j,t}^{R}$	$\Delta i_{j,t}^{R}$	$l_{j,t-1}^{R}$	$i_{j,t-1}^{R}$	constant	N	R2_within
AUD	-0.0566***	9.9450***	-5.6511***	0.5019	-0.4507**	0.0186**	955	0.2100
	(0.0161)	(2.2182)	(0.7588)	(1.3146)	(0.2186)	(0.0074)		
CAD	-0.0308**	0.7547	-6.9329***	1.2790	0.5283**	0.0017	399	0.2018
	(0.0127)	(2.2708)	(1.0802)	(1.3620)	(0.2442)	(0.0036)		
EUR	-0.0510***	2.0777	-6.0427***	2.3713**	-0.0532	-0.0140***	966	0.1866
	(0.0110)	(1.5476)	(0.5769)	(0.9485)	(0.1851)	(0.0037)		
JPY	-0.0607***	4.5740	-9.7475***	1.7616	-0.0490	0.2752***	966	0.2393
	(0.0193)	(3.1035)	(1.1419)	(1.8748)	(0.3082)	(0.0868)		
NZD	-0.0667***	4.5388*	-5.7954***	1.9098	0.3233	0.0071	943	0.1607
	(0.0159)	(2.5778)	(0.9641)	(1.4399)	(0.2727)	(0.0101)		
NOK	-0.0446***	-1.2069	-5.1485***	2.8596**	-0.0820	0.0868***	966	0.1373
	(0.0121)	(1.9480)	(0.7167)	(1.1771)	(0.2171)	(0.0241)		
SEK	-0.0559***	3.0840*	-4.1609***	1.2861	0.0484	0.1100***	966	0.1216
	(0.0119)	(1.8008)	(0.6657)	(1.0883)	(0.1960)	(0.0235)		
CHF	-0.0230*	2.4456	-0.1148	1.4120	0.1551	-0.0033	888	0.0166
	(0.0123)	(2.2902)	(0.9815)	(1.3110)	(0.2270)	(0.0032)		
GBP	-0.0491***	0.7847	-5.8242***	1.3991	-0.1526	-0.0206***	966	0.1601
	(0.0145)	(2.2277)	(0.8310)	(1.2958)	(0.2467)	(0.0066)		
USD	-0.0570***	5.1429**	-8.6497***	-0.2386	0.1627	-0.1103***	813	0.2553
	(0.0167)	(2.1134)	(0.9081)	(1.3630)	(0.2547)	(0.0330)		

The table reports the OLS estimates of the coefficient of the panel fixed effect regression listed above. The 10 currencies used are Australian Dollar (AUD), Canadian Dollar (CAD), Euro (EUR), Japanese Yen (JPY), New Zealand Dollar (NZD), Norwegian Krone (NOK), Swedish Krona (SEK), Swiss Franc (CHF), British Pound (GBP) and United States Dollar (USD). Each row represents a regression estimation using the first column currency as the home currency and the other 9 currencies as foreign currency j. $s_{j,t}$ is the nominal exchange rate between home and foreign country j, defined as home currency price of foreign currency, $q_{j,t}$ is the real exchange rate. $\tau_{j,t}$ is a measure of currency derivative friction, $l_{j,t}^{R}$ is a measure of home minus foreign default risk, $\lambda_{j,t}$ is a measure of the treasury liquidity after adjusting for derivative market friction and default risk, $i_{j,t}^{R}$ is the home minus foreign interest rates. Δ is a difference operator. The sample period is 1999M1-2018M1. Regressions involving default risk $\hat{l}_{j,t}^{R}$ are only estimated through 2008M1-2018M1 period.

Standard errors in parentheses are standard errors adjusted for cross-sectional correlation. *, **, and *** indicate that the alternative model significantly different from zero at 10%, 5%, and 1% significance level, respectively, based on standard normal critical values for the two-sided test.

Full table of Table 2B for $(\eta + l^R)_{j,t}$

Estimation result of $\Delta s_{j,t} = \alpha_j + \beta_1 q_{j,t-1} + \beta_2 \Delta(\eta + l^R)_{j,t} + \beta_3 \Delta i^R_{j,t} + \beta_4 (\eta + l^R)_{j,t-1} + \beta_5 i^R_{j,t-1} + u_{j,t}$

	$q_{j,t-1}$	$\Delta(\eta + l^R)_{j,t}$	$\Delta i^R_{j,t}$	$(\eta + l^R)_{j,t-1}$	$i^R_{j,t-1}$	constant	N	R2_within
AUD	-0.0520***	-4.2517***	-6.5840***	-0.1630	-0.3693	0.0156**	955	0.2171
	(0.0159)	(0.9598)	(0.8561)	(0.6479)	(0.2268)	(0.0076)		
CAD	-0.0273**	-5.2887***	-8.2070***	-0.5082	0.6036**	0.0016	399	0.2497
	(0.0120)	(1.2257)	(1.1374)	(0.7763)	(0.2526)	(0.0037)		
EUR	-0.0403***	-3.7550***	-7.3184***	0.3729	-0.0271	-0.0111***	966	0.2288
	(0.0106)	(0.6173)	(0.6016)	(0.4193)	(0.1788)	(0.0038)		
JPY	-0.0676***	-4.5229***	-11.0401***	2.3472***	-0.1759	0.3184***	966	0.3137
	(0.0179)	(1.1374)	(1.1185)	(0.7884)	(0.2913)	(0.0811)		
NZD	-0.0520***	-5.1871***	-7.4018***	1.0370	0.3329	0.0026	943	0.2651
	(0.0151)	(0.9127)	(0.9236)	(0.6564)	(0.2539)	(0.0095)		
NOK	-0.0380***	-4.7337***	-7.7252***	0.9777**	-0.0995	0.0743***	966	0.2531
	(0.0108)	(0.6652)	(0.7121)	(0.4369)	(0.1914)	(0.0214)		
SEK	-0.0489***	-4.1673***	-6.0427***	-0.0709	0.0455	0.0954***	966	0.1779
	(0.0112)	(0.6806)	(0.7060)	(0.4590)	(0.1925)	(0.0223)		
CHF	-0.0216*	-1.5402	-0.5613	0.0418	0.1710	-0.0030	888	0.0211
	(0.0119)	(1.0703)	(1.0174)	(0.6249)	(0.2307)	(0.0047)		
GBP	-0.0450***	-3.3605***	-7.7774***	0.9221	-0.1745	-0.0186***	966	0.2025
	(0.0139)	(0.8669)	(0.8604)	(0.5699)	(0.2380)	(0.0063)		
USD	-0.0596***	-4.5722***	-9.3961***	-0.8059	0.1448	-0.1144***	813	0.2957
	(0.0157)	(0.8519)	(0.9154)	(0.5794)	(0.2493)	(0.0311)		

The table reports the OLS estimates of the coefficient of the panel fixed effect regression listed above. The 10 currencies used are Australian Dollar (AUD), Canadian Dollar (CAD), Euro (EUR), Japanese Yen (JPY), New Zealand Dollar (NZD), Norwegian Krone (NOK), Swedish Krona (SEK), Swiss Franc (CHF), British Pound (GBP) and United States Dollar (USD). Each row represents a regression estimation using the first column currency as the home currency and the other 9 currencies as foreign currency j. $s_{j,t}$ is the nominal exchange rate between home and foreign country j, defined as home currency price of foreign currency, $q_{j,t}$ is the real exchange rate. $\tau_{j,t}$ is a measure of currency derivative friction, $l^R_{j,t}$ is a measure of home minus foreign default risk, $\lambda_{j,t}$ is a measure of the treasury liquidity after adjusting for derivative market friction and default risk, $i^R_{j,t}$ is the home minus foreign interest rates. Δ is a difference operator. The sample period is 1999M1-2018M1. Regressions involving default risk $\hat{l}^R_{j,t}$ are only estimated through 2008M1-2018M1 period.

Standard errors in parentheses are standard errors adjusted for cross-sectional correlation. *, **, and *** indicate that the alternative model significantly different from zero at 10%, 5%, and 1% significance level, respectively, based on standard normal critical values for the two-sided test.

Full table of Table 2B for $(\tau - l^R)_{j,t}$

Estimation result of $\Delta s_{j,t} = \alpha_j + \beta_1 q_{j,t-1} + \beta_2 \Delta(\tau - l^R)_{j,t} + \beta_3 \Delta i^R_{j,t} + \beta_4 (\tau - l^R)_{j,t-1} + \beta_5 i^R_{j,t-1} + u_{j,t}$

	$q_{j,t-1}$	$\Delta(\tau - l^R)_{j,t}$	$\Delta i^R_{j,t}$	$(\tau - l^R)_{j,t-1}$	$i^R_{j,t-1}$	constant	N	R2_within
AUD	-0.0554***	-4.6466***	-5.8645***	-0.9218	-0.5139**	0.0205**	955	0.2018
	(0.0161)	(1.3055)	(0.7957)	(0.8636)	(0.2356)	(0.0081)		
CAD	-0.0357***	-1.8207	-6.8766***	-1.6425**	0.3688	0.0005	399	0.2204
	(0.0127)	(1.4376)	(1.0686)	(0.7696)	(0.2464)	(0.0036)		
EUR	-0.0476***	-2.3862***	-5.6532***	-1.3870***	-0.1266	-0.0179***	966	0.1949
	(0.0107)	(0.8126)	(0.5736)	(0.5330)	(0.1827)	(0.0042)		
JPY	-0.0552***	-6.1640***	-9.9686***	0.2269	0.0108	0.2516***	966	0.2720
	(0.0185)	(1.6355)	(1.1145)	(1.0797)	(0.3084)	(0.0831)		
NZD	-0.0568***	-5.2129***	-6.2394***	-0.6536	0.2681	0.0075	943	0.1935
	(0.0160)	(1.3696)	(0.9465)	(0.9252)	(0.2689)	(0.0100)		
NOK	-0.0347***	-3.3848***	-5.1050***	-1.3151*	-0.0892	0.0643***	966	0.1393
	(0.0118)	(1.0826)	(0.7299)	(0.7213)	(0.2193)	(0.0230)		
SEK	-0.0547***	-3.7094***	-4.1018***	-1.1317*	-0.0230	0.1047***	966	0.1379
	(0.0115)	(0.9927)	(0.6640)	(0.6387)	(0.1950)	(0.0227)		
CHF	-0.0206*	-2.0616	0.1087	-0.3677	0.1478	-0.0041	888	0.0191
	(0.0117)	(1.4542)	(0.9897)	(0.8475)	(0.2270)	(0.0042)		
GBP	-0.0497***	-0.4514	-5.8717***	-0.0245	-0.1813	-0.0202***	966	0.1580
	(0.0141)	(1.2028)	(0.8406)	(0.7513)	(0.2525)	(0.0066)		
USD	-0.0587***	-4.6762***	-8.4757***	-0.4799	0.0907	-0.1125***	813	0.2729
	(0.0161)	(1.1607)	(0.9006)	(0.8272)	(0.2501)	(0.0316)		

The table reports the OLS estimates of the coefficient of the panel fixed effect regression listed above. The 10 currencies used are Australian Dollar (AUD), Canadian Dollar (CAD), Euro (EUR), Japanese Yen (JPY), New Zealand Dollar (NZD), Norwegian Krone (NOK), Swedish Krona (SEK), Swiss Franc (CHF), British Pound (GBP) and United States Dollar (USD). Each row represents a regression estimation using the first column currency as the home currency and the other 9 currencies as foreign currency j. $s_{j,t}$ is the nominal exchange rate between home and foreign country j, defined as home currency price of foreign currency, $q_{j,t}$ is the real exchange rate. $\tau_{j,t}$ is a measure of currency derivative friction, $l^R_{j,t}$ is a measure of home minus foreign default risk, $\lambda_{j,t}$ is a measure of the treasury liquidity after adjusting for derivative market friction and default risk, $i^R_{j,t}$ is the home minus foreign interest rates. Δ is a difference operator. The sample period is 1999M1-2018M1. Regressions involving default risk $\hat{l}^R_{j,t}$ are only estimated through 2008M1-2018M1 period.

Standard errors in parentheses are standard errors adjusted for cross-sectional correlation. *, **, and *** indicate that the alternative model significantly different from zero at 10%, 5%, and 1% significance level, respectively, based on standard normal critical values for the two-sided test.

Full table of Table 3A

IV Estimation result of $\Delta s_{j,t} = \alpha_j + \beta_1 q_{j,t-1} + \beta_2(\Delta\eta^{IV}_{j,t}) + \beta_3(\Delta i^R_{j,t}) + \beta_4(\eta^{IV}_{j,t-1}) + \beta_5(i^R_{j,t-1}) + u_{j,t}$

	$q_{j,t-1}$	$\Delta\eta^{IV}_{j,t}$	$\eta^{IV}_{j,t-1}$	$\Delta i^R_{j,t}$	$i^R_{j,t-1}$	constant	$\Delta\eta^{IV}_{j,t}$ 1st stage Adj R^2	$\eta^{IV}_{j,t-1}$ 1st stage Adj R^2	Cragg-Donald statistic	N
AUD	-0.02**	-17.10***	-1.98	-8.84***	-0.13	0.01*	0.21	0.47	8.92	1974
	(0.009)	(4.028)	(2.362)	(1.211)	(0.160)	(0.005)				
CAD	-0.03***	-8.30**	1.16	-6.35***	-0.30***	0.01**	0.11	0.57	6.44	1974
	(0.007)	(3.901)	(1.326)	(0.913)	(0.103)	(0.004)				
EUR	-0.03***	7.39	0.35	-2.99**	-0.24**	-0.01	0.09	0.53	2.79	1890
	(0.008)	(5.452)	(1.910)	(1.197)	(0.112)	(0.005)				
JPY	-0.04***	-10.53***	2.14	-7.67***	-0.18	0.21***	0.28	0.52	28.92	1974
	(0.011)	(2.698)	(1.873)	(0.874)	(0.126)	(0.057)				
NZD	-0.03***	-9.81***	0.90	-8.17***	-0.17	0.01**	0.34	0.52	11.08	1974
	(0.008)	(2.866)	(0.868)	(1.426)	(0.127)	(0.006)				
NOK	-0.03***	-3.25**	2.28**	-5.39***	-0.33***	0.06***	0.32	0.56	26.18	1890
	(0.008)	(1.449)	(1.027)	(0.660)	(0.124)	(0.018)				
SEK	-0.02***	-9.75***	-0.81	-6.23***	-0.10	0.04**	0.21	0.58	9.42	1974
	(0.007)	(2.817)	(0.758)	(1.045)	(0.109)	(0.015)				
CHF	-0.02***	0.38	2.31***	-2.28***	-0.20*	0.01**	0.22	0.57	20.77	1974
	(0.008)	(2.255)	(0.842)	(0.827)	(0.104)	(0.005)				
GBP	-0.03***	0.83	5.33**	-5.17***	-0.53***	-0.01**	0.26	0.51	10.41	1890
	(0.009)	(3.240)	(2.133)	(1.275)	(0.137)	(0.004)				
USD	-0.01*	-9.26***	-3.68***	-4.88***	0.02	-0.02	0.19	0.57	18.00	1974
	(0.007)	(2.306)	(0.939)	(0.776)	(0.116)	(0.015)				

The table reports the OLS estimates of the coefficient of the panel fixed effect regression listed above. The 10 currencies used are Australian Dollar (AUD), Canadian Dollar (CAD), Euro (EUR), Japanese Yen (JPY), New Zealand Dollar (NZD), Norwegian Krone (NOK), Swedish Krona (SEK), Swiss Franc (CHF), British Pound (GBP) and United States Dollar (USD). Each row represents a regression estimation using the first column currency as the home currency and the other 9 currencies as foreign currency j. $s_{j,t}$ is the nominal exchange rate between home and foreign country j, defined as home currency price of foreign currency, $q_{j,t}$ is the real exchange rate. $\eta^{IV}_{j,t}$ is a measure of the treasury liquidity, $i^R_{j,t}$ is the home minus foreign interest rates. Δ is a difference operator. The sample period is 1999M1-2018M1.

Standard errors in parentheses are standard errors adjusted for cross-sectional correlation. *, **, and *** indicate that the alternative model significantly different from zero at 10%, 5%, and 1% significance level, respectively, based on standard normal critical values for the two-sided test.

Full table of Table 3B

IV Estimation result of $\Delta s_{j,t} = \alpha_j + \beta_1 q_{j,t-1} + \beta_2 \Delta\lambda_{j,t}^{IV} + \beta_3 \Delta i_{j,t}^R + \beta_4 \Delta\tau_{j,t} + \beta_5 \lambda_{j,t-1}^{IV} + \beta_6 i_{j,t-1}^R + \beta_7 \tau_{j,t-1} + u_{j,t}$

	$q_{j,t-1}$	$\Delta\lambda_{j,t}^{IV}$	$\lambda_{j,t-1}^{IV}$	$\Delta\tau_{j,t}$	$\tau_{j,t-1}$	$\Delta i_{j,t}^R$	$i_{j,t-1}^R$	constant	$\Delta\lambda_{j,t}^{IV}$ 1st stage Adj R^2	$\lambda_{j,t-1}^{IV}$ 1st stage Adj R^2	Cragg-Donald statistic	N
AUD	-0.01	-27.58***	-6.07	-8.79***	-4.01*	-10.30***	0.27	-0.00	0.20	0.49	6.16	1950
	(0.010)	(5.830)	(3.964)	(2.342)	(2.334)	(1.414)	(0.308)	(0.008)				
CAD	-0.03***	6.53	0.36	-3.05	-0.57	-4.31***	-0.40***	0.01*	0.13	0.64	2.58	1797
	(0.009)	(7.333)	(1.274)	(1.866)	(1.275)	(1.424)	(0.144)	(0.004)				
EUR	-0.02***	-10.87*	-1.03	-7.33***	-1.38	-6.86***	-0.19*	-0.01**	0.24	0.62	2.55	1879
	(0.007)	(5.760)	(1.239)	(2.292)	(1.197)	(1.482)	(0.106)	(0.004)				
JPY	-0.05***	-14.40***	2.32	-4.68***	2.42*	-8.39***	-0.17	0.22***	0.19	0.53	17.37	1950
	(0.011)	(4.472)	(2.063)	(1.730)	(1.324)	(1.117)	(0.164)	(0.054)				
NZD	-0.03***	-7.37**	1.15	-5.71***	0.20	-7.10***	-0.24*	0.02***	0.35	0.62	9.98	1950
	(0.008)	(3.221)	(0.822)	(1.456)	(0.981)	(1.509)	(0.133)	(0.006)				
NOK	-0.03***	-3.26**	2.29**	-4.58***	1.86*	-5.44***	-0.35***	0.06***	0.39	0.57	28.15	1879
	(0.008)	(1.441)	(1.018)	(1.301)	(1.011)	(0.641)	(0.133)	(0.017)				
SEK	-0.02***	-8.60***	-0.72	-5.61***	-0.87	-5.84***	-0.09	0.04***	0.22	0.59	8.78	1950
	(0.007)	(3.182)	(0.686)	(1.121)	(0.709)	(1.096)	(0.118)	(0.015)				
CHF	-0.02***	-2.13	2.16**	-0.87	1.27	-3.06**	-0.22*	0.01*	0.23	0.44	10.05	1950
	(0.007)	(3.876)	(0.926)	(1.233)	(0.819)	(1.278)	(0.120)	(0.005)				
GBP	-0.03***	-10.59**	4.61**	-1.67	4.39***	-9.01***	-0.46***	-0.01*	0.26	0.53	6.30	1879
	(0.009)	(4.645)	(1.795)	(1.540)	(1.616)	(1.706)	(0.153)	(0.004)				
USD	-0.01*	-13.73***	-4.07***	-7.62***	-1.68*	-5.82***	0.13	-0.03*	0.17	0.56	12.60	1950
	(0.007)	(3.190)	(1.107)	(1.261)	(0.870)	(0.918)	(0.141)	(0.016)				

The table reports the OLS estimates of the coefficient of the panel fixed effect regression listed above. The 10 currencies used are Australian Dollar (AUD), Canadian Dollar (CAD), Euro (EUR), Japanese Yen (JPY), New Zealand Dollar (NZD), Norwegian Krone (NOK), Swedish Krona (SEK), Swiss Franc (CHF), British Pound (GBP) and United States Dollar (USD). Each row represents a regression estimation using the first column currency as the home currency and the other 9 currencies as foreign currency j. $s_{j,t}$ is the nominal exchange rate between home and foreign country j, defined as home currency price of foreign currency, $q_{j,t}$ is the real exchange rate. $\lambda_{j,t}^{IV}$ is a measure of the treasury liquidity, $i_{j,t}^R$ is the home minus foreign interest rates. Δ is a difference operator. The sample period is 1999M1-2018M1.

Standard errors in parentheses are standard errors adjusted for cross-sectional correlation. *, **, and *** indicate that the alternative model significantly different from zero at 10%, 5%, and 1% significance level, respectively, based on standard normal critical values for the two-sided test.

Full table of Table 3C

Full table of Table 3C

IV Estimation result of $\Delta s_{j,t} = \alpha_j + \beta_1 q_{j,t-1} + \beta_2 \Delta\lambda^{IV}_{j,t} + \beta_3 \Delta\tau_{j,t} + \beta_4 \Delta l^R_{j,t} + \beta_5 \Delta i^R_{j,t} + \beta_6 \lambda^{IV}_{j,t-1} + \beta_7 \tau_{j,t-1} + \beta_8 l^R_{j,t-1} + \beta_9 i^R_{j,t-1} + u_{j,t}$

	$q_{j,t-1}$	$\Delta\lambda^{IV}_{j,t}$	$\lambda^{IV}_{j,t-1}$	$\Delta i^R_{j,t}$	$i^R_{j,t-1}$	$\Delta\tau_{j,t}$	$\tau_{j,t-1}$	$\Delta l^R_{j,t}$	$l^R_{j,t-1}$	constant	$\Delta\lambda^{IV}_{j,t}$ 1st stage Adj R2	$\lambda^{IV}_{j,t-1}$ 1st stage Adj R2	Cragg-Donald statistic	N
AUD	-0.05***	-13.25***	-0.09	-8.40***	-0.36	-3.51**	0.31	18.37***	-0.89	0.01	0.28	0.62	8.31	919
	(0.017)	(4.333)	(2.206)	(1.141)	(0.306)	(1.700)	(1.560)	(4.094)	(2.422)	(0.009)				
CAD	-0.02	-17.81**	-2.70	-10.94***	0.63	-10.56***	-4.64**	16.45**	1.12	-0.00	0.54	0.81	1.68	363
	(0.018)	(7.807)	(3.169)	(2.113)	(0.424)	(3.629)	(2.188)	(7.328)	(3.396)	(0.007)				
EUR	-0.05***	-9.40*	-0.65	-8.86***	-0.15	-4.81***	-0.86	11.81**	2.85	-0.02***	0.50	0.66	2.30	930
	(0.012)	(4.911)	(1.618)	(1.635)	(0.186)	(1.579)	(1.275)	(5.458)	(1.879)	(0.006)				
JPY	-0.07***	-10.97**	3.07	-11.97***	-0.15	-3.22	3.79**	13.41***	-1.28	0.33***	0.42	0.70	11.07	930
	(0.018)	(4.837)	(2.450)	(1.449)	(0.363)	(1.976)	(1.671)	(5.034)	(2.822)	(0.082)				
NZD	-0.04***	-8.58***	2.84**	-8.39***	0.07	-5.49***	1.57	12.71***	-1.63	0.01	0.38	0.60	12.50	907
	(0.015)	(3.086)	(1.399)	(1.097)	(0.278)	(1.514)	(1.365)	(3.917)	(1.695)	(0.010)				
NOK	-0.05***	-4.47***	-0.33	-7.28***	-0.20	-5.81***	-0.15	3.81*	2.98*	0.09***	0.56	0.69	31.50	930
	(0.012)	(1.337)	(0.954)	(0.940)	(0.207)	(1.285)	(1.100)	(2.277)	(1.673)	(0.023)				
SEK	-0.05***	-10.37***	-0.31	-7.69***	-0.01	-3.92***	-0.78	11.74***	-0.27	0.09***	0.40	0.69	6.67	930
	(0.012)	(3.501)	(0.841)	(1.359)	(0.226)	(1.228)	(0.932)	(3.659)	(1.343)	(0.025)				
CHF	-0.03*	12.41**	-0.02	4.20**	-0.04	-4.51**	-0.01	-9.43	1.50	-0.00	0.50	0.69	7.76	852
	(0.013)	(5.755)	(1.292)	(2.142)	(0.292)	(2.217)	(1.267)	(5.949)	(1.963)	(0.007)				
GBP	-0.04***	-10.43**	1.91	-11.28***	-0.07	-0.52	3.58**	8.51**	-0.90	-0.01**	0.46	0.69	7.75	930
	(0.016)	(4.426)	(1.985)	(2.034)	(0.253)	(1.526)	(1.588)	(4.182)	(2.396)	(0.007)				
USD	-0.06***	-18.24***	-1.63	-12.37***	-0.05	-2.01	1.77	20.33***	2.26	-0.12***	0.41	0.68	8.60	777
	(0.015)	(3.416)	(1.249)	(1.229)	(0.244)	(1.376)	(1.114)	(3.427)	(1.656)	(0.031)				

The table reports the OLS estimates of the coefficient of the panel fixed effect regression listed above. The 10 currencies used are Australian Dollar (AUD), Canadian Dollar (CAD), Euro (EUR), Japanese Yen (JPY), New Zealand Dollar (NZD), Norwegian Krone (NOK), Swedish Krona (SEK), Swiss Franc (CHF), British Pound (GBP) and United States Dollar (USD). Each row represents a regression estimation using the first column currency as the home currency and the other 9 currencies as foreign currency j. $s_{j,t}$ is the nominal exchange rate between home and foreign country j, defined as home currency price of foreign currency, $q_{j,t}$ is the real exchange rate. $\lambda^{IV}_{j,t}$ is a measure of the treasury liquidity, $i^R_{j,t}$ is the home minus foreign interest rates. Δ is a difference operator. The sample period is 2008M1-2018M1.

Standard errors in parentheses are standard errors adjusted for cross-sectional correlation. *, **, and *** indicate that the alternative model significantly different from zero at 10%, 5%, and 1% significance level, respectively, based on standard normal critical values for the two-sided test.

Full table of Table 4A

Estimation result of $\Delta s_{j,t} = \alpha_j + \beta_1 q_{j,t-1} + \beta_2 \Delta\tau_{j,t} + \beta_3 \Delta\gamma_t + \beta_4 \Delta\gamma^*_{j,t} + \beta_5 \Delta i^R_{j,t} + \beta_6 \gamma_{t-1} + \beta_7 \gamma^*_{j,t-1} + \beta_8 i^R_{j,t-1} + u_{j,t}$

	$q_{j,t-1}$	$\Delta\gamma^*_{j,t}$	$\Delta\gamma_t$	$\Delta\tau_{j,t}$	$\Delta i^R_{j,t}$	$\gamma^*_{j,t-1}$	γ_{t-1}	$\tau_{j,t-1}$	$i^R_{j,t-1}$	constant	N	R2 within
AUD	-0.0272***	5.4814***	-6.7622***	-2.7406**	-5.8418***	-0.2247	0.4527	-0.1678	-0.2806**	0.0108**	2028	0.2016
	(0.0071)	(0.6856)	(1.2114)	(1.2096)	(0.5369)	(0.3710)	(0.6009)	(0.7650)	(0.1108)	(0.0046)		
CAD	-0.0285***	4.4218***	-5.9115***	-5.2253***	-6.1901***	-0.6357	0.0032	-0.1439	-0.2838**	0.0075**	1836	0.2078
	(0.0068)	(0.6851)	(1.9789)	(1.1260)	(0.5258)	(0.4004)	(1.2475)	(0.7275)	(0.1104)	(0.0035)		
EUR	-0.0191***	4.5771***	-4.9551***	-5.0824***	-5.0469***	0.0468	-0.0906	-0.3875	-0.1728*	-0.0046*	2028	0.1472
	(0.0059)	(0.5595)	(1.0948)	(0.9051)	(0.4093)	(0.3149)	(0.5339)	(0.5724)	(0.0927)	(0.0025)		
JPY	-0.0398***	4.2658***	-2.0942	-4.8186***	-6.3971***	-2.1632***	1.9088	2.0555**	-0.1397	0.1959***	2028	0.1737
	(0.0101)	(0.9865)	(5.1736)	(1.5829)	(0.7460)	(0.5728)	(2.4805)	(0.9609)	(0.1342)	(0.0473)		
NZD	-0.0317***	6.1084***	-6.7754***	-5.5521***	-6.2849***	0.9282*	0.2146	-0.7658	-0.1587	0.0109*	2028	0.2082
	(0.0076)	(0.8609)	(0.8970)	(1.2860)	(0.6118)	(0.5158)	(0.4289)	(0.7728)	(0.1261)	(0.0062)		
NOK	-0.0171**	5.5907***	-3.3078***	-5.0194***	-5.0964***	-0.2142	0.6633	0.6195	-0.1656*	0.0338**	2028	0.1640
	(0.0067)	(0.7336)	(0.7600)	(1.0395)	(0.4911)	(0.4142)	(0.4849)	(0.6848)	(0.0988)	(0.0141)		
SEK	-0.0214***	4.7890***	-4.0441***	-5.0347***	-4.6315***	0.5089	-0.0434	-0.7194	-0.1318	0.0407***	2028	0.1342
	(0.0063)	(0.6331)	(1.2212)	(0.9868)	(0.4665)	(0.3814)	(0.4909)	(0.6404)	(0.1028)	(0.0135)		
CHF	-0.0157**	3.0852***	-2.7329	-1.2225	-3.0622***	-0.5456	1.5494	0.5750	-0.1902*	0.0012	2028	0.0562
	(0.0071)	(0.7469)	(1.8882)	(1.1921)	(0.5525)	(0.4340)	(1.1054)	(0.7591)	(0.1073)	(0.0035)		
GBP	-0.0211***	4.7472***	-3.6829***	-1.1670	-5.4951***	-0.6923*	0.8916	0.6820	-0.3330***	-0.0079**	2028	0.1385
	(0.0070)	(0.7047)	(1.0823)	(1.1121)	(0.5266)	(0.4049)	(0.5855)	(0.6975)	(0.1069)	(0.0037)		
USD	-0.0129*	6.2173***	-5.8436***	-6.4704***	-5.0417***	0.0764	-1.9569***	0.0655	-0.0249	-0.0187	2028	0.1875
	(0.0069)	(0.8044)	(1.3712)	(1.2023)	(0.5772)	(0.4537)	(0.5732)	(0.7334)	(0.1111)	(0.0146)		

The table reports the OLS estimates of the coefficient of the panel fixed effect regression listed above. The 10 currencies used are Australian Dollar (AUD), Canadian Dollar (CAD), Euro (EUR), Japanese Yen (JPY), New Zealand Dollar (NZD), Norwegian Krone (NOK), Swedish Krona (SEK), Swiss Franc (CHF), British Pound (GBP) and United States Dollar (USD). Each row represents a regression estimation using the first column currency as the home currency and the other 9 currencies as foreign currency j. $s_{j,t}$ is the nominal exchange rate between home and foreign country j, defined as home currency price of foreign currency, $q_{j,t}$ is the real exchange rate. $\tau_{j,t}$ is a measure of currency derivative friction, $\gamma^*_{j,t}$ is a measure of foreign treasury liquidity, $\gamma_{j,t}$ is a measure of the home treasury liquidity, $i^R_{j,t}$ is the home minus foreign interest rates. Δ is a difference operator. The sample period is 1999M1-2018M1.

Standard errors in parentheses are standard errors adjusted for cross-sectional correlation. *, **, and *** indicate that the alternative model significantly different from zero at 10%, 5%, and 1% significance level, respectively, based on standard normal critical values for the two-sided test.

5. Regression tables of country by country regressions (full sample and post-2008)

$$\Delta s_t = \alpha + \beta_1 q_{t-1} + \beta_2 \Delta\tilde{\eta}_t + \beta_3 \Delta i_t^R + \beta_4 \tilde{\eta}_{t-1} + \beta_5 i_{t-1}^R + u_t$$

The first country is foreign country and the second country is home country

Full sample regressions

	q_{t-1}	$\Delta\tilde{\eta}_t$	Δi_t^R	$\tilde{\eta}_{t-1}$	i_{t-1}^R	constant	N	R2_adjusted
AUDCAD	-0.0674***	-5.1977***	-4.9839***	0.4442	-0.2702*	0.0060*	228	0.2304
	(0.0238)	(1.2719)	(0.6967)	(0.9489)	(0.1546)	(0.0035)		
AUDEUR	-0.0368*	-6.4516***	-5.1513***	-1.2369	-0.3213	0.0261**	228	0.1682
	(0.0200)	(1.3697)	(0.8765)	(1.0437)	(0.2176)	(0.0112)		
AUDJPY	-0.1160***	-5.2592***	-9.2078***	3.0900***	-0.3998*	-0.5208***	228	0.3342
	(0.0245)	(1.5062)	(1.0226)	(1.0712)	(0.2296)	(0.1046)		
AUDNZD	-0.0249	-6.7055***	-6.1856***	-0.0832	-0.1128	-0.0041	228	0.3011
	(0.0171)	(0.8065)	(0.6610)	(0.4691)	(0.1944)	(0.0033)		
AUDNOK	-0.0252	-3.6025***	-5.1689***	-0.0226	-0.1652	-0.0413	228	0.1637
	(0.0193)	(1.1561)	(0.7851)	(0.7725)	(0.1461)	(0.0325)		
AUDSEK	-0.0818***	-3.6198***	-3.8200***	0.6062	-0.2086	-0.1458***	228	0.1219
	(0.0286)	(1.2070)	(0.8353)	(0.8106)	(0.1886)	(0.0517)		
AUDCHF	-0.0182	-2.5989**	-3.7065***	1.0778	-0.3547	0.0074	228	0.0726
	(0.0116)	(1.1996)	(0.9659)	(0.7426)	(0.2637)	(0.0098)		
AUDGBP	-0.0442***	-5.5490***	-6.3352***	-0.6464	-0.7150***	0.0419***	228	0.1711
	(0.0168)	(1.4200)	(0.9958)	(1.3513)	(0.2557)	(0.0155)		
AUDUSD	-0.0252*	-9.9847***	-5.8320***	-2.7425**	-0.0893	0.0085	228	0.2408
	(0.0135)	(1.6060)	(0.9048)	(1.3378)	(0.2039)	(0.0064)		
CADEUR	-0.0554**	-4.7185**	-5.4935***	-1.4692	-0.2847	0.0227**	228	0.1816
	(0.0243)	(2.0046)	(0.9231)	(1.6883)	(0.2189)	(0.0096)		
CADJPY	-0.0884***	-1.8407	-7.4392***	4.6344***	-0.1505	-0.4081***	228	0.2255
	(0.0238)	(1.7781)	(1.1304)	(1.5441)	(0.1903)	(0.1078)		
CADNZD	-0.0333*	-6.6695***	-6.5682***	0.5065	-0.2106	-0.0089	228	0.2620
	(0.0175)	(0.9707)	(0.8387)	(0.6097)	(0.1956)	(0.0056)		
CADNOK	-0.0432**	-2.1132	-4.9494***	1.5138*	-0.4172**	-0.0775**	228	0.1703
	(0.0194)	(1.3576)	(0.7859)	(0.8993)	(0.1633)	(0.0337)		

CADSEK	-0.0610**	-5.3958***	-4.5688***	-0.0125	-0.2260	-0.1127**	228	0.1655
	(0.0281)	(1.3538)	(0.9582)	(0.9541)	(0.1955)	(0.0520)		
CADCHF	-0.0180	-2.9179*	-4.2925***	1.1647	-0.4738*	0.0051	228	0.0803
	(0.0142)	(1.5198)	(1.1389)	(1.1590)	(0.2860)	(0.0064)		
CADGBP	-0.0397**	-2.2840*	-4.9910***	0.7890	-0.5634	0.0255**	228	0.1180
	(0.0171)	(1.3243)	(0.8928)	(1.2594)	(0.3653)	(0.0113)		
CADUSD	-0.0188**	-7.2535***	-5.7732***	-2.0422***	0.3217	-0.0028	228	0.1652
	(0.0095)	(1.5955)	(1.0768)	(0.7669)	(0.2592)	(0.0032)		
EURJPY	-0.0679***	-1.4288	-5.3472***	8.3397***	0.2322	-0.3514***	228	0.1715
	(0.0181)	(2.3679)	(1.2447)	(2.0207)	(0.1826)	(0.0888)		
EURNZD	-0.0553***	-6.5903***	-5.9472***	-0.0517	-0.0476	-0.0322**	228	0.2048
	(0.0202)	(1.0196)	(0.9165)	(0.5902)	(0.2632)	(0.0156)		
EURNOK	-0.0121	-3.2592***	-5.3253***	0.2405	-0.1437	-0.0271	228	0.2005
	(0.0142)	(0.8626)	(0.7220)	(0.6360)	(0.1751)	(0.0302)		
EURSEK	-0.0413**	-4.8647***	-3.2700***	-1.0986*	-0.2233	-0.0939**	228	0.1664
	(0.0197)	(0.9449)	(0.6662)	(0.5785)	(0.2234)	(0.0439)		
EURGBP	-0.0167	-2.9368**	-6.6960***	0.8921	-0.4995**	0.0019	228	0.2008
	(0.0119)	(1.3973)	(0.8990)	(1.0902)	(0.2445)	(0.0036)		
EURUSD	-0.0118	-6.9337***	-5.6550***	-3.0634***	-0.0151	-0.0109***	228	0.1955
	(0.0102)	(1.4722)	(0.9898)	(0.9267)	(0.1598)	(0.0037)		
JPYNZD	-0.0728***	-8.0616***	-8.0591***	-0.0026	-0.1162	0.3111***	228	0.2104
	(0.0231)	(1.3456)	(1.2117)	(0.9449)	(0.1938)	(0.0930)		
JPYNOK	-0.0549***	-4.1603***	-6.1797***	2.8019***	-0.2494*	0.1543***	228	0.1785
	(0.0171)	(1.2717)	(1.1279)	(0.9330)	(0.1461)	(0.0468)		
JPYSEK	-0.0798***	-3.7436*	-7.6177***	2.8282**	-0.0307	0.2214***	228	0.1768
	(0.0209)	(2.0226)	(1.2391)	(1.1132)	(0.1637)	(0.0566)		
JPYUSD	-0.0283**	-1.2824	-4.1577***	1.5302**	-0.2779*	0.1359**	228	0.0986
	(0.0124)	(1.1764)	(0.9553)	(0.7623)	(0.1477)	(0.0580)		
NZDSEK	-0.0917***	-5.0676***	-5.3837***	-0.2202	-0.0685	-0.1503***	228	0.2019
	(0.0260)	(0.8964)	(0.8259)	(0.5114)	(0.2047)	(0.0414)		
NZDUSD	-0.0146	-8.6432***	-6.3106***	-0.7943	-0.1607	0.0095	228	0.2207
	(0.0129)	(1.1345)	(1.0909)	(0.7669)	(0.2005)	(0.0082)		

NOKNZD	-0.0243	-5.7511***	-6.2049***	0.4553	-0.1695	0.0369	228	0.2056
	(0.0159)	(1.0825)	(0.8605)	(0.8251)	(0.1980)	(0.0239)		
NOKSEK	-0.0053	-3.4732***	-4.2796***	-0.2574	-0.2272	0.0017	228	0.1393
	(0.0139)	(0.7597)	(0.7201)	(0.5326)	(0.1953)	(0.0029)		
NOKUSD	-0.0130	-8.5785***	-4.1838***	-0.7852	-0.0085	0.0233	228	0.2086
	(0.0103)	(1.2337)	(0.8558)	(0.7067)	(0.1315)	(0.0200)		
SEKUSD	-0.0313***	-7.6365***	-4.5536***	-3.4799***	0.1946	0.0590**	228	0.2333
	(0.0122)	(1.1943)	(0.9418)	(0.7708)	(0.1486)	(0.0246)		
CHFEUR	-0.0292***	1.7140	0.2499	2.1966**	-0.2625	0.0111**	228	0.0276
	(0.0106)	(1.1573)	(0.8086)	(0.9039)	(0.3270)	(0.0050)		
CHFJPY	-0.0369**	-7.2543***	-0.2721	-0.1446	0.3794	-0.1730**	228	0.0593
	(0.0182)	(2.1122)	(1.3765)	(1.9150)	(0.2803)	(0.0846)		
CHFNZD	-0.0314*	-2.8115***	-3.0886***	0.7583	-0.1848	-0.0099	228	0.0458
	(0.0172)	(1.0188)	(1.0260)	(0.6085)	(0.2728)	(0.0130)		
CHFNOK	-0.0098	-1.1624	-2.6851***	0.8401	-0.1825	-0.0202	228	0.0302
	(0.0097)	(0.9128)	(0.8734)	(0.6177)	(0.2065)	(0.0195)		
CHFSEK	-0.0127	-2.0541*	-1.4801	0.0020	-0.2275	-0.0283	228	0.0027
	(0.0117)	(1.2289)	(0.9061)	(0.5572)	(0.2540)	(0.0231)		
CHFGBP	-0.0257**	1.6141	-3.1949***	1.6639*	-0.5666**	0.0117	228	0.0859
	(0.0100)	(1.3582)	(1.0628)	(0.9342)	(0.2581)	(0.0077)		
CHFUSD	-0.0029	-5.2363***	-2.8313***	-1.0467	-0.2540	-0.0095**	228	0.0938
	(0.0076)	(1.1068)	(1.0503)	(0.6928)	(0.1849)	(0.0048)		
GBPJPY	-0.0551***	-1.7169	-6.1662***	4.7555***	-0.4196*	-0.2940***	228	0.1631
	(0.0192)	(1.8059)	(1.1681)	(1.3580)	(0.2437)	(0.0955)		
GBPNZD	-0.0188	-7.7192***	-7.3608***	0.3127	-0.5196*	-0.0239*	228	0.1977
	(0.0123)	(1.1931)	(1.0396)	(0.7078)	(0.2877)	(0.0145)		
GBPNOK	-0.0310**	-3.0595***	-4.1840***	1.3742*	-0.3652**	-0.0770**	228	0.1267
	(0.0132)	(0.9710)	(0.8283)	(0.7310)	(0.1662)	(0.0323)		
GBPSEK	-0.0180	-2.5245**	-4.8259***	0.5421	-0.3664*	-0.0431	228	0.0876
	(0.0127)	(1.1666)	(1.0023)	(0.8697)	(0.2091)	(0.0315)		
GBPUSD	-0.0299**	-3.1475***	-3.5440***	-2.5393***	0.0395	-0.0159**	228	0.1121
	(0.0137)	(1.0500)	(0.8787)	(0.8441)	(0.1854)	(0.0065)		

Post 2008 regressions

	q_{t-1}	$\Delta\tilde{\eta}_t$	Δi_t^R	$\tilde{\eta}_{t-1}$	i_{t-1}^R	constant	N	R2_adjusted
AUDCAD	-0.0855**	-6.4235***	-6.2099***	0.2782	-0.1615	0.0030	120	0.3193
	(0.0404)	(1.9104)	(0.9486)	(1.4404)	(0.2800)	(0.0051)		
AUDEUR	-0.0589**	-6.3257***	-5.6310***	-1.1293	-1.1834***	0.0582***	120	0.2632
	(0.0260)	(1.7232)	(1.0688)	(1.1520)	(0.4251)	(0.0197)		
AUDJPY	-0.1236***	-7.3666***	-11.8359***	2.1110	-0.5612	-0.5446***	120	0.4868
	(0.0361)	(2.0447)	(1.3431)	(1.8356)	(0.3507)	(0.1557)		
AUDNZD	-0.0431	-7.3726***	-6.7146***	-0.0737	-0.4074	-0.0053	120	0.3825
	(0.0281)	(1.0914)	(0.8830)	(0.8790)	(0.3042)	(0.0044)		
AUDNOK	-0.0479	-3.2616**	-5.9159***	-0.0203	-0.3932	-0.0797	120	0.1995
	(0.0307)	(1.4731)	(1.0822)	(1.0849)	(0.4133)	(0.0536)		
AUDSEK	-0.0949**	-3.8477**	-4.5070***	1.4597	-0.7684**	-0.1581**	120	0.1769
	(0.0374)	(1.5100)	(1.0704)	(0.9548)	(0.3756)	(0.0661)		
AUDCHF	-0.0340	-3.1074**	-4.7070***	0.9027	-0.7972	0.0258	120	0.1131
	(0.0233)	(1.5233)	(1.3802)	(1.3104)	(0.5483)	(0.0225)		
AUDGBP	-0.0550**	-4.2889**	-7.8210***	-0.1258	-0.7163*	0.0458**	120	0.2421
	(0.0270)	(1.9330)	(1.3603)	(1.8885)	(0.3894)	(0.0215)		
AUDUSD	-0.0582*	-11.8603***	-9.0333***	-2.4785	-0.2666	0.0150	120	0.4067
	(0.0306)	(2.4188)	(1.3422)	(1.7510)	(0.3408)	(0.0126)		
CADEUR	-0.0617*	-7.5273***	-7.3512***	-4.9137***	0.2804	0.0269*	120	0.3675
	(0.0345)	(2.1995)	(1.0826)	(1.9003)	(0.2832)	(0.0139)		
CADJPY	-0.0965***	-2.5057	-14.3361***	4.1998**	-0.4204	-0.4397***	120	0.3835
	(0.0359)	(2.0276)	(2.0929)	(1.8563)	(0.7761)	(0.1588)		
CADNZD	-0.0645**	-7.7645***	-6.9932***	0.1637	0.4252	0.0010	120	0.4127
	(0.0263)	(1.4393)	(1.1445)	(1.0129)	(0.3567)	(0.0065)		
CADNOK	-0.1158***	-3.1091**	-6.9945***	0.8923	-0.7379*	-0.2086***	120	0.2609
	(0.0442)	(1.5634)	(1.1005)	(1.1486)	(0.4233)	(0.0803)		
CADSEK	-0.0758*	-7.4166***	-6.3493***	0.1045	0.2299	-0.1400*	120	0.2877
	(0.0407)	(1.5027)	(1.2323)	(1.0254)	(0.2826)	(0.0752)		
CADCHF	-0.0778***	-4.4524**	-5.8910***	-0.0593	2.6786**	-0.0061	120	0.1932

	(0.0293)	(1.7865)	(1.8629)	(1.4386)	(1.1063)	(0.0087)		
CADGBP	-0.0899**	-2.4709	-5.8980***	0.0522	-0.6337	0.0503**	120	0.1485
	(0.0393)	(1.6590)	(1.3717)	(1.7186)	(0.6110)	(0.0227)		
CADUSD	-0.0382	-9.0991***	-13.6492***	-1.2651	-0.0326	0.0023	120	0.3985
	(0.0371)	(1.8750)	(1.8205)	(0.9476)	(0.9531)	(0.0091)		
EURJPY	-0.0698**	-6.3237**	-11.1725***	4.0414	-0.1078	-0.3486**	120	0.3186
	(0.0288)	(2.8254)	(1.8895)	(2.5226)	(0.3923)	(0.1395)		
EURNZD	-0.0433*	-6.4686***	-7.3175***	0.1479	0.0414	-0.0203	120	0.2813
	(0.0226)	(1.4511)	(1.3045)	(0.9342)	(0.5434)	(0.0222)		
EURNOK	-0.0148	-3.9931***	-8.4577***	0.5119	-0.1793	-0.0349	120	0.3062
	(0.0218)	(1.1211)	(1.2485)	(0.9143)	(0.9532)	(0.0553)		
EURSEK	-0.0368	-6.7133***	-5.9829***	-0.8495	-0.2773	-0.0843	120	0.3352
	(0.0302)	(1.1542)	(0.9398)	(0.7199)	(0.5015)	(0.0679)		
EURGBP	-0.0773*	-5.1340**	-9.6338***	-1.7363	-0.3035	0.0072	120	0.3169
	(0.0433)	(2.0691)	(1.4275)	(2.0862)	(0.5338)	(0.0060)		
EURUSD	-0.0743	-5.6210***	-10.2522***	-1.1514	-0.2247	-0.0244	120	0.3821
	(0.0461)	(1.8650)	(1.5379)	(1.5833)	(0.4732)	(0.0151)		
JPYNZD	-0.1011***	-9.3097***	-14.2991***	-0.0275	-0.1974	0.4302***	120	0.3973
	(0.0316)	(1.7516)	(2.1181)	(1.4227)	(0.4194)	(0.1282)		
JPYNOK	-0.1143***	-5.2508***	-12.7072***	3.8050***	-0.8701*	0.3071***	120	0.3916
	(0.0341)	(1.3733)	(1.7281)	(1.2054)	(0.5042)	(0.0860)		
JPYSEK	-0.1131***	-3.7223	-11.1959***	3.3314**	-0.3100	0.3079***	120	0.2742
	(0.0354)	(2.6713)	(1.9155)	(1.6972)	(0.3929)	(0.0953)		
JPYUSD	-0.0231	-3.0391**	-11.0678***	0.5434	0.4707	0.1098	120	0.2026
	(0.0209)	(1.4804)	(2.2242)	(1.2352)	(0.6002)	(0.0939)		
NZDSEK	-0.0953***	-5.7602***	-6.3097***	0.4668	-0.3328	-0.1542***	120	0.2944
	(0.0338)	(1.1911)	(1.1803)	(0.7337)	(0.3740)	(0.0553)		
NZDUSD	-0.1669***	-11.3702***	-10.7088***	-3.4592**	0.3404	0.0381**	120	0.4358
	(0.0391)	(1.6871)	(1.7379)	(1.4547)	(0.3041)	(0.0150)		
NOKNZD	-0.0323	-6.6913***	-8.5086***	0.8029	-0.5474	0.0492*	120	0.3234
	(0.0199)	(1.4720)	(1.3262)	(1.3022)	(0.6471)	(0.0285)		
NOKSEK	-0.0248	-3.7390***	-6.3523***	0.8128	-0.0332	-0.0001	120	0.1455

	(0.0203)	(1.0424)	(1.3454)	(0.7462)	(0.4024)	(0.0050)		
NOKUSD	-0.0251	-10.9204***	-12.3308***	0.7353	0.0318	0.0465	120	0.4697
	(0.0332)	(1.3766)	(1.4648)	(1.0388)	(0.5756)	(0.0676)		
SEKUSD	-0.1147***	-9.3184***	-9.7011***	-2.5207**	-0.2633	0.2221***	120	0.4491
	(0.0423)	(1.3431)	(1.5183)	(0.9810)	(0.3408)	(0.0831)		
CHFEUR	-0.0330**	1.5830	0.7669	2.4355*	0.0117	0.0129*	120	0.0121
	(0.0164)	(1.7645)	(1.3927)	(1.4287)	(0.5895)	(0.0075)		
CHFJPY	-0.0384	-8.6597***	-2.5390	-0.4711	0.7347	-0.1805	120	0.0916
	(0.0251)	(2.9666)	(2.5015)	(3.1030)	(0.6081)	(0.1183)		
CHFNZD	-0.0694**	-2.5187*	-3.1960*	0.7673	0.6308	-0.0028	120	0.1126
	(0.0330)	(1.3175)	(1.7418)	(0.9610)	(0.5549)	(0.0244)		
CHFNOK	-0.0111	-1.7563	-4.7434***	0.3976	0.2802	-0.0189	120	0.0521
	(0.0179)	(1.2235)	(1.7035)	(0.9765)	(0.9060)	(0.0469)		
CHFSEK	-0.0255	-4.1005**	-2.2072	-1.0538	0.4236	-0.0588	120	0.0521
	(0.0238)	(1.7582)	(1.4665)	(0.8594)	(0.6446)	(0.0507)		
CHFGBP	-0.0312*	2.9053	-4.3979**	1.5692	-0.1327	0.0154	120	0.1105
	(0.0170)	(2.0488)	(1.9337)	(1.4981)	(0.5813)	(0.0118)		
CHFUSD	-0.0692**	-5.6639***	-2.3016	-1.7140	0.5264	-0.0168*	120	0.1488
	(0.0287)	(1.4035)	(2.1029)	(1.1428)	(0.4186)	(0.0087)		
GBPJPY	-0.0694**	-3.4898	-10.6606***	4.7323**	-0.7556	-0.3632**	120	0.2721
	(0.0289)	(2.5125)	(1.8751)	(2.2340)	(0.5665)	(0.1435)		
GBPNZD	-0.0573**	-8.4851***	-10.0156***	1.2284	0.7641	-0.0181	120	0.3266
	(0.0234)	(1.8882)	(1.5111)	(1.3280)	(0.6526)	(0.0202)		
GBPNOK	-0.1160***	-4.1037***	-6.3600***	-0.5632	-2.1592**	-0.2873***	120	0.1552
	(0.0414)	(1.4124)	(1.6223)	(1.3983)	(0.9107)	(0.1020)		
GBPSEK	-0.0686**	-2.9876*	-5.9169***	-0.1121	-0.1582	-0.1628**	120	0.1168
	(0.0347)	(1.6026)	(1.6839)	(1.2211)	(0.4100)	(0.0829)		
GBPUSD	-0.1976***	-3.8274***	-5.3212***	-5.6947***	-1.9616**	-0.0826***	120	0.2118
	(0.0646)	(1.4690)	(1.8988)	(2.0484)	(0.9306)	(0.0265)		

Standard errors in parentheses are simple OLS standard error. *, **, and *** indicate that the alternative model significantly different from zero at 10%, 5%, and 1% significance level, respectively, based on standard normal critical values for the two-sided test.

6. Robustness: Baseline result (Table 1A) with simple average of foreign country variables

Estimation result of $\Delta\bar{s}_{j,t} = \alpha_j + \beta_1\bar{q}_{j,t-1} + \beta_2(\Delta\bar{\eta}_{j,t}) + \beta_3(\Delta\bar{i}^R_{j,t}) + \beta_4(\bar{\eta}_{j,t-1}) + \beta_5(\bar{i}^R_{j,t-1}) + u_{j,t}$

	$\bar{q}_{j,t-1}$	$\Delta\bar{\eta}_{j,t}$	$\Delta\bar{i}^R_{j,t}$	$\bar{\eta}_{j,t-1}$	$\bar{i}^R_{j,t-1}$	constant	N	R2_within
AUD	-0.0614***	-6.0687***	-6.1722***	-0.1867	-0.4425**	-0.0365**	228	0.2469
	(0.0236)	(1.3435)	(0.8179)	(1.0228)	(0.2129)	(0.0157)		
CAD	-0.0543**	-3.9156**	-5.6876***	1.3545	-0.3353	-0.0419**	228	0.2191
	(0.0249)	(1.6968)	(0.9024)	(1.1010)	(0.2197)	(0.0193)		
EUR	-0.0336*	-4.9391***	-4.9768***	-2.2041*	-0.4549*	-0.0454**	228	0.1651
	(0.0173)	(1.5917)	(0.8307)	(1.1837)	(0.2532)	(0.0214)		
JPY	-0.0710***	-2.7778	-7.5821***	6.1937***	-0.0513	0.3204***	228	0.2401
	(0.0186)	(1.8555)	(1.3114)	(1.4237)	(0.1703)	(0.0777)		
NZD	-0.0542***	-7.4661***	-6.8127***	-0.3037	-0.0143	-0.0297***	228	0.2530
	(0.0206)	(1.0041)	(0.9543)	(0.6242)	(0.2301)	(0.0110)		
NOK	-0.0197	-3.4964***	-4.7118***	0.8816	-0.2086	0.0245	228	0.1728
	(0.0133)	(0.9300)	(0.7642)	(0.6754)	(0.1388)	(0.0157)		
SEK	-0.0744***	-3.8231***	-3.6216***	-0.9291*	0.0694	0.0959***	228	0.1489
	(0.0257)	(1.0630)	(0.8572)	(0.5328)	(0.1746)	(0.0329)		
CHF	-0.0138	-0.4446	0.0071	0.7538	-0.3945	-0.0163	228	0.0204
	(0.0089)	(1.1473)	(1.0584)	(0.8195)	(0.3437)	(0.0113)		
GBP	-0.0461***	-1.6355	-5.1666***	1.7416	-0.8758***	-0.0688***	228	0.1423
	(0.0160)	(1.3084)	(1.0045)	(1.0702)	(0.3078)	(0.0238)		
USD	-0.0130	-8.4175***	-3.9179***	-2.6690***	0.0359	-0.0072	228	0.2299
	(0.0089)	(1.2562)	(0.9780)	(0.7743)	(0.1498)	(0.0091)		

The table reports the OLS estimates of the coefficient of the regression listed above. The 10 currencies used are Australian Dollar (AUD), Canadian Dollar (CAD), Euro (EUR), Japanese Yen (JPY), New Zealand Dollar (NZD), Norwegian Krone (NOK), Swedish Krona (SEK), Swiss Franc (CHF), British Pound (GBP) and United States Dollar (USD). Each row represents a regression estimation using the first column currency as the home currency and the other 9 currencies as foreign currency j. $s_{j,t}$ is the nominal exchange rate between home and foreign country j, defined as home currency price of foreign currency, $q_{j,t}$ is the real exchange rate. $\eta_{j,t}$ is a measure of the treasury liquidity, $i^R_{j,t}$ is the home minus foreign interest rates. Δ is a difference operator. The sample period is 1999M1-2018M1.

Standard errors in parentheses are simple OLS standard errors. *, **, and *** indicate that the alternative model significantly different from zero at 10%, 5%, and 1% significance level, respectively, based on standard normal critical values for the two-side test

7. Robustness: Baseline result (Table 1A) in quarterly frequency and quarterly change of variables

Robustness of table 1A – full table of table 1A

Estimation result of $\Delta s_{j,t} = \alpha_j + \beta_1 q_{j,t-1} + \beta_2(\Delta\tilde{\eta}_{j,t}) + \beta_3(\Delta i^R_{j,t}) + \beta_4(\tilde{\eta}_{j,t-1}) + \beta_5(i^R_{j,t-1}) + u_{j,t}$

	$q_{j,t-1}$	$\Delta\tilde{\eta}_{j,t}$	$\Delta i^R_{j,t}$	$\tilde{\eta}_{j,t-1}$	$i^R_{j,t-1}$	constant	N	R2_within
AUD	-0.0921***	-3.6750**	-5.4546***	1.9039	-0.9960***	0.0409***	675	0.2379
	(0.0210)	(1.4998)	(0.8259)	(1.3393)	(0.3109)	(0.0119)		
CAD	-0.0839***	-4.8972***	-5.1905***	2.8934***	-0.9549***	0.0255***	675	0.2541
	(0.0173)	(1.2404)	(0.7038)	(1.1110)	(0.2770)	(0.0072)		
EUR	-0.0669***	-5.2973***	-5.0077***	1.0649	-0.7177***	-0.0106	675	0.2147
	(0.0176)	(1.0584)	(0.6500)	(0.9884)	(0.2736)	(0.0065)		
JPY	-0.1212***	-0.9803	-5.4163***	6.7560***	-0.4215	0.5973***	675	0.2675
	(0.0298)	(1.9772)	(1.0659)	(1.7511)	(0.3545)	(0.1397)		
NZD	-0.0823***	-5.1755***	-4.8781***	1.8512	-0.6467*	0.0437***	675	0.2165
	(0.0237)	(1.4958)	(0.9104)	(1.2685)	(0.3502)	(0.0169)		
NOK	-0.0614***	-3.7301***	-4.5606***	3.4978***	-0.6833***	0.1331***	675	0.2530
	(0.0187)	(1.1997)	(0.6912)	(1.1292)	(0.2614)	(0.0385)		
SEK	-0.0690***	-4.9423***	-4.1352***	-0.1468	-0.4995*	0.1417***	675	0.1749
	(0.0181)	(1.1676)	(0.7171)	(1.0509)	(0.2855)	(0.0381)		
CHF	-0.0489***	-3.5282**	-3.1226***	3.4211***	-0.7530***	0.0129	675	0.1479
	(0.0173)	(1.3768)	(0.7827)	(1.2062)	(0.2785)	(0.0090)		
GBP	-0.0669***	-1.7355	-5.9619***	3.2529***	-1.0102***	-0.0207**	675	0.2305
	(0.0183)	(1.2479)	(0.7239)	(1.1803)	(0.2798)	(0.0091)		
USD	-0.0364*	-7.5254***	-4.0988***	-3.5052***	-0.3311	-0.0689*	675	0.2170
	(0.0198)	(1.4844)	(0.8492)	(1.3283)	(0.3093)	(0.0416)		

The table reports the OLS estimates of the coefficient of the panel fixed effect regression listed above. The 10 currencies used are Australian Dollar (AUD), Canadian Dollar (CAD), Euro (EUR), Japanese Yen (JPY), New Zealand Dollar (NZD), Norwegian Krone (NOK), Swedish Krona (SEK), Swiss Franc (CHF), British Pound (GBP) and United States Dollar (USD). Each row represents a regression estimation using the first column currency as the home currency and the other 9 currencies as foreign currency j. $s_{j,t}$ is the nominal exchange rate between home and foreign country j, defined as home currency price of foreign currency, $q_{j,t}$ is the real exchange rate. $\tilde{\eta}_{j,t}$ is a measure of the treasury liquidity, $i^R_{j,t}$ is the home minus foreign interest rates. Δ is a difference operator. The sample period is 1999Q1-2017Q4.

Standard errors in parentheses are standard errors adjusted for cross-sectional correlation. *, **, and *** indicate that the alternative model significantly different from zero at 10%, 5%, and 1% significance level, respectively, based on standard normal critical values for the two-sided test.

8. Robustness: Baseline result (Table 1A) with year 2000-2001, 2007-2013 excluded

Estimation result of $\Delta s_{j,t} = \alpha_j + \beta_1 q_{j,t-1} + \beta_2(\Delta\tilde{\eta}_{j,t}) + \beta_3(\Delta i^R_{j,t}) + \beta_4(\tilde{\eta}_{j,t-1}) + \beta_5(i^R_{j,t-1}) + u_{j,t}$

	$q_{j,t-1}$	$\Delta\tilde{\eta}_{j,t}$	$\Delta i^R_{j,t}$	$\tilde{\eta}_{j,t-1}$	$i^R_{j,t-1}$	constant	N	R2_within
AUD	-0.0213***	-5.0093***	-5.0754***	0.1502	-0.1602	0.0041	1170	0.1341
	(0.0082)	(1.0554)	(0.7315)	(0.5824)	(0.1252)	(0.0044)		
CAD	-0.0328***	-4.8710***	-4.8821***	0.3258	-0.4009***	0.0073**	1170	0.1395
	(0.0075)	(0.9787)	(0.7029)	(0.5707)	(0.1163)	(0.0032)		
EUR	-0.0225***	-4.7918***	-3.8285***	-0.4899	-0.2358**	-0.0090***	1170	0.0758
	(0.0069)	(0.8575)	(0.5966)	(0.4583)	(0.1096)	(0.0024)		
JPY	-0.0472***	-2.3421*	-3.4197***	2.2679***	-0.1051	0.2312***	1170	0.0722
	(0.0115)	(1.4019)	(1.0239)	(0.7011)	(0.1401)	(0.0548)		
NZD	-0.0278***	-5.9969***	-4.7987***	-0.6220	-0.1183	0.0104	1170	0.1143
	(0.0100)	(1.1803)	(0.9412)	(0.6838)	(0.1530)	(0.0067)		
NOK	-0.0163*	-4.8726***	-4.9077***	0.6076	-0.2862**	0.0304	1170	0.1296
	(0.0089)	(1.0912)	(0.7615)	(0.5974)	(0.1269)	(0.0186)		
SEK	-0.0258***	-4.3226***	-4.2231***	-0.7681	-0.1964	0.0477***	1170	0.0893
	(0.0076)	(0.9918)	(0.7086)	(0.5479)	(0.1253)	(0.0160)		
CHF	-0.0064	-1.8559*	-0.7679	0.2396	-0.1948*	-0.0026	1170	0.0139
	(0.0075)	(1.0853)	(0.7671)	(0.5765)	(0.1115)	(0.0038)		
GBP	-0.0184**	-5.0543***	-4.2766***	0.3514	-0.2763**	-0.0091**	1170	0.0884
	(0.0081)	(1.0838)	(0.7647)	(0.6008)	(0.1208)	(0.0038)		
USD	-0.0247***	-5.8187***	-4.7231***	-0.6957	-0.1320	-0.0454**	1170	0.1253
	(0.0083)	(1.1141)	(0.8008)	(0.5801)	(0.1168)	(0.0177)		

The table reports the OLS estimates of the coefficient of the panel fixed effect regression listed above. The 10 currencies used are Australian Dollar (AUD), Canadian Dollar (CAD), Euro (EUR), Japanese Yen (JPY), New Zealand Dollar (NZD), Norwegian Krone (NOK), Swedish Krona (SEK), Swiss Franc (CHF), British Pound (GBP) and United States Dollar (USD). Each row represents a regression estimation using the first column currency as the home currency and the other 9 currencies as foreign currency j. $s_{j,t}$ is the nominal exchange rate between home and foreign country j, defined as home currency price of foreign currency, $q_{j,t}$ is the real exchange rate. $\tilde{\eta}_{j,t}$ is a measure of the treasury liquidity, $i^R_{j,t}$ is the home minus foreign interest rates. Δ is a difference operator. The sample period is 1999M1-1999M12, 2002M1-2006M12, 2014M1-2018M1.

Standard errors in parentheses are standard errors adjusted for cross-sectional correlation. *, **, and *** indicate that the alternative model significantly different from zero at 10%, 5%, and 1% significance level, respectively, based on standard normal critical values for the two-sided test.

9. Robustness: Regressions tables in the main text with extreme outliner of CHF at 2015M1 excluded

Robustness of table 1A – full table of table 1A, extreme outliner of CHF at 2015M1 excluded

Estimation result of $\Delta s_{j,t} = \alpha_j + \beta_1 q_{j,t-1} + \beta_2(\Delta\tilde{\eta}_{j,t}) + \beta_3(\Delta i^R_{j,t}) + \beta_4(\tilde{\eta}_{j,t-1}) + \beta_5(i^R_{j,t-1}) + u_{j,t}$

	$q_{j,t-1}$	$\Delta\tilde{\eta}_{j,t}$	$\Delta i^R_{j,t}$	$\tilde{\eta}_{j,t-1}$	$i^R_{j,t-1}$	constant	N	R2_within
AUD	-0.0292***	-5.3880***	-5.8176***	0.2180	-0.2725***	0.0119***	2051	0.1955
	(0.0071)	(0.7154)	(0.5350)	(0.4276)	(0.1045)	(0.0040)		
CAD	-0.0275***	-4.7062***	-5.4869***	0.4856	-0.2617***	0.0069***	2051	0.1779
	(0.0061)	(0.6171)	(0.4871)	(0.3762)	(0.0960)	(0.0025)		
EUR	-0.0212***	-4.8187***	-5.1872***	-0.0804	-0.1829**	-0.0046**	2051	0.1547
	(0.0058)	(0.5144)	(0.4066)	(0.3056)	(0.0887)	(0.0021)		
JPY	-0.0408***	-4.4306***	-6.4025***	2.1611***	-0.1296	0.2008***	2051	0.1721
	(0.0102)	(0.9546)	(0.7401)	(0.5765)	(0.1225)	(0.0477)		
NZD	-0.0282***	-6.3713***	-6.1451***	0.1570	-0.1225	0.0131**	2051	0.2033
	(0.0082)	(0.7227)	(0.6056)	(0.4305)	(0.1208)	(0.0059)		
NOK	-0.0198***	-4.0788***	-4.9352***	0.5975	-0.1802*	0.0411***	2051	0.1590
	(0.0068)	(0.6140)	(0.4888)	(0.3908)	(0.0939)	(0.0139)		
SEK	-0.0236***	-4.5616***	-4.7207***	-0.3232	-0.1185	0.0479***	2051	0.1386
	(0.0062)	(0.5772)	(0.4619)	(0.3527)	(0.0964)	(0.0130)		
CHF	-0.0143**	-2.9085***	-3.6290***	0.5095	-0.2187**	0.0013	2043	0.0806
	(0.0060)	(0.6577)	(0.5162)	(0.3919)	(0.0948)	(0.0030)		
GBP	-0.0231***	-3.4784***	-5.3741***	0.7444*	-0.3459***	-0.0078**	2051	0.1346
	(0.0067)	(0.6649)	(0.5219)	(0.4080)	(0.0986)	(0.0033)		
USD	-0.0116*	-6.5121***	-4.8512***	-1.2066***	-0.0747	-0.0217	2051	0.1734
	(0.0069)	(0.7224)	(0.5720)	(0.4380)	(0.1048)	(0.0144)		

The table reports the OLS estimates of the coefficient of the panel fixed effect regression listed above. The 10 currencies used are Australian Dollar (AUD), Canadian Dollar (CAD), Euro (EUR), Japanese Yen (JPY), New Zealand Dollar (NZD), Norwegian Krone (NOK), Swedish Krona (SEK), Swiss Franc (CHF), British Pound (GBP) and United States Dollar (USD). Each row represents a regression estimation using the first column currency as the home currency and the other 9 currencies as foreign currency j. $s_{j,t}$ is the nominal exchange rate between home and foreign country j, defined as home currency price of foreign currency, $q_{j,t}$ is the real exchange rate. $\tilde{\eta}_{j,t}$ is a measure of the treasury liquidity, $i^R_{j,t}$ is the home minus foreign interest rates. Δ is a difference operator. The sample period is 1999M1-2018M1.

Standard errors in parentheses are standard errors adjusted for cross-sectional correlation. *, **, and *** indicate that the alternative model significantly different from zero at 10%, 5%, and 1% significance level, respectively, based on standard normal critical values for the two-sided test.

Robustness of table 1B – full table of table 1B, extreme outliner of CHF at 2015M1 excluded

Estimation result of $\Delta s_{j,t} = \alpha_j + \beta_1 q_{j,t-1} + \beta_2(\Delta i^R_{j,t}) + \beta_3(i^R_{j,t-1}) + u_{j,t}$

	$q_{j,t-1}$	$\Delta i^R_{j,t}$	$i^R_{j,t-1}$	constant	N	R2_within
AUD	-0.0326***	-4.1144***	-0.2835***	0.0130***	2051	0.1171
	(0.0073)	(0.5130)	(0.1086)	(0.0042)		
CAD	-0.0286***	-4.5534***	-0.2500**	0.0060***	2051	0.1203
	(0.0063)	(0.4644)	(0.0978)	(0.0023)		
EUR	-0.0236***	-3.9506***	-0.1952**	-0.0047**	2051	0.0966
	(0.0059)	(0.3816)	(0.0906)	(0.0021)		
JPY	-0.0348***	-5.4004***	-0.1559	0.1618***	2051	0.1025
	(0.0105)	(0.7281)	(0.1298)	(0.0487)		
NZD	-0.0313***	-2.7495***	-0.0997	0.0138**	2051	0.0597
	(0.0094)	(0.5935)	(0.1328)	(0.0066)		
NOK	-0.0185***	-3.5397***	-0.1251	0.0370***	2051	0.0850
	(0.0070)	(0.4703)	(0.0951)	(0.0141)		
SEK	-0.0276***	-3.3136***	-0.1351	0.0567***	2051	0.0764
	(0.0063)	(0.4335)	(0.0980)	(0.0131)		
CHF	-0.0119**	-2.6838***	-0.2266**	-0.0019	2043	0.0428
	(0.0057)	(0.4814)	(0.0972)	(0.0022)		
GBP	-0.0229***	-3.8122***	-0.3354***	-0.0083**	2051	0.0901
	(0.0068)	(0.4907)	(0.0994)	(0.0033)		
USD	-0.0143*	-3.7412***	-0.1374	-0.0293*	2051	0.0705
	(0.0076)	(0.5839)	(0.1126)	(0.0157)		

The table reports the OLS estimates of the coefficient of the panel fixed effect regression listed above. The 10 currencies used are Australian Dollar (AUD), Canadian Dollar (CAD), Euro (EUR), Japanese Yen (JPY), New Zealand Dollar (NZD), Norwegian Krone (NOK), Swedish Krona (SEK), Swiss Franc (CHF), British Pound (GBP) and United States Dollar (USD). Each row represents a regression estimation using the first column currency as the home currency and the other 9 currencies as foreign currency j. $s_{j,t}$ is the nominal exchange rate between home and foreign country j, defined as home currency price of foreign currency, $q_{j,t}$ is the real exchange rate. $\tilde{\eta}_{j,t}$ is a measure of the treasury liquidity, $i^R_{j,t}$ is the home minus foreign interest rates. Δ is a difference operator. The sample period is 1999M1-2018M1.

Standard errors in parentheses are standard errors adjusted for cross-sectional correlation. *, **, and *** indicate that the alternative model significantly different from zero at 10%, 5%, and 1% significance level, respectively, based on standard normal critical values for the two-sided test.

Robustness of table 1C – full table of table 1C 2008M1-2018M1, extreme outliner of CHF at 2015M1 excluded

Estimation result of $\Delta s_{j,t} = \alpha_j + \beta_1 q_{j,t-1} + \beta_2(\Delta\tilde{\eta}_{j,t}) + \beta_3(\Delta i^R_{j,t}) + \beta_4(\tilde{\eta}_{j,t-1}) + \beta_5(i^R_{j,t-1}) + u_{j,t}$

	$q_{j,t-1}$	$\Delta\tilde{\eta}_{j,t}$	$\Delta i^R_{j,t}$	$\tilde{\eta}_{j,t-1}$	$i^R_{j,t-1}$	constant	N	R2_within
AUD	-0.0485***	-6.2052***	-7.5654***	0.0529	-0.4063*	0.0152**	1079	0.3094
	(0.0133)	(0.8686)	(0.7367)	(0.5997)	(0.2100)	(0.0071)		
CAD	-0.0426***	-5.8707***	-7.7187***	-0.0304	0.1215	0.0048	1079	0.3057
	(0.0103)	(0.7112)	(0.6393)	(0.4858)	(0.1695)	(0.0029)		
EUR	-0.0387***	-5.5505***	-7.7025***	-0.3161	-0.1215	-0.0121***	1079	0.2854
	(0.0098)	(0.6383)	(0.5873)	(0.4413)	(0.1818)	(0.0036)		
JPY	-0.0612***	-5.8055***	-11.4309***	2.0497**	-0.1628	0.2886***	1079	0.3384
	(0.0177)	(1.2356)	(1.1326)	(0.8865)	(0.2957)	(0.0801)		
NZD	-0.0539***	-7.0047***	-8.3443***	0.3830	0.0770	0.0101	1079	0.3376
	(0.0139)	(0.9307)	(0.8652)	(0.6360)	(0.2375)	(0.0091)		
NOK	-0.0341***	-4.9972***	-8.1996***	0.8581	-0.1442	0.0671***	1079	0.2719
	(0.0111)	(0.7699)	(0.7428)	(0.5492)	(0.1942)	(0.0220)		
SEK	-0.0505***	-5.6572***	-6.8427***	-0.0305	-0.0254	0.0985***	1079	0.2445
	(0.0109)	(0.7249)	(0.6930)	(0.4848)	(0.1963)	(0.0218)		
CHF	-0.0271**	-3.6505***	-6.2321***	0.0309	0.1284	-0.0033	1071	0.1718
	(0.0110)	(0.8720)	(0.8105)	(0.6213)	(0.2014)	(0.0050)		
GBP	-0.0459***	-3.6709***	-8.1564***	0.6928	-0.2781	-0.0183***	1079	0.2229
	(0.0143)	(0.9157)	(0.8565)	(0.6265)	(0.2404)	(0.0064)		
USD	-0.0471***	-7.2161***	-9.7982***	-0.7930	0.0168	-0.0902***	1079	0.3381
	(0.0126)	(0.8648)	(0.8216)	(0.5839)	(0.2226)	(0.0251)		

The table reports the OLS estimates of the coefficient of the panel fixed effect regression listed above. The 10 currencies used are Australian Dollar (AUD), Canadian Dollar (CAD), Euro (EUR), Japanese Yen (JPY), New Zealand Dollar (NZD), Norwegian Krone (NOK), Swedish Krona (SEK), Swiss Franc (CHF), British Pound (GBP) and United States Dollar (USD). Each row represents a regression estimation using the first column currency as the home currency and the other 9 currencies as foreign currency j. $s_{j,t}$ is the nominal exchange rate between home and foreign country j, defined as home currency price of foreign currency, $q_{j,t}$ is the real exchange rate. $\tilde{\eta}_{j,t}$ is a measure of the treasury liquidity, $i^R_{j,t}$ is the home minus foreign interest rates. Δ is a difference operator. The sample period is 2008M1-2018M1.

Standard errors in parentheses are standard errors adjusted for cross-sectional correlation. *, **, and *** indicate that the alternative model significantly different from zero at 10%, 5%, and 1% significance level, respectively, based on standard normal critical values for the two-sided test.

Robustness of table 1D – full table of table 1D, extreme outliner of CHF at 2015M1 excluded

Estimation result of $\Delta s_{j,t} = \alpha_j + \beta_1 q_{j,t-1} + \beta_2(\Delta\tilde{\eta}_{j,t}) + \beta_3(\Delta i^R_{j,t}) + \beta_4(\tilde{\eta}_{j,t-1}) + \beta_5(i^R_{j,t-1}) + u_{j,t}$

	$q_{j,t-1}$	$\Delta\tilde{\eta}_{j,t}$	$\Delta i^R_{j,t}$	$\tilde{\eta}_{j,t-1}$	$i^R_{j,t-1}$	constant	N	R2_within
AUD	-0.0238***	-5.2222***	-5.0224***	0.0677	-0.2866***	0.0106***	1718	0.1349
	(0.0070)	(0.9187)	(0.6232)	(0.4899)	(0.1064)	(0.0040)		
CAD	-0.0231***	-4.8977***	-4.6715***	0.2366	-0.3151***	0.0063**	1718	0.1331
	(0.0059)	(0.7657)	(0.5404)	(0.4080)	(0.0932)	(0.0024)		
EUR	-0.0180***	-5.4512***	-4.0075***	-0.5071	-0.1871**	-0.0049**	1718	0.1022
	(0.0058)	(0.6975)	(0.4924)	(0.3590)	(0.0943)	(0.0021)		
JPY	-0.0357***	-2.3091*	-3.5781***	1.9500***	-0.1147	0.1761***	1718	0.0597
	(0.0101)	(1.2182)	(0.8857)	(0.6175)	(0.1225)	(0.0474)		
NZD	-0.0230***	-5.9985***	-4.6631***	-0.4991	-0.1503	0.0119**	1718	0.1162
	(0.0083)	(0.9440)	(0.7236)	(0.5432)	(0.1236)	(0.0058)		
NOK	-0.0153**	-4.3305***	-4.2204***	0.4245	-0.1970*	0.0320**	1718	0.1126
	(0.0070)	(0.8487)	(0.5907)	(0.4741)	(0.1009)	(0.0147)		
SEK	-0.0188***	-4.2505***	-3.5450***	-0.4321	-0.1498	0.0376***	1718	0.0848
	(0.0061)	(0.7722)	(0.5534)	(0.4053)	(0.1008)	(0.0129)		
CHF	-0.0088	-3.1338***	-2.0560***	-0.1702	-0.2525***	-0.0035	1710	0.0427
	(0.0058)	(0.8000)	(0.5738)	(0.4172)	(0.0928)	(0.0031)		
GBP	-0.0163**	-4.9478***	-4.1812***	0.0931	-0.2794***	-0.0062**	1718	0.0892
	(0.0065)	(0.8632)	(0.5995)	(0.4629)	(0.0972)	(0.0031)		
USD	-0.0081	-7.2973***	-4.4700***	-1.4375***	-0.1034	-0.0141	1718	0.1312
	(0.0069)	(0.9643)	(0.6742)	(0.4860)	(0.1063)	(0.0146)		

The table reports the OLS estimates of the coefficient of the panel fixed effect regression listed above. The 10 currencies used are Australian Dollar (AUD), Canadian Dollar (CAD), Euro (EUR), Japanese Yen (JPY), New Zealand Dollar (NZD), Norwegian Krone (NOK), Swedish Krona (SEK), Swiss Franc (CHF), British Pound (GBP) and United States Dollar (USD). Each row represents a regression estimation using the first column currency as the home currency and the other 9 currencies as foreign currency j. $s_{j,t}$ is the nominal exchange rate between home and foreign country j, defined as home currency price of foreign currency, $q_{j,t}$ is the real exchange rate. $\tilde{\eta}_{j,t}$ is a measure of the treasury liquidity, $i^R_{j,t}$ is the home minus foreign interest rates. Δ is a difference operator. The sample period is 1999M1-2018M1.

Standard errors in parentheses are standard errors adjusted for cross-sectional correlation. *, **, and *** indicate that the alternative model significantly different from zero at 10%, 5%, and 1% significance level, respectively, based on standard normal critical values for the two-sided test.

Robustness of table 1E – full table of table 1E (excluding U.S. dollar), extreme outliner of CHF at 2015M1 excluded

Estimation result of $\Delta s_{j,t} = \alpha_j + \beta_1 q_{j,t-1} + \beta_2(\Delta\tilde{\eta}_{j,t}) + \beta_3(\Delta i^R_{j,t}) + \beta_4(\tilde{\eta}_{j,t-1}) + \beta_5(i^R_{j,t-1}) + u_{j,t}$

	$q_{j,t-1}$	$\Delta\tilde{\eta}_{j,t}$	$\Delta i^R_{j,t}$	$\tilde{\eta}_{j,t-1}$	$i^R_{j,t-1}$	constant	N	R2_within
AUD	-0.0333***	-4.9296***	-5.7267***	0.4936	-0.2753**	-0.0563***	1823	0.1917
	(0.0076)	(0.7119)	(0.5274)	(0.4374)	(0.1078)	(0.0131)		
CAD	-0.0334***	-4.4184***	-5.4444***	0.8785**	-0.3018***	-0.0607***	1823	0.1839
	(0.0071)	(0.6428)	(0.4987)	(0.4002)	(0.1024)	(0.0129)		
EUR	-0.0273***	-4.5233***	-5.1418***	0.3354	-0.2210**	-0.0609***	1823	0.1543
	(0.0062)	(0.5283)	(0.4055)	(0.3219)	(0.0913)	(0.0138)		
JPY	-0.0450***	-4.8388***	-6.7360***	2.3729***	-0.1024	0.1259***	1823	0.1833
	(0.0114)	(1.0079)	(0.7755)	(0.6226)	(0.1293)	(0.0298)		
NZD	-0.0341***	-6.0421***	-6.1096***	0.3387	-0.1369	-0.0549***	1823	0.2032
	(0.0087)	(0.7160)	(0.5988)	(0.4279)	(0.1244)	(0.0134)		
NOK	-0.0241***	-3.5660***	-5.0053***	0.8823**	-0.2363**	-0.0002	1823	0.1595
	(0.0072)	(0.6054)	(0.4826)	(0.3861)	(0.0954)	(0.0016)		
SEK	-0.0306***	-4.0666***	-4.6601***	0.1372	-0.1709*	0.0478***	1823	0.1334
	(0.0063)	(0.5674)	(0.4508)	(0.3475)	(0.0973)	(0.0098)		
CHF	-0.0171***	-2.4898***	-3.6023***	0.7928*	-0.2133**	-0.0329***	1816	0.0790
	(0.0064)	(0.6746)	(0.5250)	(0.4117)	(0.0998)	(0.0124)		
GBP	-0.0246***	-3.5844***	-5.5589***	1.0375**	-0.3782***	-0.0601***	1823	0.1427
	(0.0073)	(0.7051)	(0.5477)	(0.4356)	(0.1085)	(0.0182)		

The table reports the OLS estimates of the coefficient of the panel fixed effect regression listed above. The 9 currencies used are Australian Dollar (AUD), Canadian Dollar (CAD), Euro (EUR), Japanese Yen (JPY), New Zealand Dollar (NZD), Norwegian Krone (NOK), Swedish Krona (SEK), Swiss Franc (CHF) and British Pound (GBP). We exclude United States Dollar (USD) from all the regressions. Each row represents a regression estimation using the first column currency as the home currency and the other 8 currencies as foreign currency j. $s_{j,t}$ is the nominal exchange rate between home and foreign country j, defined as home currency price of foreign currency, $q_{j,t}$ is the real exchange rate. $\tilde{\eta}_{j,t}$ is a measure of the treasury liquidity, $i^R_{j,t}$ is the home minus foreign interest rates. Δ is a difference operator. The sample period is 1999M1-2018M1.

Standard errors in parentheses are standard errors adjusted for cross-sectional correlation. *, **, and *** indicate that the alternative model significantly different from zero at 10%, 5%, and 1% significance level, respectively, based on standard normal critical values for the two-sided test.

Robustness of table 1F – full table of table 1F, extreme outliner of CHF at 2015M1 excluded
Estimation result of $\Delta s_{j,t} = \alpha_j + \beta_1 q_{j,t-1} + \beta_2(\Delta\tilde{\eta}_{j,t}) + \beta_3(\Delta i^R_{j,t}) + \beta_4(\tilde{\eta}_{j,t-1}) + \beta_5(i^R_{j,t-1}) + u_{j,t}$

	$q_{j,t-1}$	$\Delta\tilde{\eta}_{j,t}$	$\Delta i^R_{j,t}$	$\tilde{\eta}_{j,t-1}$	$i^R_{j,t-1}$	constant	N	R2_within
AUD	-0.0543**	-7.2292	-22.9042	-11.0936	-2.9609	0.0104	360	0.0535
	(0.0259)	(10.5997)	(14.9001)	(12.0581)	(3.0581)	(0.0100)		
CAD	-0.0301***	-13.5169***	-32.2577***	-9.3470*	0.0662	0.0035	1227	0.0654
	(0.0098)	(4.5978)	(7.3181)	(4.7782)	(1.8729)	(0.0031)		
EUR	-0.0810***	-21.2172***	-31.9704***	-16.3791**	1.5667	-0.0210***	608	0.1129
	(0.0151)	(7.2536)	(8.7744)	(6.6045)	(2.6306)	(0.0047)		
JPY	-0.1040***	-24.4186**	-25.1094**	-1.5197	-7.2904**	0.4815***	461	0.1468
	(0.0239)	(10.2002)	(11.9099)	(12.2109)	(3.5545)	(0.1094)		
NZD	-0.0331***	-18.5507***	-31.9789***	-12.1508**	0.7339	0.0077	1227	0.0688
	(0.0103)	(4.7909)	(7.0020)	(5.2317)	(1.5859)	(0.0070)		
SEK	-0.0334***	-15.4295***	-20.2601***	-10.8591***	-0.1253	0.0651***	1227	0.0515
	(0.0084)	(3.8630)	(5.6202)	(4.0993)	(1.2450)	(0.0175)		
CHF	-0.0547***	-9.9728	-17.2902**	-13.6131*	8.4830***	-0.0084**	724	0.0818
	(0.0116)	(7.8673)	(7.6782)	(7.9137)	(3.0055)	(0.0040)		
GBP	-0.0222*	-8.5766*	-22.3137***	-8.5154*	-1.1037	-0.0118**	1227	0.0351
	(0.0115)	(4.8987)	(7.1081)	(4.9745)	(1.6846)	(0.0055)		
USD	-0.0253***	-17.6015***	-16.6230***	-16.4997***	1.1772	-0.0464**	1227	0.0637
	(0.0088)	(3.9543)	(6.2174)	(3.9658)	(1.4349)	(0.0182)		

The table reports the OLS estimates of the coefficient of the panel fixed effect regression listed above. The 10 currencies used are Australian Dollar (AUD), Canadian Dollar (CAD), Euro (EUR), Japanese Yen (JPY), New Zealand Dollar (NZD), Norwegian Krone (NOK), Swedish Krona (SEK), Swiss Franc (CHF), British Pound (GBP) and United States Dollar (USD). Each row represents a regression estimation using the first column currency as the home currency and the other 9 currencies as foreign currency j. $s_{j,t}$ is the nominal exchange rate between home and foreign country j, defined as home currency price of foreign currency, $q_{j,t}$ is the real exchange rate. $\tilde{\eta}_{j,t}$ is a measure of the treasury liquidity, $i^R_{j,t}$ is the home minus foreign interest rates. Δ is a difference operator. The sample period is 1999M1-2018M1.

Standard errors in parentheses are standard errors adjusted for cross-sectional correlation. *, **, and *** indicate that the alternative model significantly different from zero at 10%, 5%, and 1% significance level, respectively, based on standard normal critical values for the two-sided test.

Robustness of table 1G – full table of table 1G, extreme outliner of CHF at 2015M1 excluded

Estimation result of $\Delta s_{j,t} = \alpha_j + \beta_1 q_{j,t-1} + \beta_2 \Delta\hat{\eta}_{j,t} + \beta_3 \Delta i^R_{j,t} + \beta_4 \hat{\eta}_{j,t-1} + \beta_5 i^R_{j,t-1} + u_{j,t}$

	$q_{j,t-1}$	$\Delta\hat{\eta}_{j,t}$	$\Delta i^R_{j,t}$	$\hat{\eta}_{j,t-1}$	$i^R_{j,t-1}$	constant	N	R2_within
AUD	-0.0290***	-5.9108***	-5.7064***	0.3593	-0.2795**	0.0121***	2027	0.1985
	(0.0070)	(0.7769)	(0.5328)	(0.4024)	(0.1102)	(0.0041)		
CAD	-0.0300***	-3.7373***	-6.2502***	0.6129*	-0.2651**	0.0064***	1835	0.1833
	(0.0067)	(0.7409)	(0.5376)	(0.3694)	(0.1113)	(0.0025)		
EUR	-0.0217***	-3.7149***	-5.2196***	0.0865	-0.1582*	-0.0043**	2027	0.1305
	(0.0058)	(0.5711)	(0.4126)	(0.2903)	(0.0937)	(0.0021)		
JPY	-0.0387***	-4.2481***	-6.2795***	1.7813***	-0.2904**	0.1831***	2027	0.1462
	(0.0102)	(1.0223)	(0.7654)	(0.5386)	(0.1357)	(0.0474)		
NZD	-0.0291***	-6.1113***	-6.0012***	0.2823	-0.1273	0.0134**	2027	0.1755
	(0.0086)	(0.8027)	(0.6266)	(0.3997)	(0.1288)	(0.0061)		
NOK	-0.0186***	-2.9316***	-4.4539***	0.3986	-0.1694*	0.0375***	2027	0.1256
	(0.0069)	(0.6522)	(0.5001)	(0.3778)	(0.1021)	(0.0139)		
SEK	-0.0245***	-4.2249***	-4.5719***	-0.2349	-0.0887	0.0504***	2027	0.1192
	(0.0062)	(0.6417)	(0.4739)	(0.3424)	(0.1039)	(0.0129)		
CHF	-0.0123**	-3.7831***	-4.0124***	0.5170	-0.2152**	0.0003	2019	0.0826
	(0.0057)	(0.7129)	(0.5127)	(0.3574)	(0.1009)	(0.0024)		
GBP	-0.0209***	-4.1934***	-5.4897***	0.5308	-0.3363***	-0.0077**	2027	0.1401
	(0.0067)	(0.7345)	(0.5249)	(0.3884)	(0.1054)	(0.0033)		
USD	-0.0142**	-6.0996***	-4.8139***	-1.1734***	-0.0284	-0.0294**	2027	0.1376
	(0.0071)	(0.8458)	(0.6020)	(0.4310)	(0.1144)	(0.0148)		

The table reports the OLS estimates of the coefficient of the panel fixed effect regression listed above. The 10 currencies used are Australian Dollar (AUD), Canadian Dollar (CAD), Euro (EUR), Japanese Yen (JPY), New Zealand Dollar (NZD), Norwegian Krone (NOK), Swedish Krona (SEK), Swiss Franc (CHF), British Pound (GBP) and United States Dollar (USD). Each row represents a regression estimation using the first column currency as the home currency and the other 9 currencies as foreign currency j. $s_{j,t}$ is the nominal exchange rate between home and foreign country j, defined as home currency price of foreign currency, $q_{j,t}$ is the real exchange rate, $\hat{\eta}_{j,t}$ is a measure of the treasury liquidity, $i^R_{j,t}$ is the home minus foreign interest rates. Δ is a difference operator. The sample period is 1999M1-2018M1.

Standard errors in parentheses are standard errors adjusted for cross-sectional correlation. *, **, and *** indicate that the alternative model significantly different from zero at 10%, 5%, and 1% significance level, respectively, based on standard normal critical values for the two-sided test.

Robustness of table 2A – full table of table 2A, full sample, no default risk, extreme outliner of CHF at 2015M1 excluded

Estimation result of $\Delta s_{j,t} = \alpha_j + \beta_1 q_{j,t-1} + \beta_2 \Delta\lambda_{j,t} + \beta_3 \Delta\tau_{j,t} + \beta_4 \Delta l^R_{j,t} + \beta_5 \Delta i^R_{j,t} + \beta_6 \lambda_{j,t-1} + \beta_7 \tau_{j,t-1} + \beta_8 l^R_{j,t-1} + \beta_9 i^R_{j,t-1} + u_{j,t}$

	$q_{j,t-1}$	$\Delta\lambda_{j,t}$	$\Delta\tau_{j,t}$	$\Delta i^R_{j,t}$	$\lambda_{j,t-1}$	$\tau_{j,t-1}$	$i^R_{j,t-1}$	constant	N	R2_within
AUD	-0.0282***	-6.2536***	-3.1378**	-5.9436***	0.2952	-0.2568	-0.2859***	0.0121***	2027	0.2061
	(0.0072)	(0.7880)	(1.2199)	(0.5357)	(0.4251)	(0.7571)	(0.1106)	(0.0041)		
CAD	-0.0292***	-4.6936***	-5.3454***	-6.2016***	0.5250	-0.1580	-0.2890***	0.0061**	1835	0.2135
	(0.0067)	(0.7183)	(1.1114)	(0.5232)	(0.3956)	(0.7041)	(0.1096)	(0.0025)		
EUR	-0.0199***	-4.8871***	-5.0036***	-5.2334***	-0.1073	-0.4550	-0.1705*	-0.0051**	2027	0.1589
	(0.0058)	(0.5625)	(0.8598)	(0.4049)	(0.3066)	(0.5330)	(0.0907)	(0.0022)		
JPY	-0.0407***	-4.2165***	-5.0290***	-6.5016***	2.1511***	2.0178**	-0.1516	0.1994***	2027	0.1761
	(0.0102)	(1.0032)	(1.5890)	(0.7488)	(0.5775)	(0.9618)	(0.1345)	(0.0478)		
NZD	-0.0296***	-6.6971***	-5.9202***	-6.4014***	0.1906	-0.6582	-0.1745	0.0151***	2027	0.2098
	(0.0078)	(0.7912)	(1.2847)	(0.6095)	(0.4292)	(0.7716)	(0.1258)	(0.0057)		
NOK	-0.0198***	-3.9084***	-5.1820***	-4.9689***	0.5705	0.6795	-0.1754*	0.0412***	2027	0.1629
	(0.0068)	(0.6531)	(1.0430)	(0.4885)	(0.3971)	(0.6885)	(0.0987)	(0.0141)		
SEK	-0.0224***	-4.4885***	-5.1247***	-4.7033***	-0.2920	-0.7150	-0.1268	0.0447***	2027	0.1402
	(0.0063)	(0.6409)	(0.9782)	(0.4662)	(0.3599)	(0.6317)	(0.1026)	(0.0134)		
CHF	-0.0131**	-3.7132***	-1.7331	-3.9686***	0.5469	0.1939	-0.2120**	0.0009	2019	0.0868
	(0.0060)	(0.7116)	(1.0979)	(0.5105)	(0.3855)	(0.6935)	(0.1005)	(0.0032)		
GBP	-0.0221***	-4.3195***	-1.5450	-5.6633***	0.7081*	0.5368	-0.3349***	-0.0076**	2027	0.1438
	(0.0068)	(0.7451)	(1.1210)	(0.5258)	(0.4147)	(0.6941)	(0.1065)	(0.0033)		
USD	-0.0121*	-6.3814***	-6.8336***	-4.8691***	-1.2849***	-0.9221	-0.0582	-0.0235	2027	0.1753
	(0.0070)	(0.8238)	(1.1928)	(0.5822)	(0.4460)	(0.7207)	(0.1113)	(0.0149)		

The table reports the OLS estimates of the coefficient of the panel fixed effect regression listed above. The 10 currencies used are Australian Dollar (AUD), Canadian Dollar (CAD), Euro (EUR), Japanese Yen (JPY), New Zealand Dollar (NZD), Norwegian Krone (NOK), Swedish Krona (SEK), Swiss Franc (CHF), British Pound (GBP) and United States Dollar (USD). Each row represents a regression estimation using the first column currency as the home currency and the other 9 currencies as foreign currency j. $s_{j,t}$ is the nominal exchange rate between home and foreign country j, defined as home currency price of foreign currency, $q_{j,t}$ is the real exchange rate. $\tau_{j,t}$ is a measure of currency derivative friction, $l^R_{j,t}$ is a measure of home minus foreign default risk, $\lambda_{j,t}$ is a measure of the treasury liquidity after adjusting for derivative market friction and default risk, $i^R_{j,t}$ is the home minus foreign interest rates. Δ is a difference operator. The sample period is 1999M1-2018M1.

Standard errors in parentheses are standard errors adjusted for cross-sectional correlation. *, **, and *** indicate that the alternative model significantly different from zero at 10%, 5%, and 1% significance level, respectively, based on standard normal critical values for the two-sided test.

Robustness of table 2A – full table of table 2A, post 2008, with default risk, extreme outliner of CHF at 2015M1 excluded

Estimation result of $\Delta s_{j,t} = \alpha_j + \beta_1 q_{j,t-1} + \beta_2 \Delta\lambda_{j,t} + \beta_3 \Delta\tau_{j,t} + \beta_4 \Delta l^R_{j,t} + \beta_5 \Delta i^R_{j,t} + \beta_6 \lambda_{j,t-1} + \beta_7 \tau_{j,t-1} + \beta_8 l^R_{j,t-1} + \beta_9 i^R_{j,t-1} + u_{j,t}$

	$q_{j,t-1}$	$\Delta\lambda_{j,t}$	$\Delta\tau_{j,t}$	$\Delta l^R_{j,t}$	$\Delta i^R_{j,t}$	$\lambda_{j,t-1}$	$\tau_{j,t-1}$	$l^R_{j,t-1}$	$i^R_{j,t-1}$	N	R2_within
AUD	-0.0513***	-7.2053***	-3.3530**	14.5092***	-7.3038***	-0.4305	-0.5560	0.1797	-0.3734*	954	0.3029
	(0.0152)	(1.1091)	(1.5116)	(2.3297)	(0.7981)	(0.6495)	(1.1709)	(1.4068)	(0.2101)		
CAD	-0.0313***	-8.8567***	-6.8906***	8.3213***	-8.9747***	-0.6043	-3.5155***	-0.6392	0.3944	399	0.3046
	(0.0118)	(1.5154)	(1.7969)	(2.5681)	(1.1122)	(0.8526)	(1.0528)	(1.5427)	(0.2489)		
EUR	-0.0477***	-6.5882***	-4.0138***	8.6759***	-8.3319***	-0.1026	-0.7853	2.1128**	-0.0665	965	0.2919
	(0.0104)	(0.7780)	(0.9240)	(1.6170)	(0.6126)	(0.4515)	(0.6943)	(1.0123)	(0.1726)		
JPY	-0.0654***	-6.9260***	-4.4754**	10.4870***	-11.5341***	2.0343**	2.9395**	-0.2503	-0.0736	965	0.3486
	(0.0178)	(1.3761)	(1.8480)	(3.1817)	(1.1389)	(0.8053)	(1.4171)	(1.9958)	(0.2788)		
NZD	-0.0544***	-7.8269***	-6.0864***	12.3531***	-8.3548***	0.6825	0.2931	-0.0311	0.1621	942	0.3321
	(0.0137)	(1.1326)	(1.4691)	(2.4818)	(0.9011)	(0.6844)	(1.1942)	(1.4007)	(0.2444)		
NOK	-0.0426***	-5.2487***	-5.8965***	4.2135**	-8.1066***	0.6287	0.6719	1.4380	-0.1173	965	0.2752
	(0.0111)	(0.8105)	(1.1987)	(1.9603)	(0.7364)	(0.5300)	(0.8958)	(1.2685)	(0.1921)		
SEK	-0.0497***	-5.6003***	-4.3565***	7.3048***	-6.4572***	0.1517	-1.0694	-0.1471	-0.0534	965	0.2228
	(0.0111)	(0.8805)	(1.1318)	(1.8924)	(0.7211)	(0.5018)	(0.8421)	(1.1388)	(0.1894)		
CHF	-0.0249**	-5.8228***	-1.0930	7.9530***	-4.9992***	-0.5818	-0.5845	2.0607	0.1926	881	0.0880
	(0.0111)	(1.3117)	(1.5992)	(2.3441)	(0.9353)	(0.6809)	(1.0374)	(1.3520)	(0.2040)		
GBP	-0.0486***	-6.4730***	-0.6533	5.8833**	-9.3742***	0.3684	1.9781*	0.9996	-0.0670	965	0.2468
	(0.0136)	(1.1133)	(1.4022)	(2.3437)	(0.8828)	(0.6481)	(1.0200)	(1.4796)	(0.2350)		
USD	-0.0560***	-8.9086***	-3.2019**	12.5574***	-10.1507***	-0.9368	0.4045	1.0582	0.1366	813	0.3756
	(0.0138)	(1.1126)	(1.2482)	(2.1570)	(0.8834)	(0.6296)	(0.9356)	(1.3704)	(0.2270)		

The table reports the OLS estimates of the coefficient of the panel fixed effect regression listed above. The 10 currencies used are Australian Dollar (AUD), Canadian Dollar (CAD), Euro (EUR), Japanese Yen (JPY), New Zealand Dollar (NZD), Norwegian Krone (NOK), Swedish Krona (SEK), Swiss Franc (CHF), British Pound (GBP) and United States Dollar (USD). Each row represents a regression estimation using the first column currency as the home currency and the other 9 currencies as foreign currency j. $s_{j,t}$ is the nominal exchange rate between home and foreign country j, defined as home currency price of foreign currency, $q_{j,t}$ is the real exchange rate. $\tau_{j,t}$ is a measure of currency derivative friction, $l^R_{j,t}$ is a measure of home minus foreign default risk, $\lambda_{j,t}$ is a measure of the treasury liquidity after adjusting for derivative market friction and default risk, $i^R_{j,t}$ is the home minus foreign interest rates. Δ is a difference operator. The sample period is 2008M1-2018M1.

Standard errors in parentheses are standard errors adjusted for cross-sectional correlation. *, **, and *** indicate that the alternative model significantly different from zero at 10%, 5%, and 1% significance level, respectively, based on standard normal critical values for the two-sided test.

Robustness of table 2B – full table of table 2B for $\lambda_{j,t}$, extreme outliner of CHF at 2015M1 excluded

Estimation result of $\Delta s_{j,t} = \alpha_j + \beta_1 q_{j,t-1} + \beta_2 \Delta\lambda_{j,t} + \beta_3 \Delta i^R_{j,t} + \beta_4 \lambda_{j,t-1} + \beta_5 i^R_{j,t-1} + u_{j,t}$

	$q_{j,t-1}$	$\Delta\lambda_{j,t}$	$\Delta i^R_{j,t}$	$\lambda_{j,t-1}$	$i^R_{j,t-1}$	constant	N	R2_within
AUD	-0.0548***	-4.4892***	-6.4274***	-0.0210	-0.3793*	0.0159**	954	0.2194
	(0.0157)	(1.0744)	(0.8423)	(0.5668)	(0.2274)	(0.0076)		
CAD	-0.0359***	-3.6265***	-7.9490***	0.9625	0.4427*	0.0038	399	0.2396
	(0.0125)	(1.3326)	(1.1357)	(0.7107)	(0.2646)	(0.0035)		
EUR	-0.0426***	-3.4544***	-8.0497***	0.6814*	-0.0377	-0.0134***	965	0.2424
	(0.0103)	(0.7207)	(0.6233)	(0.3932)	(0.1825)	(0.0036)		
JPY	-0.0704***	-4.9658***	-10.9949***	1.6701**	-0.3591	0.3213***	965	0.2858
	(0.0184)	(1.3638)	(1.1874)	(0.6485)	(0.2952)	(0.0829)		
NZD	-0.0542***	-4.9241***	-7.1773***	0.9769	0.2323	0.0069	942	0.2358
	(0.0160)	(1.1240)	(0.9658)	(0.6579)	(0.2672)	(0.0100)		
NOK	-0.0364***	-4.2428***	-7.3424***	0.8598*	-0.0874	0.0683***	965	0.2237
	(0.0112)	(0.7759)	(0.7554)	(0.4492)	(0.2025)	(0.0221)		
SEK	-0.0525***	-4.0889***	-6.2107***	0.2019	0.0339	0.1021***	965	0.1773
	(0.0111)	(0.8147)	(0.7272)	(0.4550)	(0.1968)	(0.0220)		
CHF	-0.0235**	-3.5106***	-4.5120***	-0.1109	0.1738	-0.0046	881	0.0633
	(0.0106)	(1.1842)	(0.9489)	(0.5623)	(0.2077)	(0.0035)		
GBP	-0.0448***	-5.2950***	-8.5265***	0.1084	-0.1244	-0.0194***	965	0.2259
	(0.0133)	(1.0231)	(0.8687)	(0.5483)	(0.2379)	(0.0061)		
USD	-0.0595***	-5.1253***	-9.8593***	-0.7254	0.1777	-0.1159***	813	0.2804
	(0.0163)	(1.1080)	(0.9587)	(0.6271)	(0.2570)	(0.0322)		

The table reports the OLS estimates of the coefficient of the panel fixed effect regression listed above. The 10 currencies used are Australian Dollar (AUD), Canadian Dollar (CAD), Euro (EUR), Japanese Yen (JPY), New Zealand Dollar (NZD), Norwegian Krone (NOK), Swedish Krona (SEK), Swiss Franc (CHF), British Pound (GBP) and United States Dollar (USD). Each row represents a regression estimation using the first column currency as the home currency and the other 9 currencies as foreign currency j. $s_{j,t}$ is the nominal exchange rate between home and foreign country j, defined as home currency price of foreign currency, $q_{j,t}$ is the real exchange rate. $\tau_{j,t}$ is a measure of currency derivative friction, $l^R_{j,t}$ is a measure of home minus foreign default risk, $\lambda_{j,t}$ is a measure of the treasury liquidity after adjusting for derivative market friction and default risk, $i^R_{j,t}$ is the home minus foreign interest rates. Δ is a difference operator. The sample period is 2008M1-2018M1. Regressions involving default risk $\hat{l}^R_{j,t}$ are only estimated through 2008M1-2018M1 period.

Standard errors in parentheses are standard errors adjusted for cross-sectional correlation. *, **, and *** indicate that the alternative model significantly different from zero at 10%, 5%, and 1% significance level, respectively, based on standard normal critical values for the two-sided test.

Robustness of table 2B – full table of table 2B for $\tau_{j,t}$, extreme outliner of CHF at 2015M1 excluded

Estimation result of $\Delta s_{j,t} = \alpha_j + \beta_1 q_{j,t-1} + \beta_2 \Delta\tau_{j,t} + \beta_3 \Delta i^R_{j,t} + \beta_4 \tau_{j,t-1} + \beta_5 i^R_{j,t-1} + u_{j,t}$

	$q_{j,t-1}$	$\Delta\tau_{j,t}$	$\Delta i^R_{j,t}$	$\tau_{j,t-1}$	$i^R_{j,t-1}$	constant	N	R2_within
AUD	-0.0320***	-1.5353	-4.2424***	-0.3062	-0.2969***	0.0133***	2027	0.1201
	(0.0075)	(1.2740)	(0.5164)	(0.7480)	(0.1144)	(0.0043)		
CAD	-0.0296***	-4.4586***	-5.3357***	-0.6788	-0.2922***	0.0051**	1835	0.1763
	(0.0067)	(1.1111)	(0.4934)	(0.6416)	(0.1086)	(0.0023)		
EUR	-0.0216***	-3.1621***	-3.7711***	-0.4263	-0.1949**	-0.0053**	2027	0.1111
	(0.0059)	(0.8675)	(0.3712)	(0.4797)	(0.0907)	(0.0022)		
JPY	-0.0347***	-5.8441***	-5.6721***	0.6453	-0.1159	0.1634***	2027	0.1310
	(0.0103)	(1.6373)	(0.7093)	(0.9138)	(0.1357)	(0.0483)		
NZD	-0.0314***	-4.1731***	-2.9760***	-0.4427	-0.1216	0.0146**	2027	0.0807
	(0.0088)	(1.4047)	(0.5814)	(0.7741)	(0.1351)	(0.0063)		
NOK	-0.0184***	-3.0822***	-3.6837***	0.1610	-0.1232	0.0370**	2027	0.0993
	(0.0070)	(1.0560)	(0.4673)	(0.6614)	(0.0977)	(0.0144)		
SEK	-0.0253***	-4.4653***	-3.3708***	-0.6392	-0.1635	0.0508***	2027	0.0921
	(0.0063)	(0.9870)	(0.4258)	(0.6007)	(0.1009)	(0.0135)		
CHF	-0.0119**	-2.0420*	-2.7135***	-0.0208	-0.2162**	-0.0018	2019	0.0492
	(0.0059)	(1.1117)	(0.4725)	(0.6566)	(0.0996)	(0.0027)		
GBP	-0.0223***	-0.7693	-3.8679***	-0.3056	-0.3479***	-0.0083**	2027	0.0924
	(0.0070)	(1.1399)	(0.4911)	(0.6717)	(0.1063)	(0.0033)		
USD	-0.0129*	-6.2108***	-3.8031***	-0.6893	-0.1674	-0.0249	2027	0.1036
	(0.0076)	(1.2382)	(0.5687)	(0.6968)	(0.1143)	(0.0160)		

The table reports the OLS estimates of the coefficient of the panel fixed effect regression listed above. The 10 currencies used are Australian Dollar (AUD), Canadian Dollar (CAD), Euro (EUR), Japanese Yen (JPY), New Zealand Dollar (NZD), Norwegian Krone (NOK), Swedish Krona (SEK), Swiss Franc (CHF), British Pound (GBP) and United States Dollar (USD). Each row represents a regression estimation using the first column currency as the home currency and the other 9 currencies as foreign currency j. $s_{j,t}$ is the nominal exchange rate between home and foreign country j, defined as home currency price of foreign currency, $q_{j,t}$ is the real exchange rate. $\tau_{j,t}$ is a measure of currency derivative friction, $l^R_{j,t}$ is a measure of home minus foreign default risk, $\lambda_{j,t}$ is a measure of the treasury liquidity after adjusting for derivative market friction and default risk, $i^R_{j,t}$ is the home minus foreign interest rates. Δ is a difference operator. The sample period is 1999M1-2018M1. Regressions involving default risk $\hat{l}^R_{j,t}$ are only estimated through 2008M1-2018M1 period.

Standard errors in parentheses are standard errors adjusted for cross-sectional correlation. *, **, and *** indicate that the alternative model significantly different from zero at 10%, 5%, and 1% significance level, respectively, based on standard normal critical values for the two-sided test.

Robustness of table 2B – full table of table 2B for $l_{j,t}^{R}$, extreme outliner of CHF at 2015M1 excluded

Estimation result of $\Delta s_{j,t} = \alpha_j + \beta_1 q_{j,t-1} + \beta_2 \Delta l_{j,t}^{R} + \beta_3 \Delta i_{j,t}^{R} + \beta_4 l_{j,t-1}^{R} + \beta_5 i_{j,t-1}^{R} + u_{j,t}$

	$q_{j,t-1}$	$\Delta l_{j,t}^{R}$	$\Delta i_{j,t}^{R}$	$l_{j,t-1}^{R}$	$i_{j,t-1}^{R}$	constant	N	R2_within
AUD	-0.0572***	9.9471***	-5.7573***	0.5040	-0.4473**	0.0185**	954	0.2194
	(0.0159)	(2.1987)	(0.7584)	(1.3025)	(0.2176)	(0.0074)		
CAD	-0.0308**	0.7547	-6.9329***	1.2790	0.5283**	0.0017	399	0.2018
	(0.0127)	(2.2708)	(1.0802)	(1.3620)	(0.2442)	(0.0036)		
EUR	-0.0512***	2.0137	-6.3724***	2.3257**	-0.0624	-0.0142***	965	0.2069
	(0.0108)	(1.5065)	(0.5710)	(0.9197)	(0.1832)	(0.0037)		
JPY	-0.0623***	4.7482	-10.0143***	1.6921	-0.0719	0.2825***	965	0.2477
	(0.0194)	(3.1077)	(1.1494)	(1.8797)	(0.3087)	(0.0872)		
NZD	-0.0664***	4.5846*	-6.1433***	1.8722	0.2763	0.0081	942	0.1730
	(0.0158)	(2.5575)	(0.9643)	(1.4215)	(0.2708)	(0.0100)		
NOK	-0.0452***	-1.2134	-5.2769***	2.8374**	-0.0823	0.0880***	965	0.1447
	(0.0121)	(1.9512)	(0.7214)	(1.1799)	(0.2170)	(0.0241)		
SEK	-0.0565***	2.9482	-4.4351***	1.2175	0.0452	0.1109***	965	0.1340
	(0.0118)	(1.7924)	(0.6650)	(1.0864)	(0.1952)	(0.0234)		
CHF	-0.0247**	2.2263	-3.1002***	1.3974	0.1175	-0.0042	881	0.0456
	(0.0110)	(2.0983)	(0.8766)	(1.1801)	(0.2053)	(0.0032)		
GBP	-0.0484***	0.7863	-6.0860***	1.4121	-0.1539	-0.0204***	965	0.1712
	(0.0144)	(2.2231)	(0.8362)	(1.2948)	(0.2463)	(0.0066)		
USD	-0.0570***	5.1429**	-8.6497***	-0.2386	0.1627	-0.1103***	813	0.2553
	(0.0167)	(2.1134)	(0.9081)	(1.3630)	(0.2547)	(0.0330)		

The table reports the OLS estimates of the coefficient of the panel fixed effect regression listed above. The 10 currencies used are Australian Dollar (AUD), Canadian Dollar (CAD), Euro (EUR), Japanese Yen (JPY), New Zealand Dollar (NZD), Norwegian Krone (NOK), Swedish Krona (SEK), Swiss Franc (CHF), British Pound (GBP) and United States Dollar (USD). Each row represents a regression estimation using the first column currency as the home currency and the other 9 currencies as foreign currency j. $s_{j,t}$ is the nominal exchange rate between home and foreign country j, defined as home currency price of foreign currency, $q_{j,t}$ is the real exchange rate. $\tau_{j,t}$ is a measure of currency derivative friction, $l_{j,t}^{R}$ is a measure of home minus foreign default risk, $\lambda_{j,t}$ is a measure of the treasury liquidity after adjusting for derivative market friction and default risk, $i_{j,t}^{R}$ is the home minus foreign interest rates. Δ is a difference operator. The sample period is 1999M1-2018M1. Regressions involving default risk $\hat{l}_{j,t}^{R}$ are only estimated through 2008M1-2018M1 period.

Standard errors in parentheses are standard errors adjusted for cross-sectional correlation. *, **, and *** indicate that the alternative model significantly different from zero at 10%, 5%, and 1% significance level, respectively, based on standard normal critical values for the two-sided test.

Robustness of table 2B – full table of table 2B for $(\eta + l^R)_{j,t}$, extreme outliner of CHF at 2015M1 excluded

Estimation result of $\Delta s_{j,t} = \alpha_j + \beta_1 q_{j,t-1} + \beta_2 \Delta(\eta + l^R)_{j,t} + \beta_3 \Delta i^R_{j,t} + \beta_4 (\eta + l^R)_{j,t-1} + \beta_5 i^R_{j,t-1} + u_{j,t}$

	$q_{j,t-1}$	$\Delta(\eta + l^R)_{j,t}$	$\Delta i^R_{j,t}$	$(\eta + l^R)_{j,t-1}$	$i^R_{j,t-1}$	constant	N	R2_within
AUD	-0.0522***	-4.4479***	-6.7364***	-0.2415	-0.3564	0.0153**	954	0.2299
	(0.0157)	(0.9424)	(0.8535)	(0.6316)	(0.2251)	(0.0075)		
CAD	-0.0273**	-5.2887***	-8.2070***	-0.5082	0.6036**	0.0016	399	0.2497
	(0.0120)	(1.2257)	(1.1374)	(0.7763)	(0.2526)	(0.0037)		
EUR	-0.0406***	-4.0124***	-7.7359***	0.3185	-0.0381	-0.0115***	965	0.2564
	(0.0103)	(0.6037)	(0.5951)	(0.3991)	(0.1764)	(0.0037)		
JPY	-0.0692***	-4.5828***	-11.3109***	2.2805***	-0.1964	0.3253***	965	0.3217
	(0.0181)	(1.1377)	(1.1269)	(0.7851)	(0.2926)	(0.0818)		
NZD	-0.0519***	-5.2704***	-7.7770***	0.9965	0.2855	0.0037	942	0.2814
	(0.0151)	(0.9046)	(0.9226)	(0.6417)	(0.2518)	(0.0094)		
NOK	-0.0389***	-4.8577***	-7.9348***	0.9800**	-0.1026	0.0759***	965	0.2678
	(0.0107)	(0.6646)	(0.7161)	(0.4346)	(0.1908)	(0.0214)		
SEK	-0.0499***	-4.2427***	-6.3769***	-0.0080	0.0342	0.0973***	965	0.1952
	(0.0111)	(0.6756)	(0.7062)	(0.4504)	(0.1919)	(0.0221)		
CHF	-0.0233**	-2.4752**	-3.8496***	-0.1723	0.1487	-0.0052	881	0.0632
	(0.0106)	(0.9612)	(0.9103)	(0.5461)	(0.2060)	(0.0044)		
GBP	-0.0444***	-3.6011***	-8.1602***	0.8494	-0.1785	-0.0185***	965	0.2179
	(0.0138)	(0.8638)	(0.8653)	(0.5628)	(0.2370)	(0.0063)		
USD	-0.0596***	-4.5722***	-9.3961***	-0.8059	0.1448	-0.1144***	813	0.2957
	(0.0157)	(0.8519)	(0.9154)	(0.5794)	(0.2493)	(0.0311)		

The table reports the OLS estimates of the coefficient of the panel fixed effect regression listed above. The 10 currencies used are Australian Dollar (AUD), Canadian Dollar (CAD), Euro (EUR), Japanese Yen (JPY), New Zealand Dollar (NZD), Norwegian Krone (NOK), Swedish Krona (SEK), Swiss Franc (CHF), British Pound (GBP) and United States Dollar (USD). Each row represents a regression estimation using the first column currency as the home currency and the other 9 currencies as foreign currency j. $s_{j,t}$ is the nominal exchange rate between home and foreign country j, defined as home currency price of foreign currency, $q_{j,t}$ is the real exchange rate. $\tau_{j,t}$ is a measure of currency derivative friction, $l^R_{j,t}$ is a measure of home minus foreign default risk, $\lambda_{j,t}$ is a measure of the treasury liquidity after adjusting for derivative market friction and default risk, $i^R_{j,t}$ is the home minus foreign interest rates. Δ is a difference operator. The sample period is 1999M1-2018M1. Regressions involving default risk $\hat{l}^R_{j,t}$ are only estimated through 2008M1-2018M1 period.

Standard errors in parentheses are standard errors adjusted for cross-sectional correlation. *, **, and *** indicate that the alternative model significantly different from zero at 10%, 5%, and 1% significance level, respectively, based on standard normal critical values for the two-sided test.

Robustness of table 2B – full table of table 2B for $(\tau - l^R)_{j,t}$, extreme outliner of CHF at 2015M1 excluded

Estimation result of $\Delta s_{j,t} = \alpha_j + \beta_1 q_{j,t-1} + \beta_2 \Delta(\tau - l^R)_{j,t} + \beta_3 \Delta i^R_{j,t} + \beta_4 (\tau - l^R)_{j,t-1} + \beta_5 i^R_{j,t-1} + u_{j,t}$

	$q_{j,t-1}$	$\Delta(\tau - l^R)_{j,t}$	$\Delta i^R_{j,t}$	$(\tau - l^R)_{j,t-1}$	$i^R_{j,t-1}$	constant	N	R2_within
AUD	-0.0561***	-4.7837***	-5.9795***	-1.0041	-0.5195**	0.0207***	954	0.2127
	(0.0159)	(1.2895)	(0.7940)	(0.8484)	(0.2337)	(0.0080)		
CAD	-0.0357***	-1.8207	-6.8766***	-1.6425**	0.3688	0.0005	399	0.2204
	(0.0127)	(1.4376)	(1.0686)	(0.7696)	(0.2464)	(0.0036)		
EUR	-0.0484***	-2.3497***	-5.9865***	-1.4418***	-0.1389	-0.0184***	965	0.2161
	(0.0104)	(0.7944)	(0.5670)	(0.5189)	(0.1804)	(0.0041)		
JPY	-0.0570***	-6.2547***	-10.2499***	0.2292	-0.0145	0.2597***	965	0.2813
	(0.0186)	(1.6331)	(1.1204)	(1.0798)	(0.3086)	(0.0834)		
NZD	-0.0570***	-5.3858***	-6.6085***	-0.7078	0.2140	0.0088	942	0.2089
	(0.0159)	(1.3571)	(0.9433)	(0.9077)	(0.2660)	(0.0099)		
NOK	-0.0355***	-3.4656***	-5.2402***	-1.3365*	-0.0909	0.0657***	965	0.1477
	(0.0118)	(1.0828)	(0.7346)	(0.7222)	(0.2190)	(0.0231)		
SEK	-0.0554***	-3.7487***	-4.3686***	-1.1369*	-0.0270	0.1060***	965	0.1515
	(0.0114)	(0.9855)	(0.6629)	(0.6368)	(0.1942)	(0.0226)		
CHF	-0.0225**	-2.2309*	-2.8585***	-0.7918	0.1033	-0.0063	881	0.0502
	(0.0105)	(1.3036)	(0.8806)	(0.7633)	(0.2048)	(0.0039)		
GBP	-0.0489***	-0.5402	-6.1315***	-0.0555	-0.1844	-0.0199***	965	0.1691
	(0.0140)	(1.2007)	(0.8462)	(0.7509)	(0.2522)	(0.0066)		
USD	-0.0587***	-4.6762***	-8.4757***	-0.4799	0.0907	-0.1125***	813	0.2729
	(0.0161)	(1.1607)	(0.9006)	(0.8272)	(0.2501)	(0.0316)		

The table reports the OLS estimates of the coefficient of the panel fixed effect regression listed above. The 10 currencies used are Australian Dollar (AUD), Canadian Dollar (CAD), Euro (EUR), Japanese Yen (JPY), New Zealand Dollar (NZD), Norwegian Krone (NOK), Swedish Krona (SEK), Swiss Franc (CHF), British Pound (GBP) and United States Dollar (USD). Each row represents a regression estimation using the first column currency as the home currency and the other 9 currencies as foreign currency j. $s_{j,t}$ is the nominal exchange rate between home and foreign country j, defined as home currency price of foreign currency, $q_{j,t}$ is the real exchange rate. $\tau_{j,t}$ is a measure of currency derivative friction, $l^R_{j,t}$ is a measure of home minus foreign default risk, $\lambda_{j,t}$ is a measure of the treasury liquidity after adjusting for derivative market friction and default risk, $i^R_{j,t}$ is the home minus foreign interest rates. Δ is a difference operator. The sample period is 1999M1-2018M1. Regressions involving default risk $\hat{l}^R_{j,t}$ are only estimated through 2008M1-2018M1 period.

Standard errors in parentheses are standard errors adjusted for cross-sectional correlation. *, **, and *** indicate that the alternative model significantly different from zero at 10%, 5%, and 1% significance level, respectively, based on standard normal critical values for the two-sided test.

Robustness of table 3A – full table of table 3A, extreme outliner of CHF at 2015M1 excluded

IV Estimation result of $\Delta s_{j,t} = \alpha_j + \beta_1 q_{j,t-1} + \beta_2(\Delta\eta^{IV}_{j,t}) + \beta_3(\Delta i^R_{j,t}) + \beta_4(\eta^{IV}_{j,t-1}) + \beta_5(i^R_{j,t-1}) + u_{j,t}$

	$q_{j,t-1}$	$\Delta\eta^{IV}_{j,t}$	$\eta^{IV}_{j,t-1}$	$\Delta i^R_{j,t}$	$i^R_{j,t-1}$	constant	$\Delta\eta^{IV}_{j,t}$ 1st stage Adj R^2	$\eta^{IV}_{j,t-1}$ 1st stage Adj R^2	Cragg-Donald statistic	N
AUD	-0.02**	-16.95***	-2.16	-8.84***	-0.13	0.01*	0.21	0.46	9.06	1973
	(0.009)	(3.967)	(2.347)	(1.198)	(0.159)	(0.005)				
CAD	-0.03***	-7.95**	1.03	-6.29***	-0.29***	0.01**	0.11	0.57	6.49	1973
	(0.007)	(3.837)	(1.313)	(0.899)	(0.101)	(0.004)				
EUR	-0.03***	6.39	0.26	-3.31***	-0.24**	-0.01	0.09	0.53	2.72	1889
	(0.008)	(5.381)	(1.865)	(1.189)	(0.110)	(0.005)				
JPY	-0.04***	-10.68***	2.16	-7.79***	-0.18	0.21***	0.28	0.52	28.93	1973
	(0.011)	(2.713)	(1.879)	(0.880)	(0.127)	(0.058)				
NZD	-0.03***	-9.90***	0.90	-8.32***	-0.17	0.01**	0.34	0.52	11.07	1973
	(0.008)	(2.850)	(0.862)	(1.423)	(0.127)	(0.006)				
NOK	-0.03***	-3.00**	2.32**	-5.38***	-0.33***	0.07***	0.32	0.56	26.29	1889
	(0.008)	(1.439)	(1.028)	(0.660)	(0.124)	(0.018)				
SEK	-0.02***	-9.84***	-0.74	-6.40***	-0.10	0.04***	0.21	0.58	9.40	1973
	(0.007)	(2.818)	(0.758)	(1.048)	(0.109)	(0.015)				
CHF	-0.03***	1.17	2.18***	-2.74***	-0.20**	0.01**	0.25	0.57	23.19	1965
	(0.007)	(1.985)	(0.777)	(0.774)	(0.099)	(0.005)				
GBP	-0.03***	0.43	5.11**	-5.38***	-0.52***	-0.01**	0.26	0.51	10.33	1889
	(0.009)	(3.250)	(2.131)	(1.281)	(0.137)	(0.004)				
USD	-0.01*	-8.99***	-3.81***	-4.88***	0.02	-0.02	0.19	0.57	18.34	1973
	(0.007)	(2.305)	(0.941)	(0.780)	(0.117)	(0.015)				

The table reports the OLS estimates of the coefficient of the panel fixed effect regression listed above. The 10 currencies used are Australian Dollar (AUD), Canadian Dollar (CAD), Euro (EUR), Japanese Yen (JPY), New Zealand Dollar (NZD), Norwegian Krone (NOK), Swedish Krona (SEK), Swiss Franc (CHF), British Pound (GBP) and United States Dollar (USD). Each row represents a regression estimation using the first column currency as the home currency and the other 9 currencies as foreign currency j. $s_{j,t}$ is the nominal exchange rate between home and foreign country j, defined as home currency price of foreign currency, $q_{j,t}$ is the real exchange rate. $\eta^{IV}_{j,t}$ is a measure of the treasury liquidity, $i^R_{j,t}$ is the home minus foreign interest rates. Δ is a difference operator. The sample period is 1999M1-2018M1.

Standard errors in parentheses are standard errors adjusted for cross-sectional correlation. *, **, and *** indicate that the alternative model significantly different from zero at 10%, 5%, and 1% significance level, respectively, based on standard normal critical values for the two-sided test.

Robustness of table 3B – full table of table 3B, extreme outliner of CHF at 2015M1 excluded

IV Estimation result of $\Delta s_{j,t} = \alpha_j + \beta_1 q_{j,t-1} + \beta_2 \Delta\lambda^{IV}_{j,t} + \beta_3 \Delta i^R_{j,t} + \beta_4 \Delta\tau_{j,t} + \beta_5 \lambda^{IV}_{j,t-1} + \beta_6 i^R_{j,t-1} + \beta_7 \tau_{j,t-1} + u_{j,t}$

	$q_{j,t-1}$	$\Delta\lambda^{IV}_{j,t}$	$\lambda^{IV}_{j,t-1}$	$\Delta\tau_{j,t}$	$\tau_{j,t-1}$	$\Delta i^R_{j,t}$	$i^R_{j,t-1}$	$\Delta\lambda^{IV}_{j,t}$ 1st stage Adj R^2	$\lambda^{IV}_{j,t-1}$ 1st stage Adj R^2	Cragg-Donald statistic	N
AUD	-0.01	-27.11***	-5.84	-8.82***	-4.00*	-10.29***	0.24	0.20	0.49	4.25	1949
	(0.010)	(5.685)	(3.878)	(2.305)	(2.295)	(1.389)	(0.300)				
CAD	-0.03***	5.88	0.30	-3.30*	-0.64	-4.43***	-0.40***	0.13	0.64	2.58	1796
	(0.008)	(7.223)	(1.257)	(1.838)	(1.255)	(1.404)	(0.142)				
EUR	-0.02***	-11.85**	-1.32	-7.76***	-1.68	-7.24***	-0.18*	0.25	0.62	2.53	1878
	(0.007)	(5.716)	(1.228)	(2.280)	(1.184)	(1.483)	(0.106)				
JPY	-0.05***	-14.65***	2.31	-4.71***	2.41*	-8.52***	-0.18	0.19	0.53	17.30	1949
	(0.011)	(4.500)	(2.074)	(1.736)	(1.330)	(1.126)	(0.164)				
NZD	-0.03***	-7.97**	1.13	-6.00***	0.05	-7.48***	-0.26**	0.35	0.62	9.89	1949
	(0.008)	(3.202)	(0.816)	(1.444)	(0.971)	(1.502)	(0.132)				
NOK	-0.03***	-3.01**	2.32**	-4.52***	1.83*	-5.44***	-0.36***	0.39	0.57	28.25	1878
	(0.008)	(1.431)	(1.020)	(1.299)	(1.012)	(0.641)	(0.133)				
SEK	-0.02***	-8.52***	-0.68	-5.69***	-0.91	-5.93***	-0.09	0.22	0.59	8.78	1949
	(0.007)	(3.165)	(0.683)	(1.115)	(0.704)	(1.092)	(0.117)				
CHF	-0.02***	0.79	2.23***	-1.65	0.81	-2.89**	-0.26**	0.25	0.44	12.22	1941
	(0.007)	(3.239)	(0.841)	(1.138)	(0.770)	(1.131)	(0.112)				
GBP	-0.03***	-10.78**	4.34**	-1.90	4.10**	-9.15***	-0.45***	0.26	0.53	6.32	1878
	(0.009)	(4.635)	(1.791)	(1.538)	(1.607)	(1.708)	(0.153)				
USD	-0.01*	-13.47***	-4.22***	-7.73***	-1.78**	-5.82***	0.14	0.17	0.56	12.72	1949
	(0.007)	(3.189)	(1.106)	(1.263)	(0.870)	(0.920)	(0.141)				

The table reports the OLS estimates of the coefficient of the panel fixed effect regression listed above. The 10 currencies used are Australian Dollar (AUD), Canadian Dollar (CAD), Euro (EUR), Japanese Yen (JPY), New Zealand Dollar (NZD), Norwegian Krone (NOK), Swedish Krona (SEK), Swiss Franc (CHF), British Pound (GBP) and United States Dollar (USD). Each row represents a regression estimation using the first column currency as the home currency and the other 9 currencies as foreign currency j. $s_{j,t}$ is the nominal exchange rate between home and foreign country j, defined as home currency price of foreign currency, $q_{j,t}$ is the real exchange rate. $\lambda^{IV}_{j,t}$ is a measure of the treasury liquidity, $i^R_{j,t}$ is the home minus foreign interest rates. Δ is a difference operator. The sample period is 1999M1-2018M1.

Standard errors in parentheses are standard errors adjusted for cross-sectional correlation. *, **, and *** indicate that the alternative model significantly different from zero at 10%, 5%, and 1% significance level, respectively, based on standard normal critical values for the two-sided test.

Robustness of table 3C – full table of table 3C, extreme outliner of CHF at 2015M1 excluded

IV Estimation result of $\Delta s_{j,t} = \alpha_j + \beta_1 q_{j,t-1} + \beta_2 \Delta\lambda_{j,t}^{IV} + \beta_3 \Delta\tau_{j,t} + \beta_4 \Delta l_{j,t}^{R} + \beta_5 \Delta i_{j,t}^{R} + \beta_6 \lambda_{j,t-1}^{IV} + \beta_7 \tau_{j,t-1} + \beta_8 l_{j,t-1}^{R} + \beta_9 i_{j,t-1}^{R} + u_{j,t}$

	$q_{j,t-1}$	$\Delta\lambda_{j,t}^{IV}$	$\lambda_{j,t-1}^{IV}$	$\Delta i_{j,t}^{R}$	$i_{j,t-1}^{R}$	$\Delta\tau_{j,t}$	$\tau_{j,t-1}$	$\Delta l_{j,t}^{R}$	$l_{j,t-1}^{R}$	$\Delta\lambda_{j,t}^{IV}$ 1st stage Adj R2	$\lambda_{j,t-1}^{IV}$ 1st stage Adj R2	Cragg-Donald statistic	N
AUD	-0.05***	-13.20***	-0.03	-8.53***	-0.37	-3.73**	0.21	18.32***	-0.90	0.29	0.62	8.37	918
	(0.017)	(4.279)	(2.178)	(1.134)	(0.301)	(1.669)	(1.538)	(4.044)	(2.385)				
CAD	-0.02	-17.81**	-2.70	-10.94***	0.63	-10.56***	-4.64**	16.45**	1.12	0.54	0.81	1.68	363
	(0.018)	(7.807)	(3.169)	(2.113)	(0.424)	(3.629)	(2.188)	(7.328)	(3.396)				
EUR	-0.05***	-11.44**	-1.14	-9.88***	-0.16	-5.35***	-1.22	13.92***	3.29*	0.50	0.66	2.23	929
	(0.012)	(4.854)	(1.598)	(1.643)	(0.183)	(1.554)	(1.268)	(5.391)	(1.827)				
JPY	-0.07***	-11.16**	2.96	-12.29***	-0.17	-3.27*	3.73**	13.74***	-1.29	0.42	0.69	11.02	929
	(0.018)	(4.853)	(2.465)	(1.463)	(0.364)	(1.978)	(1.678)	(5.054)	(2.837)				
NZD	-0.04***	-9.16***	2.77**	-8.89***	0.00	-5.79***	1.42	13.35***	-1.71	0.38	0.60	12.52	906
	(0.015)	(3.056)	(1.379)	(1.091)	(0.276)	(1.498)	(1.341)	(3.881)	(1.675)				
NOK	-0.05***	-4.17***	-0.24	-7.31***	-0.20	-5.84***	-0.17	3.48	2.86*	0.57	0.69	31.78	929
	(0.012)	(1.328)	(0.957)	(0.944)	(0.207)	(1.284)	(1.100)	(2.272)	(1.676)				
SEK	-0.05***	-10.52***	-0.09	-8.12***	-0.06	-4.10***	-0.80	11.72***	-0.56	0.40	0.69	6.65	929
	(0.012)	(3.507)	(0.835)	(1.366)	(0.224)	(1.216)	(0.926)	(3.662)	(1.347)				
CHF	-0.03**	-0.35	-0.56	-3.00	0.06	-2.29	-0.58	2.78	2.19	0.50	0.69	5.88	845
	(0.012)	(5.653)	(1.124)	(2.184)	(0.235)	(1.946)	(1.078)	(5.750)	(1.692)				
GBP	-0.04***	-11.09**	1.45	-11.78***	-0.07	-0.85	3.21**	9.09**	-0.47	0.46	0.69	7.43	929
	(0.016)	(4.441)	(1.991)	(2.057)	(0.252)	(1.521)	(1.580)	(4.190)	(2.396)				
USD	-0.06***	-18.24***	-1.63	-12.37***	-0.05	-2.01	1.77	20.33***	2.26	0.41	0.68	8.60	777
	(0.015)	(3.416)	(1.249)	(1.229)	(0.244)	(1.376)	(1.114)	(3.427)	(1.656)				

The table reports the OLS estimates of the coefficient of the panel fixed effect regression listed above. The 10 currencies used are Australian Dollar (AUD), Canadian Dollar (CAD), Euro (EUR), Japanese Yen (JPY), New Zealand Dollar (NZD), Norwegian Krone (NOK), Swedish Krona (SEK), Swiss Franc (CHF), British Pound (GBP) and United States Dollar (USD). Each row represents a regression estimation using the first column currency as the home currency and the other 9 currencies as foreign currency j. $s_{j,t}$ is the nominal exchange rate between home and foreign country j, defined as home currency price of foreign currency, $q_{j,t}$ is the real exchange rate. $\lambda_{j,t}^{IV}$ is a measure of the treasury liquidity, $i_{j,t}^{R}$ is the home minus foreign interest rates. Δ is a difference operator. The sample period is 2008M1-2018M1.

Standard errors in parentheses are standard errors adjusted for cross-sectional correlation. *, **, and *** indicate that the alternative model significantly different from zero at 10%, 5%, and 1% significance level, respectively, based on standard normal critical values for the two-sided test.

Robustness of table 4A – full table of table 4A, extreme outliner of CHF at 2015M1 excluded

Estimation result of $\Delta s_{j,t} = \alpha_j + \beta_1 q_{j,t-1} + \beta_2 \Delta\tau_{j,t} + \beta_3 \Delta\gamma_t + \beta_4 \Delta\gamma^*_{j,t} + \beta_5 \Delta i^R_{j,t} + \beta_6 \gamma_{t-1} + \beta_7 \gamma^*_{j,t-1} + \beta_8 i^R_{j,t-1} + u_{j,t}$

	$q_{j,t-1}$	$\Delta\gamma^*_{j,t}$	$\Delta\gamma_t$	$\Delta\tau_{j,t}$	$\Delta i^R_{j,t}$	$\gamma^*_{j,t-1}$	γ_{t-1}	$\tau_{j,t-1}$	$i^R_{j,t-1}$	constant	N	R2 within
AUD	-0.0280***	5.5961***	-6.8581***	-2.9017**	-5.9156***	-0.1666	0.4068	-0.2829	-0.2816**	0.0110**	2027	0.2082
	(0.0071)	(0.6832)	(1.2076)	(1.2032)	(0.5360)	(0.3671)	(0.5979)	(0.7601)	(0.1105)	(0.0046)		
CAD	-0.0291***	4.5341***	-5.9784***	-5.3881***	-6.2179***	-0.5539	-0.2016	-0.2669	-0.2838***	0.0077**	1835	0.2149
	(0.0067)	(0.6815)	(1.9588)	(1.1120)	(0.5219)	(0.3941)	(1.2300)	(0.7169)	(0.1095)	(0.0035)		
EUR	-0.0199***	4.7862***	-5.2400***	-5.2134***	-5.2391***	0.1091	-0.1477	-0.4698	-0.1712*	-0.0050**	2027	0.1591
	(0.0058)	(0.5569)	(1.0692)	(0.8926)	(0.4055)	(0.3093)	(0.5161)	(0.5679)	(0.0923)	(0.0025)		
JPY	-0.0407***	4.3243***	-1.9827	-4.8411***	-6.4875***	-2.1454***	1.9348	2.0260**	-0.1486	0.1997***	2027	0.1767
	(0.0101)	(0.9876)	(5.1896)	(1.5851)	(0.7495)	(0.5721)	(2.4880)	(0.9619)	(0.1347)	(0.0474)		
NZD	-0.0326***	6.2598***	-6.8412***	-5.7259***	-6.4160***	0.9929*	0.1996	-0.8909	-0.1721	0.0114*	2027	0.2171
	(0.0076)	(0.8569)	(0.8899)	(1.2724)	(0.6085)	(0.5100)	(0.4249)	(0.7619)	(0.1252)	(0.0062)		
NOK	-0.0178***	5.6901***	-3.3614***	-5.1197***	-5.1663***	-0.1887	0.6584	0.5733	-0.1657*	0.0351**	2027	0.1698
	(0.0067)	(0.7323)	(0.7606)	(1.0386)	(0.4921)	(0.4132)	(0.4846)	(0.6837)	(0.0988)	(0.0141)		
SEK	-0.0223***	4.9061***	-3.9380***	-5.1512***	-4.7600***	0.5291	-0.0031	-0.7903	-0.1351	0.0421***	2027	0.1421
	(0.0063)	(0.6320)	(1.2143)	(0.9801)	(0.4649)	(0.3791)	(0.4870)	(0.6361)	(0.1024)	(0.0134)		
CHF	-0.0152**	3.5183***	-4.1800**	-1.8215*	-3.9956***	-0.4722	1.1342	0.1253	-0.2127**	0.0006	2019	0.0882
	(0.0066)	(0.6924)	(1.7224)	(1.0940)	(0.5113)	(0.3965)	(1.0083)	(0.7031)	(0.1002)	(0.0033)		
GBP	-0.0215***	4.8877***	-3.8070***	-1.3110	-5.6315***	-0.6401	0.8236	0.5672	-0.3345***	-0.0081**	2027	0.1451
	(0.0069)	(0.7036)	(1.0815)	(1.1103)	(0.5273)	(0.4029)	(0.5838)	(0.6936)	(0.1069)	(0.0037)		
USD	-0.0131*	6.3062***	-5.8798***	-6.5810***	-5.1169***	0.1079	-1.9605***	0.0112	-0.0255	-0.0192	2027	0.1917
	(0.0070)	(0.8049)	(1.3767)	(1.2061)	(0.5802)	(0.4530)	(0.5751)	(0.7353)	(0.1115)	(0.0147)		

The table reports the OLS estimates of the coefficient of the panel fixed effect regression listed above. The 10 currencies used are Australian Dollar (AUD), Canadian Dollar (CAD), Euro (EUR), Japanese Yen (JPY), New Zealand Dollar (NZD), Norwegian Krone (NOK), Swedish Krona (SEK), Swiss Franc (CHF), British Pound (GBP) and United States Dollar (USD). Each row represents a regression estimation using the first column currency as the home currency and the other 9 currencies as foreign currency j. $s_{j,t}$ is the nominal exchange rate between home and foreign country j, defined as home currency price of foreign currency, $q_{j,t}$ is the real exchange rate. $\tau_{j,t}$ is a measure of currency derivative friction, $\gamma^*_{j,t}$ is a measure of foreign treasury liquidity, $\gamma_{j,t}$ is a measure of the home treasury liquidity, $i^R_{j,t}$ is the home minus foreign interest rates. Δ is a difference operator. The sample period is 1999M1-2018M1.

Standard errors in parentheses are standard errors adjusted for cross-sectional correlation. *, **, and *** indicate that the alternative model significantly different from zero at 10%, 5%, and 1% significance level, respectively, based on standard normal critical values for the two-sided test.

10.Robustness: Regressions tables in the main text with CHF excluded

Robustness of table 1A – full table of table 1A, with CHF excluded

Estimation result of $\Delta s_{j,t} = \alpha_j + \beta_1 q_{j,t-1} + \beta_2(\Delta\tilde{\eta}_{j,t}) + \beta_3(\Delta i^R_{j,t}) + \beta_4(\tilde{\eta}_{j,t-1}) + \beta_5(i^R_{j,t-1}) + u_{j,t}$

	$q_{j,t-1}$	$\Delta\tilde{\eta}_{j,t}$	$\Delta i^R_{j,t}$	$\tilde{\eta}_{j,t-1}$	$i^R_{j,t-1}$	constant	N	R2_within
AUD	-0.0339***	-5.7707***	-5.9978***	0.0364	-0.2777***	0.0133***	1824	0.2087
	(0.0087)	(0.7140)	(0.5286)	(0.4316)	(0.1024)	(0.0042)		
CAD	-0.0334***	-4.9720***	-5.5980***	0.2538	-0.2460***	0.0076***	1824	0.1895
	(0.0072)	(0.6130)	(0.4751)	(0.3835)	(0.0922)	(0.0026)		
EUR	-0.0234***	-5.2314***	-5.4526***	-0.2984	-0.1668*	-0.0055**	1824	0.1663
	(0.0071)	(0.5501)	(0.4330)	(0.3393)	(0.0909)	(0.0023)		
JPY	-0.0471***	-4.4000***	-6.7706***	2.1643***	-0.1937	0.2293***	1824	0.1893
	(0.0117)	(0.9758)	(0.7389)	(0.5998)	(0.1269)	(0.0542)		
NZD	-0.0270***	-6.8214***	-6.3993***	0.0840	-0.1050	0.0122*	1824	0.2184
	(0.0097)	(0.7382)	(0.6065)	(0.4481)	(0.1184)	(0.0063)		
NOK	-0.0236***	-4.5295***	-5.1565***	0.5006	-0.1757*	0.0480***	1824	0.1730
	(0.0079)	(0.6353)	(0.4965)	(0.4113)	(0.0939)	(0.0160)		
SEK	-0.0276***	-4.8590***	-4.9335***	-0.4927	-0.1038	0.0559***	1824	0.1508
	(0.0075)	(0.5996)	(0.4748)	(0.3795)	(0.0970)	(0.0157)		
GBP	-0.0261***	-3.9282***	-5.4146***	0.5725	-0.3411***	-0.0093**	1824	0.1402
	(0.0078)	(0.6841)	(0.5271)	(0.4345)	(0.0984)	(0.0037)		
USD	-0.0158**	-6.6931***	-4.9629***	-1.3677***	-0.0583	-0.0302*	1824	0.1809
	(0.0077)	(0.7426)	(0.5750)	(0.4654)	(0.1039)	(0.0160)		

The table reports the OLS estimates of the coefficient of the panel fixed effect regression listed above. The 10 currencies used are Australian Dollar (AUD), Canadian Dollar (CAD), Euro (EUR), Japanese Yen (JPY), New Zealand Dollar (NZD), Norwegian Krone (NOK), Swedish Krona (SEK), Swiss Franc (CHF), British Pound (GBP) and United States Dollar (USD). Each row represents a regression estimation using the first column currency as the home currency and the other 8 currencies as foreign currency j. $s_{j,t}$ is the nominal exchange rate between home and foreign country j, defined as home currency price of foreign currency, $q_{j,t}$ is the real exchange rate. $\tilde{\eta}_{j,t}$ is a measure of the treasury liquidity, $i^R_{j,t}$ is the home minus foreign interest rates. Δ is a difference operator. The sample period is 1999M1-2018M1.

Standard errors in parentheses are standard errors adjusted for cross-sectional correlation. *, **, and *** indicate that the alternative model significantly different from zero at 10%, 5%, and 1% significance level, respectively, based on standard normal critical values for the two-sided test.

Robustness of table 1B – full table of table 1B, with CHF excluded

Estimation result of $\Delta s_{j,t} = \alpha_j + \beta_1 q_{j,t-1} + \beta_2(\Delta i^R_{j,t}) + \beta_3(i^R_{j,t-1}) + u_{j,t}$

	$q_{j,t-1}$	$\Delta i^R_{j,t}$	$i^R_{j,t-1}$	constant	N	R2_within
AUD	-0.0394***	-4.1914***	-0.3012***	0.0151***	1824	0.1262
	(0.0092)	(0.5036)	(0.1065)	(0.0045)		
CAD	-0.0364***	-4.5876***	-0.2409**	0.0076***	1824	0.1297
	(0.0074)	(0.4500)	(0.0936)	(0.0024)		
EUR	-0.0265***	-4.1544***	-0.1822**	-0.0052**	1824	0.1030
	(0.0073)	(0.4070)	(0.0926)	(0.0022)		
JPY	-0.0406***	-5.7467***	-0.2204	0.1882***	1824	0.1177
	(0.0122)	(0.7265)	(0.1345)	(0.0561)		
NZD	-0.0316***	-2.8511***	-0.0892	0.0137*	1824	0.0631
	(0.0111)	(0.5977)	(0.1311)	(0.0071)		
NOK	-0.0247***	-3.6090***	-0.1299	0.0489***	1824	0.0915
	(0.0084)	(0.4751)	(0.0947)	(0.0168)		
SEK	-0.0323***	-3.4127***	-0.1306	0.0664***	1824	0.0820
	(0.0079)	(0.4435)	(0.0986)	(0.0164)		
GBP	-0.0275***	-3.7175***	-0.3363***	-0.0104***	1824	0.0887
	(0.0080)	(0.4934)	(0.0997)	(0.0038)		
USD	-0.0169**	-3.8682***	-0.1297	-0.0346**	1824	0.0768
	(0.0085)	(0.5832)	(0.1109)	(0.0175)		

The table reports the OLS estimates of the coefficient of the panel fixed effect regression listed above. The 10 currencies used are Australian Dollar (AUD), Canadian Dollar (CAD), Euro (EUR), Japanese Yen (JPY), New Zealand Dollar (NZD), Norwegian Krone (NOK), Swedish Krona (SEK), Swiss Franc (CHF), British Pound (GBP) and United States Dollar (USD). Each row represents a regression estimation using the first column currency as the home currency and the other 8 currencies as foreign currency j. $s_{j,t}$ is the nominal exchange rate between home and foreign country j, defined as home currency price of foreign currency, $q_{j,t}$ is the real exchange rate. $\tilde{\eta}_{j,t}$ is a measure of the treasury liquidity, $i^R_{j,t}$ is the home minus foreign interest rates. Δ is a difference operator. The sample period is 1999M1-2018M1.

Standard errors in parentheses are standard errors adjusted for cross-sectional correlation. *, **, and *** indicate that the alternative model significantly different from zero at 10%, 5%, and 1% significance level, respectively, based on standard normal critical values for the two-sided test.

Robustness of table 1C – full table of table 1C 1999M1-2007M12, with CHF excluded

Estimation result of $\Delta s_{j,t} = \alpha_j + \beta_1 q_{j,t-1} + \beta_2(\Delta\tilde{\eta}_{j,t}) + \beta_3(\Delta i^R_{j,t}) + \beta_4(\tilde{\eta}_{j,t-1}) + \beta_5(i^R_{j,t-1}) + u_{j,t}$

	$q_{j,t-1}$	$\Delta\tilde{\eta}_{j,t}$	$\Delta i^R_{j,t}$	$\tilde{\eta}_{j,t-1}$	$i^R_{j,t-1}$	constant	N	R2_within
AUD	-0.0433***	-4.0743***	-3.5553***	-0.2706	-0.1409	0.0166**	864	0.0943
	(0.0167)	(1.1485)	(0.7484)	(0.7041)	(0.1599)	(0.0067)		
CAD	-0.0318**	-3.1122***	-3.4772***	-0.1338	-0.3094**	0.0073	864	0.0983
	(0.0148)	(1.0582)	(0.7152)	(0.6571)	(0.1509)	(0.0051)		
EUR	-0.0216	-3.1517***	-2.2988***	-0.3934	-0.1997	-0.0047	864	0.0491
	(0.0139)	(0.9009)	(0.5882)	(0.5896)	(0.1335)	(0.0031)		
JPY	-0.0493**	-1.2176	-1.9986**	0.6790	0.0858	0.2475**	864	0.0475
	(0.0199)	(1.3346)	(0.8917)	(0.8786)	(0.1795)	(0.0980)		
NZD	-0.0482***	-4.7768***	-3.8331***	-1.0448	-0.1660	0.0301***	864	0.1073
	(0.0169)	(1.1017)	(0.8496)	(0.6734)	(0.1623)	(0.0100)		
NOK	-0.0231	-3.8077***	-2.9528***	-0.0982	-0.0923	0.0443	864	0.0957
	(0.0155)	(1.0349)	(0.6648)	(0.6981)	(0.1370)	(0.0306)		
SEK	-0.0407***	-3.3855***	-2.6788***	-2.0091***	0.0058	0.0824***	864	0.0833
	(0.0145)	(0.9508)	(0.6368)	(0.6090)	(0.1425)	(0.0312)		
GBP	-0.0382***	-4.3386***	-3.0487***	-0.0971	-0.1709	-0.0189**	864	0.1009
	(0.0133)	(0.9140)	(0.5919)	(0.6238)	(0.1275)	(0.0076)		
USD	-0.0030	-4.0533***	-1.9258***	-1.4997**	-0.1651	-0.0013	864	0.0800
	(0.0121)	(1.1060)	(0.6965)	(0.7453)	(0.1482)	(0.0260)		

The table reports the OLS estimates of the coefficient of the panel fixed effect regression listed above. The 10 currencies used are Australian Dollar (AUD), Canadian Dollar (CAD), Euro (EUR), Japanese Yen (JPY), New Zealand Dollar (NZD), Norwegian Krone (NOK), Swedish Krona (SEK), Swiss Franc (CHF), British Pound (GBP) and United States Dollar (USD). Each row represents a regression estimation using the first column currency as the home currency and the other 8 currencies as foreign currency j. $s_{j,t}$ is the nominal exchange rate between home and foreign country j, defined as home currency price of foreign currency, $q_{j,t}$ is the real exchange rate. $\tilde{\eta}_{j,t}$ is a measure of the treasury liquidity, $i^R_{j,t}$ is the home minus foreign interest rates. Δ is a difference operator. The sample period is 2008M1-2018M1.

Standard errors in parentheses are standard errors adjusted for cross-sectional correlation. *, **, and *** indicate that the alternative model significantly different from zero at 10%, 5%, and 1% significance level, respectively, based on standard normal critical values for the two-sided test.

Robustness of table 1C – full table of table 1C 2008M1-2018M1, with CHF excluded

Estimation result of $\Delta s_{j,t} = \alpha_j + \beta_1 q_{j,t-1} + \beta_2(\Delta\tilde{\eta}_{j,t}) + \beta_3(\Delta i^R_{j,t}) + \beta_4(\tilde{\eta}_{j,t-1}) + \beta_5(i^R_{j,t-1}) + u_{j,t}$

	$q_{j,t-1}$	$\Delta\tilde{\eta}_{j,t}$	$\Delta i^R_{j,t}$	$\tilde{\eta}_{j,t-1}$	$i^R_{j,t-1}$	constant	N	R2_within
AUD	-0.0551***	-6.5375***	-7.7810***	0.1772	-0.4210*	0.0152**	960	0.3235
	(0.0161)	(0.8951)	(0.7416)	(0.6108)	(0.2158)	(0.0071)		
CAD	-0.0537***	-5.9988***	-7.7935***	0.0505	0.0134	0.0048	960	0.3131
	(0.0118)	(0.7276)	(0.6331)	(0.5010)	(0.1712)	(0.0029)		
EUR	-0.0436***	-5.9758***	-8.1407***	-0.4740	-0.1342	-0.0121***	960	0.3085
	(0.0123)	(0.6861)	(0.6129)	(0.4693)	(0.1898)	(0.0036)		
JPY	-0.0726***	-5.6558***	-11.8075***	2.2534**	-0.3162	0.2886***	960	0.3631
	(0.0200)	(1.2600)	(1.1183)	(0.9095)	(0.3021)	(0.0801)		
NZD	-0.0526***	-7.7335***	-8.5373***	0.3425	0.0747	0.0101	960	0.3549
	(0.0153)	(0.9770)	(0.8670)	(0.6626)	(0.2342)	(0.0091)		
NOK	-0.0428***	-5.5701***	-8.5901***	0.9560*	-0.2428	0.0671***	960	0.2962
	(0.0125)	(0.7802)	(0.7295)	(0.5491)	(0.1966)	(0.0220)		
SEK	-0.0542***	-5.8241***	-7.1465***	0.0956	-0.0489	0.0985***	960	0.2557
	(0.0133)	(0.7554)	(0.7063)	(0.5067)	(0.2007)	(0.0218)		
GBP	-0.0545***	-4.1554***	-8.1722***	0.6418	-0.3541	-0.0183***	960	0.2308
	(0.0165)	(0.9519)	(0.8591)	(0.6440)	(0.2391)	(0.0064)		
USD	-0.0507***	-7.5754***	-10.2740***	-0.7230	-0.0625	-0.0902***	960	0.3574
	(0.0146)	(0.8951)	(0.8249)	(0.6000)	(0.2299)	(0.0251)		

The table reports the OLS estimates of the coefficient of the panel fixed effect regression listed above. The 10 currencies used are Australian Dollar (AUD), Canadian Dollar (CAD), Euro (EUR), Japanese Yen (JPY), New Zealand Dollar (NZD), Norwegian Krone (NOK), Swedish Krona (SEK), Swiss Franc (CHF), British Pound (GBP) and United States Dollar (USD). Each row represents a regression estimation using the first column currency as the home currency and the other 8 currencies as foreign currency j. $s_{j,t}$ is the nominal exchange rate between home and foreign country j, defined as home currency price of foreign currency, $q_{j,t}$ is the real exchange rate. $\tilde{\eta}_{j,t}$ is a measure of the treasury liquidity, $i^R_{j,t}$ is the home minus foreign interest rates. Δ is a difference operator. The sample period is 2008M1-2018M1.

Standard errors in parentheses are standard errors adjusted for cross-sectional correlation. *, **, and *** indicate that the alternative model significantly different from zero at 10%, 5%, and 1% significance level, respectively, based on standard normal critical values for the two-sided test.

Robustness of table 1D – full table of table 1D, with CHF excluded

Estimation result of $\Delta s_{j,t} = \alpha_j + \beta_1 q_{j,t-1} + \beta_2(\Delta\tilde{\eta}_{j,t}) + \beta_3(\Delta i^R_{j,t}) + \beta_4(\tilde{\eta}_{j,t-1}) + \beta_5(i^R_{j,t-1}) + u_{j,t}$

	$q_{j,t-1}$	$\Delta\tilde{\eta}_{j,t}$	$\Delta i^R_{j,t}$	$\tilde{\eta}_{j,t-1}$	$i^R_{j,t-1}$	constant	N	R2_within
AUD	-0.0286***	-5.5617***	-5.2162***	0.0176	-0.3012***	0.0122***	1528	0.1466
	(0.0088)	(0.9275)	(0.6171)	(0.5136)	(0.1036)	(0.0043)		
CAD	-0.0290***	-5.1630***	-4.8499***	-0.0341	-0.2985***	0.0071***	1528	0.1437
	(0.0071)	(0.7797)	(0.5344)	(0.4319)	(0.0908)	(0.0026)		
EUR	-0.0210***	-6.1378***	-4.2496***	-0.8571**	-0.1624*	-0.0061***	1528	0.1157
	(0.0071)	(0.7527)	(0.5202)	(0.4077)	(0.0962)	(0.0023)		
JPY	-0.0420***	-1.9631	-3.9142***	1.9980***	-0.1678	0.2051***	1528	0.0681
	(0.0118)	(1.2780)	(0.8905)	(0.6505)	(0.1266)	(0.0546)		
NZD	-0.0226**	-6.4827***	-5.0164***	-0.5729	-0.1281	0.0113*	1528	0.1273
	(0.0101)	(0.9716)	(0.7316)	(0.5802)	(0.1215)	(0.0064)		
NOK	-0.0183**	-4.9083***	-4.5088***	0.3426	-0.1907*	0.0377**	1528	0.1266
	(0.0085)	(0.8965)	(0.6104)	(0.5216)	(0.1024)	(0.0174)		
SEK	-0.0225***	-4.7594***	-3.9331***	-0.6268	-0.1270	0.0451***	1528	0.1008
	(0.0076)	(0.8138)	(0.5745)	(0.4531)	(0.1015)	(0.0159)		
GBP	-0.0196**	-5.3764***	-4.3250***	0.0088	-0.2798***	-0.0078**	1528	0.0966
	(0.0077)	(0.9077)	(0.6147)	(0.5156)	(0.0984)	(0.0036)		
USD	-0.0123	-7.3617***	-4.6206***	-1.6579***	-0.0814	-0.0224	1528	0.1343
	(0.0079)	(1.0012)	(0.6833)	(0.5399)	(0.1056)	(0.0165)		

The table reports the OLS estimates of the coefficient of the panel fixed effect regression listed above. The 10 currencies used are Australian Dollar (AUD), Canadian Dollar (CAD), Euro (EUR), Japanese Yen (JPY), New Zealand Dollar (NZD), Norwegian Krone (NOK), Swedish Krona (SEK), Swiss Franc (CHF), British Pound (GBP) and United States Dollar (USD). Each row represents a regression estimation using the first column currency as the home currency and the other 8 currencies as foreign currency j. $s_{j,t}$ is the nominal exchange rate between home and foreign country j, defined as home currency price of foreign currency, $q_{j,t}$ is the real exchange rate. $\tilde{\eta}_{j,t}$ is a measure of the treasury liquidity, $i^R_{j,t}$ is the home minus foreign interest rates. Δ is a difference operator. The sample period is 1999M1-2018M1.

Standard errors in parentheses are standard errors adjusted for cross-sectional correlation. *, **, and *** indicate that the alternative model significantly different from zero at 10%, 5%, and 1% significance level, respectively, based on standard normal critical values for the two-sided test.

Robustness of table 1E – full table of table 1E (excluding U.S. dollar), with CHF excluded

Estimation result of $\Delta s_{j,t} = \alpha_j + \beta_1 q_{j,t-1} + \beta_2(\Delta\tilde{\eta}_{j,t}) + \beta_3(\Delta i^R_{j,t}) + \beta_4(\tilde{\eta}_{j,t-1}) + \beta_5(i^R_{j,t-1}) + u_{j,t}$

	$q_{j,t-1}$	$\Delta\tilde{\eta}_{j,t}$	$\Delta i^R_{j,t}$	$\tilde{\eta}_{j,t-1}$	$i^R_{j,t-1}$	constant	N	R2_within
AUD	-0.0417***	-5.2704***	-5.9295***	0.3636	-0.2945***	-0.0708***	1596	0.2073
	(0.0095)	(0.7031)	(0.5164)	(0.4384)	(0.1059)	(0.0163)		
CAD	-0.0432***	-4.6639***	-5.5561***	0.6765*	-0.3043***	-0.0789***	1596	0.1984
	(0.0086)	(0.6395)	(0.4875)	(0.4096)	(0.0994)	(0.0158)		
EUR	-0.0314***	-4.9848***	-5.4520***	0.1149	-0.2119**	-0.0702***	1596	0.1674
	(0.0079)	(0.5684)	(0.4360)	(0.3566)	(0.0948)	(0.0177)		
JPY	-0.0532***	-4.8625***	-7.1865***	2.3748***	-0.1796	0.1464***	1596	0.2040
	(0.0134)	(1.0352)	(0.7780)	(0.6527)	(0.1366)	(0.0348)		
NZD	-0.0335***	-6.5109***	-6.3905***	0.2658	-0.1162	-0.0542***	1596	0.2203
	(0.0106)	(0.7305)	(0.5986)	(0.4426)	(0.1222)	(0.0164)		
NOK	-0.0304***	-3.9795***	-5.2641***	0.8377**	-0.2447**	-0.0010	1596	0.1755
	(0.0088)	(0.6261)	(0.4907)	(0.4052)	(0.0962)	(0.0017)		
SEK	-0.0374***	-4.3404***	-4.9082***	0.0494	-0.1689*	0.0589***	1596	0.1470
	(0.0081)	(0.5907)	(0.4647)	(0.3750)	(0.0997)	(0.0125)		
GBP	-0.0276***	-4.1047***	-5.6502***	0.9126**	-0.3790***	-0.0675***	1596	0.1501
	(0.0086)	(0.7301)	(0.5560)	(0.4656)	(0.1100)	(0.0214)		

The table reports the OLS estimates of the coefficient of the panel fixed effect regression listed above. The 9 currencies used are Australian Dollar (AUD), Canadian Dollar (CAD), Euro (EUR), Japanese Yen (JPY), New Zealand Dollar (NZD), Norwegian Krone (NOK), Swedish Krona (SEK) and British Pound (GBP). We exclude Swiss Franc (CHF) and United States Dollar (USD) from all the regressions. Each row represents a regression estimation using the first column currency as the home currency and the other 7 currencies as foreign currency j. $s_{j,t}$ is the nominal exchange rate between home and foreign country j, defined as home currency price of foreign currency, $q_{j,t}$ is the real exchange rate. $\tilde{\eta}_{j,t}$ is a measure of the treasury liquidity, $i^R_{j,t}$ is the home minus foreign interest rates. Δ is a difference operator. The sample period is 1999M1-2018M1.

Standard errors in parentheses are standard errors adjusted for cross-sectional correlation. *, **, and *** indicate that the alternative model significantly different from zero at 10%, 5%, and 1% significance level, respectively, based on standard normal critical values for the two-sided test.

Robustness of table 1F – full table of table 1F, with CHF excluded

Estimation result of $\Delta s_{j,t} = \alpha_j + \beta_1 q_{j,t-1} + \beta_2(\Delta\tilde{\eta}_{j,t}) + \beta_3(\Delta i^R_{j,t}) + \beta_4(\tilde{\eta}_{j,t-1}) + \beta_5(i^R_{j,t-1}) + u_{j,t}$

	$q_{j,t-1}$	$\Delta\tilde{\eta}_{j,t}$	$\Delta i^R_{j,t}$	$\tilde{\eta}_{j,t-1}$	$i^R_{j,t-1}$	constant	N	R2_within
AUD	-0.0517**	-6.8823	-20.7537	-7.8786	-3.5718	0.0119	320	0.0460
	(0.0202)	(10.9945)	(13.9123)	(12.3911)	(2.7578)	(0.0089)		
CAD	-0.0322***	-13.9490***	-32.7070***	-9.3565*	-0.3054	0.0041	1120	0.0655
	(0.0090)	(4.2981)	(6.9136)	(4.9935)	(1.6557)	(0.0029)		
EUR	-0.0905***	-25.4278***	-44.1946***	-17.0089**	0.6397	-0.0239***	523	0.1384
	(0.0143)	(6.4942)	(9.2660)	(6.8064)	(2.3221)	(0.0042)		
JPY	-0.1070***	-22.8305**	-24.7507	-1.0194	-8.0759**	0.4955***	397	0.1336
	(0.0236)	(10.2244)	(19.5927)	(11.5514)	(3.6969)	(0.1077)		
NZD	-0.0323**	-20.2957***	-33.2623***	-12.7645*	0.7103	0.0073	1120	0.0724
	(0.0143)	(6.6694)	(9.7585)	(6.6508)	(2.1103)	(0.0093)		
SEK	-0.0332***	-16.5632***	-20.3370**	-10.7233**	-0.1962	0.0648***	1120	0.0526
	(0.0110)	(5.5384)	(8.2876)	(5.2088)	(1.6714)	(0.0228)		
GBP	-0.0228**	-8.4952**	-22.6602***	-8.3824*	-1.2993	-0.0119**	1120	0.0352
	(0.0100)	(4.0540)	(7.0246)	(4.4440)	(1.6564)	(0.0050)		
USD	-0.0235*	-16.9230***	-16.3964*	-16.4460***	1.1472	-0.0428	1120	0.0616
	(0.0136)	(6.0231)	(9.9272)	(6.1601)	(2.1943)	(0.0284)		

The table reports the OLS estimates of the coefficient of the panel fixed effect regression listed above. The 10 currencies used are Australian Dollar (AUD), Canadian Dollar (CAD), Euro (EUR), Japanese Yen (JPY), New Zealand Dollar (NZD), Norwegian Krone (NOK), Swedish Krona (SEK), Swiss Franc (CHF), British Pound (GBP) and United States Dollar (USD). Each row represents a regression estimation using the first column currency as the home currency and the other 8 currencies as foreign currency j. $s_{j,t}$ is the nominal exchange rate between home and foreign country j, defined as home currency price of foreign currency, $q_{j,t}$ is the real exchange rate. $\tilde{\eta}_{j,t}$ is a measure of the treasury liquidity, $i^R_{j,t}$ is the home minus foreign interest rates. Δ is a difference operator. The sample period is 1999M1-2018M1.

Standard errors in parentheses are standard errors adjusted for cross-sectional correlation. *, **, and *** indicate that the alternative model significantly different from zero at 10%, 5%, and 1% significance level, respectively, based on standard normal critical values for the two-sided test.

Robustness of table 1G – full table of table 1G, with CHF excluded

Estimation result of $\Delta s_{j,t} = \alpha_j + \beta_1 q_{j,t-1} + \beta_2 \Delta\hat{\eta}_{j,t} + \beta_3 \Delta i^R_{j,t} + \beta_4 \hat{\eta}_{j,t-1} + \beta_5 i^R_{j,t-1} + u_{j,t}$

	$q_{j,t-1}$	$\Delta\hat{\eta}_{j,t}$	$\Delta i^R_{j,t}$	$\hat{\eta}_{j,t-1}$	$i^R_{j,t-1}$	constant	N	R2_within
AUD	-0.0348***	-5.8705***	-5.7773***	0.3781	-0.3013***	0.0140***	1800	0.2081
	(0.0088)	(0.7577)	(0.5208)	(0.4054)	(0.1082)	(0.0044)		
CAD	-0.0353***	-3.7929***	-6.2774***	0.4883	-0.2594**	0.0072***	1632	0.1934
	(0.0078)	(0.7288)	(0.5167)	(0.3696)	(0.1091)	(0.0026)		
EUR	-0.0245***	-3.8766***	-5.4469***	-0.0556	-0.1406	-0.0048**	1800	0.1373
	(0.0073)	(0.6064)	(0.4362)	(0.3270)	(0.0967)	(0.0022)		
JPY	-0.0457***	-4.1483***	-6.6419***	1.7671***	-0.3665***	0.2148***	1800	0.1627
	(0.0118)	(1.0339)	(0.7602)	(0.5540)	(0.1409)	(0.0547)		
NZD	-0.0285***	-6.2101***	-6.0964***	0.2783	-0.1113	0.0128*	1800	0.1829
	(0.0101)	(0.8036)	(0.6243)	(0.4007)	(0.1278)	(0.0066)		
NOK	-0.0236***	-3.1411***	-4.5956***	0.3131	-0.1633	0.0471***	1800	0.1344
	(0.0082)	(0.6638)	(0.5065)	(0.3872)	(0.1025)	(0.0165)		
SEK	-0.0286***	-4.3899***	-4.7373***	-0.3903	-0.0683	0.0590***	1800	0.1278
	(0.0078)	(0.6509)	(0.4843)	(0.3567)	(0.1054)	(0.0161)		
GBP	-0.0251***	-4.4752***	-5.4642***	0.4355	-0.3362***	-0.0096**	1800	0.1435
	(0.0079)	(0.7348)	(0.5253)	(0.3950)	(0.1070)	(0.0037)		
USD	-0.0176**	-5.8134***	-4.8570***	-1.1732***	-0.0193	-0.0364**	1800	0.1395
	(0.0081)	(0.8484)	(0.6031)	(0.4405)	(0.1147)	(0.0168)		

The table reports the OLS estimates of the coefficient of the panel fixed effect regression listed above. The 10 currencies used are Australian Dollar (AUD), Canadian Dollar (CAD), Euro (EUR), Japanese Yen (JPY), New Zealand Dollar (NZD), Norwegian Krone (NOK), Swedish Krona (SEK), Swiss Franc (CHF), British Pound (GBP) and United States Dollar (USD). Each row represents a regression estimation using the first column currency as the home currency and the other 8 currencies as foreign currency j. $s_{j,t}$ is the nominal exchange rate between home and foreign country j, defined as home currency price of foreign currency, $q_{j,t}$ is the real exchange rate, $\hat{\eta}_{j,t}$ is a measure of the treasury liquidity, $i^R_{j,t}$ is the home minus foreign interest rates. Δ is a difference operator. The sample period is 1999M1-2018M1.

Standard errors in parentheses are standard errors adjusted for cross-sectional correlation. *, **, and *** indicate that the alternative model significantly different from zero at 10%, 5%, and 1% significance level, respectively, based on standard normal critical values for the two-sided test.

Robustness of table 2A – full table of table 2A, full sample, no default risk, with CHF excluded

Estimation result of $\Delta s_{j,t} = \alpha_j + \beta_1 q_{j,t-1} + \beta_2 \Delta\lambda_{j,t} + \beta_3 \Delta\tau_{j,t} + \beta_4 \Delta l^R_{j,t} + \beta_5 \Delta i^R_{j,t} + \beta_6 \lambda_{j,t-1} + \beta_7 \tau_{j,t-1} + \beta_8 l^R_{j,t-1} + \beta_9 i^R_{j,t-1} + u_{j,t}$

	$q_{j,t-1}$	$\Delta\lambda_{j,t}$	$\Delta\tau_{j,t}$	$\Delta i^R_{j,t}$	$\lambda_{j,t-1}$	$\tau_{j,t-1}$	$i^R_{j,t-1}$	constant	N	R2_within
AUD	-0.0346***	-6.4515***	-3.9071***	-6.0862***	0.1370	-0.7074	-0.3135***	0.0145***	1800	0.2191
	(0.0086)	(0.7720)	(1.2067)	(0.5250)	(0.4322)	(0.7555)	(0.1088)	(0.0043)		
CAD	-0.0344***	-4.9467***	-5.6085***	-6.2997***	0.3365	-0.3453	-0.2897***	0.0067***	1632	0.2244
	(0.0076)	(0.7116)	(1.0905)	(0.5056)	(0.4043)	(0.6865)	(0.1070)	(0.0026)		
EUR	-0.0220***	-5.2205***	-5.5812***	-5.4720***	-0.3186	-0.6202	-0.1542*	-0.0059**	1800	0.1711
	(0.0071)	(0.5985)	(0.9141)	(0.4283)	(0.3446)	(0.5440)	(0.0934)	(0.0024)		
JPY	-0.0473***	-4.1142***	-5.1573***	-6.8808***	2.1386***	2.0529**	-0.2182	0.2297***	1800	0.1945
	(0.0116)	(1.0137)	(1.6054)	(0.7443)	(0.6014)	(0.9654)	(0.1400)	(0.0540)		
NZD	-0.0316***	-7.0363***	-6.9714***	-6.6004***	0.0617	-1.1214	-0.1784	0.0162***	1800	0.2263
	(0.0092)	(0.7909)	(1.3167)	(0.6051)	(0.4403)	(0.8066)	(0.1249)	(0.0063)		
NOK	-0.0234***	-4.3438***	-5.8921***	-5.1996***	0.4728	0.5472	-0.1727*	0.0477***	1800	0.1781
	(0.0079)	(0.6680)	(1.0751)	(0.4951)	(0.4150)	(0.7104)	(0.0986)	(0.0161)		
SEK	-0.0265***	-4.7234***	-5.6800***	-4.9144***	-0.4683	-0.8071	-0.1090	0.0530***	1800	0.1528
	(0.0076)	(0.6535)	(1.0287)	(0.4775)	(0.3843)	(0.6625)	(0.1039)	(0.0159)		
GBP	-0.0252***	-4.7037***	-2.2087*	-5.6704***	0.5393	0.2393	-0.3404***	-0.0094**	1800	0.1491
	(0.0079)	(0.7517)	(1.1500)	(0.5290)	(0.4369)	(0.7212)	(0.1080)	(0.0038)		
USD	-0.0159**	-6.3490***	-7.6474***	-4.9476***	-1.3808***	-1.3348*	-0.0570	-0.0305*	1800	0.1837
	(0.0078)	(0.8291)	(1.2164)	(0.5827)	(0.4705)	(0.7342)	(0.1108)	(0.0163)		

The table reports the OLS estimates of the coefficient of the panel fixed effect regression listed above. The 10 currencies used are Australian Dollar (AUD), Canadian Dollar (CAD), Euro (EUR), Japanese Yen (JPY), New Zealand Dollar (NZD), Norwegian Krone (NOK), Swedish Krona (SEK), Swiss Franc (CHF), British Pound (GBP) and United States Dollar (USD). Each row represents a regression estimation using the first column currency as the home currency and the other 8 currencies as foreign currency j. $s_{j,t}$ is the nominal exchange rate between home and foreign country j, defined as home currency price of foreign currency, $q_{j,t}$ is the real exchange rate. $\tau_{j,t}$ is a measure of currency derivative friction, $l^R_{j,t}$ is a measure of home minus foreign default risk, $\lambda_{j,t}$ is a measure of the treasury liquidity after adjusting for derivative market friction and default risk, $i^R_{j,t}$ is the home minus foreign interest rates. Δ is a difference operator. The sample period is 1999M1-2018M1.

Standard errors in parentheses are standard errors adjusted for cross-sectional correlation. *, **, and *** indicate that the alternative model significantly different from zero at 10%, 5%, and 1% significance level, respectively, based on standard normal critical values for the two-sided test.

Robustness of table 2A – full table of table 2A, post 2008, with default risk, with CHF excluded

Estimation result of $\Delta s_{j,t} = \alpha_j + \beta_1 q_{j,t-1} + \beta_2 \Delta\lambda_{j,t} + \beta_3 \Delta\tau_{j,t} + \beta_4 \Delta l^R_{j,t} + \beta_5 \Delta i^R_{j,t} + \beta_6 \lambda_{j,t-1} + \beta_7 \tau_{j,t-1} + \beta_8 l^R_{j,t-1} + \beta_9 i^R_{j,t-1} + u_{j,t}$

	$q_{j,t-1}$	$\Delta\lambda_{j,t}$	$\Delta\tau_{j,t}$	$\Delta l^R_{j,t}$	$\Delta i^R_{j,t}$	$\lambda_{j,t-1}$	$\tau_{j,t-1}$	$l^R_{j,t-1}$	$i^R_{j,t-1}$	N	R2_within
AUD	-0.0617***	-7.3246***	-3.8874**	14.7095***	-7.5579***	-0.2044	-0.3545	0.2423	-0.4382*	847	0.3262
	(0.0178)	(1.1654)	(1.6683)	(2.4208)	(0.8274)	(0.7369)	(1.2455)	(1.4865)	(0.2287)		
CAD	-0.0455***	-8.4448***	-6.9717***	7.1595***	-8.8556***	-0.5355	-3.3505***	-1.0804	0.3126	354	0.3039
	(0.0160)	(1.5224)	(2.1366)	(2.5463)	(1.0602)	(0.9366)	(1.1584)	(1.5500)	(0.2427)		
EUR	-0.0511***	-6.8363***	-4.5878***	9.0551***	-8.5559***	-0.0906	-1.0481	1.9918*	-0.1184	858	0.3157
	(0.0127)	(0.7946)	(0.9673)	(1.6522)	(0.6143)	(0.4771)	(0.7207)	(1.0554)	(0.1834)		
JPY	-0.0796***	-6.3816***	-4.6534**	10.6119***	-11.6876***	2.3505***	3.3847**	0.1648	-0.2154	858	0.3766
	(0.0198)	(1.3792)	(1.8841)	(3.1280)	(1.1240)	(0.8395)	(1.4156)	(1.9424)	(0.2884)		
NZD	-0.0520***	-8.1048***	-6.8952***	12.9479***	-8.6530***	0.7225	0.5779	-0.0485	0.1744	835	0.3556
	(0.0157)	(1.1336)	(1.5240)	(2.4700)	(0.8896)	(0.7156)	(1.2405)	(1.3882)	(0.2432)		
NOK	-0.0515***	-5.4895***	-6.4144***	4.6641**	-8.4870***	0.8235	0.6662	1.2043	-0.2236	858	0.3044
	(0.0129)	(0.8189)	(1.2288)	(1.9507)	(0.7275)	(0.5414)	(0.9147)	(1.2657)	(0.2024)		
SEK	-0.0551***	-5.5748***	-4.8080***	7.4730***	-6.7519***	0.4073	-0.9178	-0.1588	-0.1047	858	0.2444
	(0.0132)	(0.8773)	(1.1882)	(1.9070)	(0.7165)	(0.5129)	(0.8747)	(1.1399)	(0.1964)		
GBP	-0.0551***	-6.4945***	-1.0137	5.8926**	-9.4345***	0.4629	1.9710*	0.8890	-0.1608	858	0.2605
	(0.0159)	(1.1199)	(1.4748)	(2.3784)	(0.8822)	(0.6763)	(1.0792)	(1.4716)	(0.2456)		
USD	-0.0642***	-8.7478***	-3.5078***	11.9301***	-10.3989***	-1.0270	0.2283	0.6063	0.0416	726	0.3903
	(0.0157)	(1.1105)	(1.2754)	(2.1573)	(0.8679)	(0.6560)	(0.9512)	(1.3786)	(0.2374)		

The table reports the OLS estimates of the coefficient of the panel fixed effect regression listed above. The 10 currencies used are Australian Dollar (AUD), Canadian Dollar (CAD), Euro (EUR), Japanese Yen (JPY), New Zealand Dollar (NZD), Norwegian Krone (NOK), Swedish Krona (SEK), Swiss Franc (CHF), British Pound (GBP) and United States Dollar (USD). Each row represents a regression estimation using the first column currency as the home currency and the other 8 currencies as foreign currency j. $s_{j,t}$ is the nominal exchange rate between home and foreign country j, defined as home currency price of foreign currency, $q_{j,t}$ is the real exchange rate. $\tau_{j,t}$ is a measure of currency derivative friction, $l^R_{j,t}$ is a measure of home minus foreign default risk, $\lambda_{j,t}$ is a measure of the treasury liquidity after adjusting for derivative market friction and default risk, $i^R_{j,t}$ is the home minus foreign interest rates. Δ is a difference operator. The sample period is 2008M1-2018M1.

Standard errors in parentheses are standard errors adjusted for cross-sectional correlation. *, **, and *** indicate that the alternative model significantly different from zero at 10%, 5%, and 1% significance level, respectively, based on standard normal critical values for the two-sided test.

Robustness of table 2B – full table of table 2B for $\lambda_{j,t}$, with CHF excluded

Estimation result of $\Delta s_{j,t} = \alpha_j + \beta_1 q_{j,t-1} + \beta_2 \Delta\lambda_{j,t} + \beta_3 \Delta i^R_{j,t} + \beta_4 \lambda_{j,t-1} + \beta_5 i^R_{j,t-1} + u_{j,t}$

	$q_{j,t-1}$	$\Delta\lambda_{j,t}$	$\Delta i^R_{j,t}$	$\lambda_{j,t-1}$	$i^R_{j,t-1}$	constant	N	R2_within
AUD	-0.0672***	-4.4248***	-6.5808***	0.2408	-0.4653*	0.0196**	847	0.2382
	(0.0193)	(1.1619)	(0.8799)	(0.6757)	(0.2495)	(0.0085)		
CAD	-0.0511***	-3.7008***	-7.9366***	0.8493	0.3676	0.0061	354	0.2519
	(0.0163)	(1.2409)	(1.0451)	(0.6358)	(0.2538)	(0.0038)		
EUR	-0.0455***	-3.5153***	-8.3289***	0.7925*	-0.0712	-0.0144***	858	0.2600
	(0.0126)	(0.7374)	(0.6268)	(0.4199)	(0.1932)	(0.0042)		
JPY	-0.0835***	-4.5211***	-11.0772***	2.0122***	-0.5438*	0.3806***	858	0.3066
	(0.0209)	(1.3730)	(1.1801)	(0.6918)	(0.3071)	(0.0940)		
NZD	-0.0521***	-4.9385***	-7.2324***	0.9889	0.2351	0.0062	835	0.2419
	(0.0173)	(1.1435)	(0.9663)	(0.6927)	(0.2691)	(0.0104)		
NOK	-0.0469***	-4.3751***	-7.6026***	0.9921**	-0.2045	0.0893***	858	0.2465
	(0.0130)	(0.7815)	(0.7458)	(0.4602)	(0.2141)	(0.0257)		
SEK	-0.0590***	-3.9851***	-6.3983***	0.4719	-0.0228	0.1144***	858	0.1925
	(0.0134)	(0.8146)	(0.7220)	(0.4667)	(0.2042)	(0.0264)		
GBP	-0.0531***	-5.3176***	-8.5520***	0.1501	-0.2299	-0.0228***	858	0.2389
	(0.0157)	(1.0253)	(0.8639)	(0.5670)	(0.2484)	(0.0070)		
USD	-0.0675***	-5.2872***	-10.1467***	-0.9025	0.0807	-0.1320***	726	0.3021
	(0.0181)	(1.0916)	(0.9333)	(0.6373)	(0.2665)	(0.0358)		

The table reports the OLS estimates of the coefficient of the panel fixed effect regression listed above. The 10 currencies used are Australian Dollar (AUD), Canadian Dollar (CAD), Euro (EUR), Japanese Yen (JPY), New Zealand Dollar (NZD), Norwegian Krone (NOK), Swedish Krona (SEK), Swiss Franc (CHF), British Pound (GBP) and United States Dollar (USD). Each row represents a regression estimation using the first column currency as the home currency and the other 8 currencies as foreign currency j. $s_{j,t}$ is the nominal exchange rate between home and foreign country j, defined as home currency price of foreign currency, $q_{j,t}$ is the real exchange rate. $\tau_{j,t}$ is a measure of currency derivative friction, $l^R_{j,t}$ is a measure of home minus foreign default risk, $\lambda_{j,t}$ is a measure of the treasury liquidity after adjusting for derivative market friction and default risk, $i^R_{j,t}$ is the home minus foreign interest rates. Δ is a difference operator. The sample period is 2008M1-2018M1. Regressions involving default risk $\hat{l}^R_{j,t}$ are only estimated through 2008M1-2018M1 period.

Standard errors in parentheses are standard errors adjusted for cross-sectional correlation. *, **, and *** indicate that the alternative model significantly different from zero at 10%, 5%, and 1% significance level, respectively, based on standard normal critical values for the two-sided test.

Robustness of table 2B – full table of table 2B for $\tau_{j,t}$, with CHF excluded

Estimation result of $\Delta s_{j,t} = \alpha_j + \beta_1 q_{j,t-1} + \beta_2 \Delta\tau_{j,t} + \beta_3 \Delta i^R_{j,t} + \beta_4 \tau_{j,t-1} + \beta_5 i^R_{j,t-1} + u_{j,t}$

	$q_{j,t-1}$	$\Delta\tau_{j,t}$	$\Delta i^R_{j,t}$	$\tau_{j,t-1}$	$i^R_{j,t-1}$	constant	N	R2_within
AUD	-0.0405***	-1.7697	-4.3301***	-0.7707	-0.3418***	0.0166***	1800	0.1309
	(0.0091)	(1.2550)	(0.5044)	(0.7354)	(0.1125)	(0.0046)		
CAD	-0.0370***	-4.3257***	-5.4073***	-0.7635	-0.3095***	0.0065***	1632	0.1841
	(0.0077)	(1.0847)	(0.4755)	(0.6156)	(0.1051)	(0.0025)		
EUR	-0.0241***	-3.5327***	-3.9699***	-0.3876	-0.1817*	-0.0056**	1800	0.1205
	(0.0072)	(0.9232)	(0.3950)	(0.4956)	(0.0928)	(0.0023)		
JPY	-0.0407***	-6.0205***	-6.0569***	0.6457	-0.1827	0.1903***	1800	0.1488
	(0.0119)	(1.6544)	(0.7067)	(0.9043)	(0.1416)	(0.0549)		
NZD	-0.0342***	-4.7384***	-3.1233***	-0.8494	-0.1438	0.0163**	1800	0.0882
	(0.0105)	(1.4436)	(0.5833)	(0.7968)	(0.1354)	(0.0070)		
NOK	-0.0240***	-3.3622***	-3.7628***	0.0667	-0.1315	0.0477***	1800	0.1075
	(0.0083)	(1.0822)	(0.4721)	(0.6669)	(0.0975)	(0.0168)		
SEK	-0.0300***	-4.8452***	-3.5053***	-0.5631	-0.1562	0.0605***	1800	0.1003
	(0.0078)	(1.0346)	(0.4356)	(0.6148)	(0.1022)	(0.0164)		
GBP	-0.0272***	-1.2267	-3.7831***	-0.4812	-0.3616***	-0.0107***	1800	0.0921
	(0.0081)	(1.1635)	(0.4942)	(0.6761)	(0.1083)	(0.0039)		
USD	-0.0158*	-6.5410***	-3.9408***	-0.9311	-0.1696	-0.0305*	1800	0.1115
	(0.0083)	(1.2465)	(0.5685)	(0.6747)	(0.1131)	(0.0174)		

The table reports the OLS estimates of the coefficient of the panel fixed effect regression listed above. The 10 currencies used are Australian Dollar (AUD), Canadian Dollar (CAD), Euro (EUR), Japanese Yen (JPY), New Zealand Dollar (NZD), Norwegian Krone (NOK), Swedish Krona (SEK), Swiss Franc (CHF), British Pound (GBP) and United States Dollar (USD). Each row represents a regression estimation using the first column currency as the home currency and the other 8 currencies as foreign currency j. $s_{j,t}$ is the nominal exchange rate between home and foreign country j, defined as home currency price of foreign currency, $q_{j,t}$ is the real exchange rate. $\tau_{j,t}$ is a measure of currency derivative friction, $l^R_{j,t}$ is a measure of home minus foreign default risk, $\lambda_{j,t}$ is a measure of the treasury liquidity after adjusting for derivative market friction and default risk, $i^R_{j,t}$ is the home minus foreign interest rates. Δ is a difference operator. The sample period is 1999M1-2018M1. Regressions involving default risk $\hat{l}^R_{j,t}$ are only estimated through 2008M1-2018M1 period.

Standard errors in parentheses are standard errors adjusted for cross-sectional correlation. *, **, and *** indicate that the alternative model significantly different from zero at 10%, 5%, and 1% significance level, respectively, based on standard normal critical values for the two-sided test.

Robustness of table 2B – full table of table 2B for $l^R_{j,t}$, with CHF excluded

Estimation result of $\Delta s_{j,t} = \alpha_j + \beta_1 q_{j,t-1} + \beta_2 \Delta l^R_{j,t} + \beta_3 \Delta i^R_{j,t} + \beta_4 l^R_{j,t-1} + \beta_5 i^R_{j,t-1} + u_{j,t}$

	$q_{j,t-1}$	$\Delta l^R_{j,t}$	$\Delta i^R_{j,t}$	$l^R_{j,t-1}$	$i^R_{j,t-1}$	constant	N	R2_within
AUD	-0.0709***	10.2422***	-5.8959***	0.7815	-0.5038**	0.0217***	847	0.2379
	(0.0190)	(2.3201)	(0.7922)	(1.4180)	(0.2329)	(0.0081)		
CAD	-0.0483***	0.1008	-6.8726***	0.7753	0.4390*	0.0046	354	0.2127
	(0.0169)	(2.1774)	(0.9851)	(1.2343)	(0.2329)	(0.0040)		
EUR	-0.0551***	2.1824	-6.6515***	2.3728**	-0.0966	-0.0153***	858	0.2218
	(0.0134)	(1.5534)	(0.5770)	(0.9814)	(0.1934)	(0.0043)		
JPY	-0.0721***	5.4482*	-10.1721***	2.0152	-0.1757	0.3261***	858	0.2702
	(0.0220)	(3.0734)	(1.1441)	(1.8770)	(0.3204)	(0.0991)		
NZD	-0.0668***	4.9577*	-6.1932***	2.0583	0.2756	0.0081	835	0.1789
	(0.0179)	(2.6064)	(0.9647)	(1.4513)	(0.2740)	(0.0105)		
NOK	-0.0569***	-1.0191	-5.4385***	2.7889**	-0.1983	0.1110***	858	0.1554
	(0.0146)	(1.9705)	(0.7216)	(1.2065)	(0.2295)	(0.0290)		
SEK	-0.0616***	3.2781*	-4.6074***	1.3203	0.0276	0.1208***	858	0.1470
	(0.0142)	(1.8187)	(0.6598)	(1.1054)	(0.1994)	(0.0280)		
GBP	-0.0578***	1.0074	-6.1628***	1.3975	-0.2703	-0.0241***	858	0.1834
	(0.0169)	(2.2452)	(0.8340)	(1.2906)	(0.2572)	(0.0076)		
USD	-0.0623***	4.5951**	-8.9423***	-0.7163	0.0935	-0.1206***	726	0.2711
	(0.0187)	(2.1035)	(0.8860)	(1.3652)	(0.2679)	(0.0369)		

The table reports the OLS estimates of the coefficient of the panel fixed effect regression listed above. The 10 currencies used are Australian Dollar (AUD), Canadian Dollar (CAD), Euro (EUR), Japanese Yen (JPY), New Zealand Dollar (NZD), Norwegian Krone (NOK), Swedish Krona (SEK), Swiss Franc (CHF), British Pound (GBP) and United States Dollar (USD). Each row represents a regression estimation using the first column currency as the home currency and the other 8 currencies as foreign currency j. $s_{j,t}$ is the nominal exchange rate between home and foreign country j, defined as home currency price of foreign currency, $q_{j,t}$ is the real exchange rate. $\tau_{j,t}$ is a measure of currency derivative friction, $l^R_{j,t}$ is a measure of home minus foreign default risk, $\lambda_{j,t}$ is a measure of the treasury liquidity after adjusting for derivative market friction and default risk, $i^R_{j,t}$ is the home minus foreign interest rates. Δ is a difference operator. The sample period is 1999M1-2018M1. Regressions involving default risk $\hat{l}^R_{j,t}$ are only estimated through 2008M1-2018M1 period.

Standard errors in parentheses are standard errors adjusted for cross-sectional correlation. *, **, and *** indicate that the alternative model significantly different from zero at 10%, 5%, and 1% significance level, respectively, based on standard normal critical values for the two-sided test.

Robustness of table 2B – full table of table 2B for $(\eta + l^R)_{j,t}$, with CHF excluded

Estimation result of $\Delta s_{j,t} = \alpha_j + \beta_1 q_{j,t-1} + \beta_2 \Delta(\eta + l^R)_{j,t} + \beta_3 \Delta i^R_{j,t} + \beta_4 (\eta + l^R)_{j,t-1} + \beta_5 i^R_{j,t-1} + u_{j,t}$

	$q_{j,t-1}$	$\Delta(\eta + l^R)_{j,t}$	$\Delta i^R_{j,t}$	$(\eta + l^R)_{j,t-1}$	$i^R_{j,t-1}$	constant	N	R2_within
AUD	-0.0630***	-4.7002***	-7.0058***	0.0107	-0.4190*	0.0179**	847	0.2519
	(0.0192)	(0.9771)	(0.8899)	(0.6951)	(0.2385)	(0.0083)		
CAD	-0.0417***	-5.4191***	-8.2019***	-0.4889	0.5181**	0.0038	354	0.2589
	(0.0157)	(1.2842)	(1.0569)	(0.7942)	(0.2442)	(0.0040)		
EUR	-0.0414***	-4.3067***	-8.0713***	0.2874	-0.0551	-0.0120***	858	0.2770
	(0.0126)	(0.6303)	(0.6024)	(0.4333)	(0.1858)	(0.0043)		
JPY	-0.0837***	-4.3901***	-11.5411***	2.7494***	-0.3579	0.3926***	858	0.3493
	(0.0202)	(1.1684)	(1.1203)	(0.8290)	(0.3012)	(0.0915)		
NZD	-0.0494***	-5.6105***	-8.0163***	1.1609*	0.2846	0.0027	835	0.2995
	(0.0163)	(0.9354)	(0.9160)	(0.6846)	(0.2499)	(0.0098)		
NOK	-0.0483***	-5.0881***	-8.2944***	1.1234**	-0.1994	0.0948***	858	0.2954
	(0.0124)	(0.6828)	(0.7082)	(0.4519)	(0.2010)	(0.0247)		
SEK	-0.0544***	-4.3539***	-6.7184***	0.2382	-0.0056	0.1064***	858	0.2141
	(0.0135)	(0.6926)	(0.7071)	(0.4719)	(0.1984)	(0.0267)		
GBP	-0.0514***	-3.8162***	-8.3340***	0.8929	-0.2739	-0.0213***	858	0.2336
	(0.0160)	(0.8934)	(0.8693)	(0.6071)	(0.2450)	(0.0072)		
USD	-0.0689***	-4.7561***	-9.7078***	-0.9760	0.0265	-0.1325***	726	0.3179
	(0.0175)	(0.8636)	(0.8951)	(0.6069)	(0.2589)	(0.0346)		

The table reports the OLS estimates of the coefficient of the panel fixed effect regression listed above. The 10 currencies used are Australian Dollar (AUD), Canadian Dollar (CAD), Euro (EUR), Japanese Yen (JPY), New Zealand Dollar (NZD), Norwegian Krone (NOK), Swedish Krona (SEK), Swiss Franc (CHF), British Pound (GBP) and United States Dollar (USD). Each row represents a regression estimation using the first column currency as the home currency and the other 8 currencies as foreign currency j. $s_{j,t}$ is the nominal exchange rate between home and foreign country j, defined as home currency price of foreign currency, $q_{j,t}$ is the real exchange rate. $\tau_{j,t}$ is a measure of currency derivative friction, $l^R_{j,t}$ is a measure of home minus foreign default risk, $\lambda_{j,t}$ is a measure of the treasury liquidity after adjusting for derivative market friction and default risk, $i^R_{j,t}$ is the home minus foreign interest rates. Δ is a difference operator. The sample period is 1999M1-2018M1. Regressions involving default risk $\hat{l}^R_{j,t}$ are only estimated through 2008M1-2018M1 period.

Standard errors in parentheses are standard errors adjusted for cross-sectional correlation. *, **, and *** indicate that the alternative model significantly different from zero at 10%, 5%, and 1% significance level, respectively, based on standard normal critical values for the two-sided test.

Robustness of table 2B – full table of table 2B for $(\tau - l^R)_{j,t}$, with CHF excluded

Estimation result of $\Delta s_{j,t} = \alpha_j + \beta_1 q_{j,t-1} + \beta_2 \Delta(\tau - l^R)_{j,t} + \beta_3 \Delta i^R_{j,t} + \beta_4 (\tau - l^R)_{j,t-1} + \beta_5 i^R_{j,t-1} + u_{j,t}$

	$q_{j,t-1}$	$\Delta(\tau - l^R)_{j,t}$	$\Delta i^R_{j,t}$	$(\tau - l^R)_{j,t-1}$	$i^R_{j,t-1}$	constant	N	R2_within
AUD	-0.0692***	-5.1221***	-6.1511***	-1.1610	-0.5801**	0.0241***	847	0.2325
	(0.0198)	(1.4415)	(0.8318)	(0.8906)	(0.2558)	(0.0090)		
CAD	-0.0546***	-0.9734	-6.8016***	-1.4092**	0.2937	0.0038	354	0.2260
	(0.0173)	(1.4441)	(0.9776)	(0.7024)	(0.2374)	(0.0040)		
EUR	-0.0551***	-2.6557***	-6.2226***	-1.6343***	-0.2007	-0.0210***	858	0.2349
	(0.0129)	(0.8257)	(0.5716)	(0.5352)	(0.1913)	(0.0048)		
JPY	-0.0649***	-6.5977***	-10.5294***	0.3689	-0.0817	0.2959***	858	0.3075
	(0.0210)	(1.6615)	(1.1122)	(1.0688)	(0.3203)	(0.0942)		
NZD	-0.0555***	-5.8720***	-6.7651***	-0.7393	0.2174	0.0082	835	0.2212
	(0.0178)	(1.4145)	(0.9388)	(0.9304)	(0.2702)	(0.0105)		
NOK	-0.0482***	-3.7168***	-5.4454***	-1.4094*	-0.2222	0.0908***	858	0.1622
	(0.0143)	(1.1084)	(0.7334)	(0.7277)	(0.2322)	(0.0278)		
SEK	-0.0602***	-4.0482***	-4.5861***	-1.1476*	-0.0488	0.1152***	858	0.1671
	(0.0138)	(1.0247)	(0.6569)	(0.6490)	(0.1981)	(0.0272)		
GBP	-0.0578***	-0.7623	-6.2034***	-0.1776	-0.3052	-0.0237***	858	0.1816
	(0.0166)	(1.2445)	(0.8440)	(0.7551)	(0.2644)	(0.0076)		
USD	-0.0638***	-4.4516***	-8.8626***	-0.2944	0.0152	-0.1229***	726	0.2877
	(0.0183)	(1.1720)	(0.8814)	(0.8251)	(0.2657)	(0.0359)		

The table reports the OLS estimates of the coefficient of the panel fixed effect regression listed above. The 10 currencies used are Australian Dollar (AUD), Canadian Dollar (CAD), Euro (EUR), Japanese Yen (JPY), New Zealand Dollar (NZD), Norwegian Krone (NOK), Swedish Krona (SEK), Swiss Franc (CHF), British Pound (GBP) and United States Dollar (USD). Each row represents a regression estimation using the first column currency as the home currency and the other 8 currencies as foreign currency j. $s_{j,t}$ is the nominal exchange rate between home and foreign country j, defined as home currency price of foreign currency, $q_{j,t}$ is the real exchange rate. $\tau_{j,t}$ is a measure of currency derivative friction, $l^R_{j,t}$ is a measure of home minus foreign default risk, $\lambda_{j,t}$ is a measure of the treasury liquidity after adjusting for derivative market friction and default risk, $i^R_{j,t}$ is the home minus foreign interest rates. Δ is a difference operator. The sample period is 1999M1-2018M1. Regressions involving default risk $\hat{l}^R_{j,t}$ are only estimated through 2008M1-2018M1 period.

Standard errors in parentheses are standard errors adjusted for cross-sectional correlation. *, **, and *** indicate that the alternative model significantly different from zero at 10%, 5%, and 1% significance level, respectively, based on standard normal critical values for the two-sided test.

Robustness of table 3A – full table of table 3A, with CHF excluded

IV Estimation result of $\Delta s_{j,t} = \alpha_j + \beta_1 q_{j,t-1} + \beta_2(\Delta\eta^{IV}_{j,t}) + \beta_3(\Delta i^R_{j,t}) + \beta_4(\eta^{IV}_{j,t-1}) + \beta_5(i^R_{j,t-1}) + u_{j,t}$

	$q_{j,t-1}$	$\Delta\eta^{IV}_{j,t}$	$\eta^{IV}_{j,t-1}$	$\Delta i^R_{j,t}$	$i^R_{j,t-1}$	constant	$\Delta\eta^{IV}_{j,t}$ 1st stage Adj R^2	$\eta^{IV}_{j,t-1}$ 1st stage Adj R^2	Cragg-Donald statistic	N
AUD	-0.02**	-20.47***	-2.73	-9.80***	-0.10	0.01*	0.21	0.44	7.21	1750
	(0.011)	(4.422)	(1.995)	(1.347)	(0.148)	(0.005)				
CAD	-0.03***	-8.99**	0.51	-6.57***	-0.26***	0.01**	0.10	0.53	4.42	1750
	(0.008)	(4.323)	(1.163)	(1.013)	(0.099)	(0.004)				
EUR	-0.03***	6.55	0.92	-3.62***	-0.23**	-0.00	0.10	0.48	4.25	1680
	(0.009)	(4.403)	(1.415)	(1.000)	(0.111)	(0.005)				
JPY	-0.05***	-9.84***	1.87	-8.07***	-0.26**	0.24***	0.31	0.46	38.94	1750
	(0.013)	(2.457)	(1.494)	(0.864)	(0.129)	(0.061)				
NZD	-0.02**	-11.21***	0.90	-8.97***	-0.16	0.01*	0.33	0.52	9.52	1750
	(0.010)	(2.962)	(0.877)	(1.435)	(0.125)	(0.007)				
NOK	-0.03***	-3.35**	2.09**	-5.50***	-0.32***	0.06***	0.32	0.53	22.75	1680
	(0.009)	(1.535)	(1.015)	(0.688)	(0.124)	(0.018)				
SEK	-0.02***	-8.90***	-0.96	-6.25***	-0.08	0.05***	0.23	0.56	9.89	1750
	(0.008)	(2.624)	(0.789)	(1.025)	(0.110)	(0.017)				
GBP	-0.03***	0.89	4.65***	-5.10***	-0.51***	-0.01	0.27	0.48	12.08	1680
	(0.009)	(2.813)	(1.532)	(1.135)	(0.126)	(0.004)				
USD	-0.02**	-10.51***	-3.96***	-5.21***	0.05	-0.04**	0.19	0.56	14.66	1750
	(0.008)	(2.447)	(0.998)	(0.818)	(0.118)	(0.017)				

The table reports the OLS estimates of the coefficient of the panel fixed effect regression listed above. The 10 currencies used are Australian Dollar (AUD), Canadian Dollar (CAD), Euro (EUR), Japanese Yen (JPY), New Zealand Dollar (NZD), Norwegian Krone (NOK), Swedish Krona (SEK), Swiss Franc (CHF), British Pound (GBP) and United States Dollar (USD). Each row represents a regression estimation using the first column currency as the home currency and the other 8 currencies as foreign currency j. $s_{j,t}$ is the nominal exchange rate between home and foreign country j, defined as home currency price of foreign currency, $q_{j,t}$ is the real exchange rate. $\eta^{IV}_{j,t}$ is a measure of the treasury liquidity, $i^R_{j,t}$ is the home minus foreign interest rates. Δ is a difference operator. The sample period is 1999M1-2018M1.

Standard errors in parentheses are standard errors adjusted for cross-sectional correlation. *, **, and *** indicate that the alternative model significantly different from zero at 10%, 5%, and 1% significance level, respectively, based on standard normal critical values for the two-sided test.

Robustness of table 3B – full table of table 3B, with CHF excluded

IV Estimation result of $\Delta s_{j,t} = \alpha_j + \beta_1 q_{j,t-1} + \beta_2 \Delta\lambda_{j,t}^{IV} + \beta_3 \Delta i_{j,t}^{R} + \beta_4 \Delta\tau_{j,t} + \beta_5 \lambda_{j,t-1}^{IV} + \beta_6 i_{j,t-1}^{R} + \beta_7 \tau_{j,t-1} + u_{j,t}$

	$q_{j,t-1}$	$\Delta\lambda_{j,t}^{IV}$	$\lambda_{j,t-1}^{IV}$	$\Delta\tau_{j,t}$	$\tau_{j,t-1}$	$\Delta i_{j,t}^{R}$	$i_{j,t-1}^{R}$	$\Delta\lambda_{j,t}^{IV}$ 1st stage Adj R^2	$\lambda_{j,t-1}^{IV}$ 1st stage Adj R^2	Cragg-Donald statistic	N
AUD	-0.02*	-25.46***	-3.27	-10.37***	-3.14*	-10.23***	0.01	0.21	0.50	6.65	1726
	(0.011)	(4.982)	(2.132)	(2.278)	(1.666)	(1.313)	(0.188)				
CAD	-0.04***	4.54	0.18	-3.25*	-0.80	-4.72***	-0.39***	0.15	0.64	2.65	1597
	(0.009)	(6.342)	(1.115)	(1.949)	(1.216)	(1.243)	(0.136)				
EUR	-0.02***	-6.99	-0.45	-6.17**	-0.93	-6.25***	-0.20*	0.24	0.61	2.27	1669
	(0.008)	(5.830)	(1.132)	(2.409)	(1.072)	(1.445)	(0.106)				
JPY	-0.05***	-13.97***	1.81	-4.99***	2.14*	-8.88***	-0.26	0.21	0.50	17.79	1726
	(0.013)	(4.102)	(1.634)	(1.711)	(1.183)	(1.092)	(0.167)				
NZD	-0.03***	-8.83***	0.94	-7.23***	-0.31	-7.89***	-0.25*	0.34	0.64	9.41	1726
	(0.010)	(3.071)	(0.815)	(1.526)	(1.061)	(1.396)	(0.129)				
NOK	-0.03***	-3.39**	2.10**	-5.31***	1.58	-5.58***	-0.35***	0.40	0.57	24.67	1669
	(0.008)	(1.506)	(1.011)	(1.371)	(1.059)	(0.664)	(0.131)				
SEK	-0.02***	-8.14***	-0.98	-6.27***	-1.16	-5.96***	-0.07	0.24	0.58	8.45	1726
	(0.008)	(3.080)	(0.720)	(1.206)	(0.774)	(1.103)	(0.120)				
GBP	-0.03***	-8.80**	4.17***	-2.13	3.82***	-8.31***	-0.47***	0.25	0.53	5.79	1669
	(0.009)	(4.376)	(1.417)	(1.552)	(1.417)	(1.570)	(0.142)				
USD	-0.02**	-14.09***	-4.06***	-9.14***	-2.40**	-5.99***	0.12	0.18	0.55	11.53	1726
	(0.009)	(3.166)	(1.104)	(1.342)	(0.963)	(0.925)	(0.140)				

The table reports the OLS estimates of the coefficient of the panel fixed effect regression listed above. The 10 currencies used are Australian Dollar (AUD), Canadian Dollar (CAD), Euro (EUR), Japanese Yen (JPY), New Zealand Dollar (NZD), Norwegian Krone (NOK), Swedish Krona (SEK), Swiss Franc (CHF), British Pound (GBP) and United States Dollar (USD). Each row represents a regression estimation using the first column currency as the home currency and the other 8 currencies as foreign currency j. $s_{j,t}$ is the nominal exchange rate between home and foreign country j, defined as home currency price of foreign currency, $q_{j,t}$ is the real exchange rate. $\lambda_{j,t}^{IV}$ is a measure of the treasury liquidity, $i_{j,t}^{R}$ is the home minus foreign interest rates. Δ is a difference operator. The sample period is 1999M1-2018M1.

Standard errors in parentheses are standard errors adjusted for cross-sectional correlation. *, **, and *** indicate that the alternative model significantly different from zero at 10%, 5%, and 1% significance level, respectively, based on standard normal critical values for the two-sided test.

Robustness of table 3C – full table of table 3C, with CHF excluded

IV Estimation result of $\Delta s_{j,t} = \alpha_j + \beta_1 q_{j,t-1} + \beta_2 \Delta\lambda_{j,t}^{IV} + \beta_3 \Delta\tau_{j,t} + \beta_4 \Delta l_{j,t}^{R} + \beta_5 \Delta i_{j,t}^{R} + \beta_6 \lambda_{j,t-1}^{IV} + \beta_7 \tau_{j,t-1} + \beta_8 l_{j,t-1}^{R} + \beta_9 i_{j,t-1}^{R} + u_{j,t}$

	$q_{j,t-1}$	$\Delta\lambda_{j,t}^{IV}$	$\lambda_{j,t-1}^{IV}$	$\Delta i_{j,t}^{R}$	$i_{j,t-1}^{R}$	$\Delta\tau_{j,t}$	$\tau_{j,t-1}$	$\Delta l_{j,t}^{R}$	$l_{j,t-1}^{R}$	$\Delta\lambda_{j,t}^{IV}$ 1st stage Adj R2	$\lambda_{j,t-1}^{IV}$ 1st stage Adj R2	Cragg-Donald statistic	N
AUD	-0.06***	-13.16***	1.01	-8.91***	-0.50	-4.33**	1.06	18.16***	-1.48	0.30	0.59	7.85	815
	(0.019)	(4.309)	(1.977)	(1.196)	(0.305)	(1.861)	(1.667)	(4.035)	(2.083)				
CAD	-0.03	-14.37**	-2.74	-10.05***	0.52	-10.59**	-4.86**	12.35*	0.87	0.55	0.81	1.71	322
	(0.021)	(7.112)	(2.663)	(1.997)	(0.372)	(4.417)	(2.184)	(6.405)	(2.841)				
EUR	-0.06***	-11.55**	-0.40	-10.11***	-0.23	-5.79***	-0.94	14.17**	2.42	0.49	0.60	1.71	826
	(0.014)	(5.205)	(1.467)	(1.702)	(0.195)	(1.666)	(1.171)	(5.732)	(1.613)				
JPY	-0.08***	-8.95**	3.20	-12.14***	-0.33	-3.80*	3.96**	12.51***	-0.64	0.41	0.64	11.75	826
	(0.021)	(4.526)	(2.141)	(1.410)	(0.378)	(1.972)	(1.591)	(4.718)	(2.540)				
NZD	-0.04**	-9.90***	3.09**	-9.37***	0.00	-6.56***	2.21	14.28***	-2.00	0.38	0.55	11.63	803
	(0.017)	(2.974)	(1.443)	(1.086)	(0.273)	(1.578)	(1.479)	(3.844)	(1.669)				
NOK	-0.06***	-4.27***	0.07	-7.65***	-0.31	-6.20***	-0.09	3.72*	2.41	0.59	0.66	30.98	826
	(0.013)	(1.290)	(0.929)	(0.917)	(0.216)	(1.308)	(1.092)	(2.237)	(1.608)				
SEK	-0.05***	-10.28***	0.43	-8.42***	-0.16	-4.65***	-0.60	11.64***	-0.74	0.40	0.66	6.07	826
	(0.014)	(3.506)	(0.841)	(1.348)	(0.236)	(1.264)	(0.959)	(3.610)	(1.332)				
GBP	-0.05***	-10.71**	1.11	-11.52***	-0.15	-1.37	2.90*	8.76**	-0.11	0.45	0.69	6.46	826
	(0.018)	(4.435)	(1.823)	(2.027)	(0.262)	(1.596)	(1.573)	(4.120)	(2.209)				
USD	-0.07***	-17.37***	-1.96*	-12.34***	-0.15	-2.72**	1.37	19.12***	1.85	0.40	0.66	7.85	694
	(0.017)	(3.353)	(1.145)	(1.192)	(0.254)	(1.356)	(1.137)	(3.399)	(1.620)				

The table reports the OLS estimates of the coefficient of the panel fixed effect regression listed above. The 10 currencies used are Australian Dollar (AUD), Canadian Dollar (CAD), Euro (EUR), Japanese Yen (JPY), New Zealand Dollar (NZD), Norwegian Krone (NOK), Swedish Krona (SEK), Swiss Franc (CHF), British Pound (GBP) and United States Dollar (USD). Each row represents a regression estimation using the first column currency as the home currency and the other 8 currencies as foreign currency j. $s_{j,t}$ is the nominal exchange rate between home and foreign country j, defined as home currency price of foreign currency, $q_{j,t}$ is the real exchange rate. $\lambda_{j,t}^{IV}$ is a measure of the treasury liquidity, $i_{j,t}^{R}$ is the home minus foreign interest rates. Δ is a difference operator. The sample period is 2008M1-2018M1.

Standard errors in parentheses are standard errors adjusted for cross-sectional correlation. *, **, and *** indicate that the alternative model significantly different from zero at 10%, 5%, and 1% significance level, respectively, based on standard normal critical values for the two-sided test.

Robustness of table 4A – full table of table 4A, with CHF excluded

Estimation result of $\Delta s_{j,t} = \alpha_j + \beta_1 q_{j,t-1} + \beta_2 \Delta\tau_{j,t} + \beta_3 \Delta\gamma_t + \beta_4 \Delta\gamma^*_{j,t} + \beta_5 \Delta i^R_{j,t} + \beta_6 \gamma_{t-1} + \beta_7 \gamma^*_{j,t-1} + \beta_8 i^R_{j,t-1} + u_{j,t}$

	$q_{j,t-1}$	$\Delta\gamma^*_{j,t}$	$\Delta\gamma_t$	$\Delta\tau_{j,t}$	$\Delta i^R_{j,t}$	$\gamma^*_{j,t-1}$	γ_{t-1}	$\tau_{j,t-1}$	$i^R_{j,t-1}$	constant	N	R2 within
AUD	-0.0350***	5.8589***	-7.0284***	-3.6892***	-6.0529***	0.0257	0.2929	-0.7461	-0.3123***	0.0133***	1800	0.2214
	(0.0086)	(0.6965)	(1.1868)	(1.1887)	(0.5251)	(0.3915)	(0.5988)	(0.7569)	(0.1086)	(0.0048)		
CAD	-0.0350***	4.7716***	-6.8209***	-5.7245***	-6.3034***	-0.3241	-0.7176	-0.5701	-0.2840***	0.0090**	1632	0.2272
	(0.0075)	(0.6896)	(1.8915)	(1.0908)	(0.5034)	(0.4036)	(1.2114)	(0.6971)	(0.1068)	(0.0035)		
EUR	-0.0223***	5.0912***	-5.8180***	-5.9629***	-5.4758***	0.3331	-0.5077	-0.7386	-0.1571*	-0.0056**	1800	0.1716
	(0.0071)	(0.5832)	(1.2075)	(0.9695)	(0.4297)	(0.3431)	(0.6132)	(0.5940)	(0.0946)	(0.0026)		
JPY	-0.0476***	4.1854***	-2.1277	-4.9911***	-6.8761***	-2.1503***	2.2418	2.0686**	-0.2179	0.2309***	1800	0.1949
	(0.0116)	(1.0017)	(5.2443)	(1.6051)	(0.7454)	(0.5973)	(2.5278)	(0.9658)	(0.1402)	(0.0537)		
NZD	-0.0390***	6.9813***	-7.1412***	-7.0202***	-6.5786***	1.5545***	0.0019	-1.7482**	-0.1799	0.0131**	1800	0.2370
	(0.0090)	(0.8955)	(0.8813)	(1.3052)	(0.6015)	(0.5505)	(0.4272)	(0.7919)	(0.1237)	(0.0064)		
NOK	-0.0213***	6.1246***	-3.7375***	-5.7582***	-5.4035***	-0.0845	0.5692	0.4329	-0.1623*	0.0415***	1800	0.1857
	(0.0078)	(0.7600)	(0.7780)	(1.0707)	(0.4969)	(0.4322)	(0.5044)	(0.7036)	(0.0986)	(0.0159)		
SEK	-0.0267***	5.2214***	-3.9404***	-5.7279***	-4.9794***	0.6904*	-0.1504	-0.8924	-0.1195	0.0511***	1800	0.1553
	(0.0076)	(0.6509)	(1.2496)	(1.0323)	(0.4760)	(0.4018)	(0.5142)	(0.6672)	(0.1039)	(0.0158)		
GBP	-0.0246***	5.0267***	-4.3648***	-2.0374*	-5.6439***	-0.4826	0.6602	0.2947	-0.3380***	-0.0098**	1800	0.1496
	(0.0080)	(0.7264)	(1.0991)	(1.1396)	(0.5305)	(0.4312)	(0.6117)	(0.7194)	(0.1085)	(0.0041)		
USD	-0.0143*	6.2431***	-5.8393***	-7.3036***	-5.2097***	0.2077	-1.9940***	-0.1971	-0.0193	-0.0216	1800	0.1985
	(0.0077)	(0.8328)	(1.3850)	(1.2344)	(0.5817)	(0.4860)	(0.5866)	(0.7459)	(0.1114)	(0.0162)		

The table reports the OLS estimates of the coefficient of the panel fixed effect regression listed above. The 10 currencies used are Australian Dollar (AUD), Canadian Dollar (CAD), Euro (EUR), Japanese Yen (JPY), New Zealand Dollar (NZD), Norwegian Krone (NOK), Swedish Krona (SEK), Swiss Franc (CHF), British Pound (GBP) and United States Dollar (USD). Each row represents a regression estimation using the first column currency as the home currency and the other 8 currencies as foreign currency j. $s_{j,t}$ is the nominal exchange rate between home and foreign country j, defined as home currency price of foreign currency, $q_{j,t}$ is the real exchange rate. $\tau_{j,t}$ is a measure of currency derivative friction, $\gamma^*_{j,t}$ is a measure of foreign treasury liquidity, $\gamma_{j,t}$ is a measure of the home treasury liquidity, $i^R_{j,t}$ is the home minus foreign interest rates. Δ is a difference operator. The sample period is 1999M1-2018M1.

Standard errors in parentheses are standard errors adjusted for cross-sectional correlation. *, **, and *** indicate that the alternative model significantly different from zero at 10%, 5%, and 1% significance level, respectively, based on standard normal critical values for the two-sided test.

11. Robustness: Meese Rogoff 1983 out-of-sample-fit exercise extreme outliner of CHF at 2015M1 excluded and with recursive window

Table 5: Out-of-sample fit comparison of different models with extreme outliner of CHF at 2015M1 excluded

Rolling window prediction error of regression model (20) with liquidity return:

$$\Delta\hat{s}_{j,t} = \hat{\alpha}_j + \hat{\beta}_1 q_{j,t-1} + \hat{\beta}_2 \Delta\tilde{\eta}_{j,t} + \hat{\beta}_3 \Delta i^R_{j,t} + \hat{\beta}_4 \tilde{\eta}_{j,t-1} + \hat{\beta}_5 i^R_{j,t-1}$$

Rolling window prediction error of regression model (21) without liquidity return:

$$\Delta\hat{s}_{j,t} = \hat{\alpha}_j + \hat{\beta}_1 q_{j,t-1} + \hat{\beta}_2 \Delta i^R_{j,t} + \hat{\beta}_3 i^R_{j,t-1}$$

and random walk (RW) model: $\Delta\hat{s}^{RW}_{j,t} = 0$

Home Currency	RMSE of RW	RMSE of model (21)	RMSE of model (20)	DMW statistics of (21) vs RW	DMW statistics of (20) vs RW	DMW statistics of (20) vs (21)
(1)	(2)	(3)	(4)	(5)	(6)	(7)
AUD	0.0331	0.0307	0.0291	5.353	5.529	3.174
CAD	0.0301	0.0276	0.0263	6.379	6.573	4.328
EUR	0.0309	0.0305	0.0301	1.384	2.017	1.421
JPY	0.0282	0.0263	0.0252	5.608	7.189	4.782
NZD	0.0331	0.0313	0.0309	4.719	5.198	1.559
NOK	0.0428	0.0402	0.0393	5.424	6.511	3.256
SEK	0.0309	0.0295	0.0279	4.399	4.992	3.224
CHF	0.0361	0.0345	0.0310	4.481	6.523	5.762
GBP	0.0294	0.0282	0.0271	3.360	4.807	3.913

USD	0.0348	0.0335	0.0309	4.713	7.731	6.064

Home Currency	CW statistics of (21) vs RW	p-value of CW test (21) vs RW	CW statistics of (20) vs RW	p-value of CW test (20) vs RW	CW statistics of (20) vs (21)	p-value of CW test (20) vs (21)
	(8)	(9)	(10)	(12)	(13)	(14)
AUD	10.891	0.000***	10.606	0.000***	5.522	0.000***
CAD	11.544	0.000***	11.132	0.000***	6.437	0.000***
EUR	5.461	0.000***	6.406	0.000***	3.754	0.000***
JPY	10.225	0.000***	12.230	0.000***	7.150	0.000***
NZD	8.371	0.000***	9.737	0.000***	4.083	0.000***
NOK	10.195	0.000***	11.490	0.000***	6.631	0.000***
SEK	8.941	0.000***	8.718	0.000***	5.286	0.000***
CHF	9.040	0.000***	12.077	0.000**	9.332	0.000***
GBP	7.636	0.000***	9.536	0.000***	6.717	0.000***
USD	9.348	0.000***	12.763	0.000***	9.644	0.000***

The 10 currencies used are Australian Dollar (AUD), Canadian Dollar (CAD), Euro (EUR), Japanese Yen (JPY), New Zealand Dollar (NZD), Norwegian Krone (NOK), Swedish Krone (SEK), Swiss Franc (CHF), British Pound (GBP) and United States Dollar (USD). Each row represents a rolling window predictive regression using the column (1) currency as the home currency and the other 9 currencies as foreign currency *j*. $s_{j,t}$ is the nominal exchange rate between home and foreign country *j*, defined as home currency price of foreign currency, $q_{j,t}$ is the real exchange rate. $\tilde{\eta}_{j,t}$ is the measure of government bond liquidity, $i_{j,t}^{R}$ is the home minus foreign interest rates. Δ is a difference operator. The rolling window is 108 months. The first estimated coefficient uses sample from 1999M1 to 2007M12. Germany government interest rate is used for EUR case. DMW stands for Diebold and Mariano (1995) and West (1996) and CW stands for Clark and West (2007)

The null hypotheses are that the models MSE are equal. The alternative hypotheses are that the larger models MSE are smaller than the nested models. *, **, and *** indicate that the alternative model significantly outperforms the smaller nested model at 10%, 5%, and 1% significance level, respectively, based on standard normal critical values for the one-sided test.

Table 5: Out-of-sample fit comparison of different models with CHF excluded
Rolling window prediction error of regression model (20) with liquidity return:

$$\Delta\hat{s}_{j,t} = \hat{\alpha}_j + \hat{\beta}_1 q_{j,t-1} + \hat{\beta}_2 \Delta\tilde{\eta}_{j,t} + \hat{\beta}_3 \Delta i^R_{j,t} + \hat{\beta}_4 \tilde{\eta}_{j,t-1} + \hat{\beta}_5 i^R_{j,t-1}$$

Rolling window prediction error of regression model (21) without liquidity return:

$$\Delta\hat{s}_{j,t} = \hat{\alpha}_j + \hat{\beta}_1 q_{j,t-1} + \hat{\beta}_2 \Delta i^R_{j,t} + \hat{\beta}_3 i^R_{j,t-1}$$

and random walk (RW) model: $\Delta\hat{s}^{RW}_{j,t} = 0$

Home Currency	RMSE of RW	RMSE of model (21)	RMSE of model (20)	DMW statistics of (21) vs RW	DMW statistics of (20) vs RW	DMW statistics of (20) vs (21)
(1)	(2)	(3)	(4)	(5)	(6)	(7)
AUD	0.0333	0.0307	0.0289	5.565	5.508	3.097
CAD	0.0300	0.0273	0.0259	6.262	6.235	3.881
EUR	0.0290	0.0269	0.0256	5.799	7.481	5.009
JPY	0.0330	0.0312	0.0306	4.739	5.442	2.000
NZD	0.0434	0.0403	0.0393	5.801	6.740	3.202
NOK	0.0310	0.0295	0.0274	4.502	5.025	3.314
SEK	0.0366	0.0349	0.0310	4.414	6.521	5.823
GBP	0.0297	0.0284	0.0270	3.540	4.846	3.840
USD	0.0350	0.0335	0.0309	5.156	7.398	5.461

Home Currency	CW statistics of (21) vs RW	p-value of CW test (21) vs RW	CW statistics of (20) vs RW	p-value of CW test (20) vs RW	CW statistics of (20) vs (21)	p-value of CW test (20) vs (21)
	(8)	(9)	(10)	(12)	(13)	(14)
AUD	10.709	0.000***	10.221	0.000***	5.231	0.000***
CAD	10.977	0.000***	10.369	0.000***	5.756	0.000***
EUR	10.342	0.000***	12.544	0.000***	7.282	0.000***
JPY	8.133	0.000***	9.757	0.000***	4.511	0.000***
NZD	10.306	0.000***	11.374	0.000***	6.554	0.000***
NOK	8.957	0.000***	8.543	0.000***	5.233	0.000***
SEK	8.718	0.000***	11.738	0.000***	9.175	0.000***
GBP	7.607	0.000***	9.385	0.000***	6.518	0.000***
USD	9.623	0.000***	11.980	0.000***	8.661	0.000***

The 10 currencies used are Australian Dollar (AUD), Canadian Dollar (CAD), Euro (EUR), Japanese Yen (JPY), New Zealand Dollar (NZD), Norwegian Krone (NOK), Swedish Krone (SEK), Swiss Franc (CHF), British Pound (GBP) and United States Dollar (USD). Each row represents a rolling window predictive regression using the column (1) currency as the home currency and the other 9 currencies as foreign currency j. $s_{j,t}$ is the nominal exchange rate between home and foreign country j, defined as home currency price of foreign currency, $q_{j,t}$ is the real exchange rate. $\tilde{\eta}_{j,t}$ is the measure of government bond liquidity, $i_{j,t}^R$ is the home minus foreign interest rates. Δ is a difference operator. The rolling window is 108 months. The first estimated coefficient uses sample from 1999M1 to 2007M12. Germany government interest rate is used for EUR case. DMW stands for Diebold and Mariano (1995) and West (1996) and CW stands for Clark and West (2007)

The null hypotheses are that the models MSE are equal. The alternative hypotheses are that the larger models MSE are smaller than the nested models. *, **, and *** indicate that the alternative model significantly outperforms the smaller nested model at 10%, 5%, and 1% significance level, respectively, based on standard normal critical values for the one-sided test.

Recursive window prediction error of regression model with liquidity return:

$\Delta\hat{s}_{j,t} = \hat{\alpha}_j + \hat{\beta}_1 q_{j,t-1} + \hat{\beta}_2 \Delta\tilde{\eta}_{j,t} + \hat{\beta}_3 \Delta i^R_{j,t} + \hat{\beta}_4 \tilde{\eta}_{j,t-1} + \hat{\beta}_5 i^R_{j,t-1}$ and random walk model: $\Delta\hat{s}^{RW}_{j,t} = 0$

Home Currency	RMSE of the model (20)	RMSE of random walk	RMSE of the model (20) CHF 2015M1 excluded	RMSE of random walk CHF 2015M1 excluded	RMSE of the model (20) CHF excluded	RMSE of random walk CHF excluded
(1)	(2)	(3)	(4)	(5)	(6)	(7)
AUD	0.0268	0.0294	0.0263	0.0291	0.0287	0.0333
CAD	0.0250	0.0275	0.0243	0.0270	0.0262	0.0300
EUR	0.0295	0.0291	0.0262	0.0266	0.0325	0.0328
JPY	0.0241	0.0259	0.0233	0.0255	0.0257	0.0290
NOK	0.0285	0.0300	0.0281	0.0297	0.0309	0.0330
NZD	0.0361	0.0382	0.0359	0.0382	0.0398	0.0434
SEK	0.0264	0.0285	0.0260	0.0283	0.0276	0.0310
CHF	0.0306	0.0335	0.0300	0.0332	0.0313	0.0366
GBP	0.0261	0.0277	0.0256	0.0274	0.0270	0.0297
USD	0.0291	0.0320	0.0289	0.0319	0.0311	0.0350

The 10 currencies used are Australian Dollar (AUD), Canadian Dollar (CAD), Euro (EUR), Japanese Yen (JPY), New Zealand Dollar (NZD), Norwegian Krone (NOK), Swedish Krona (SEK), Swiss Franc (CHF), British Pound (GBP) and United States Dollar (USD). Each row represents a recursive window predictive regression using the column (1) currency as the home currency and the other 9 currencies as foreign currency j. $s_{j,t}$ is the nominal exchange rate between home and foreign country j, defined as home currency price of foreign currency, $q_{j,t}$ is the real exchange rate. η_t is the measure of treasury liquidity, $i^R_{j,t}$ is the home minus foreign interest rates. Δ is a difference operator. The first estimated coefficient uses sample from 1999M1 to 2007M12. The first prediction is 2008M1 and last prediction is 2018M1. Germany government interest rate is used for EUR case.

12.Robustness: Regressions in the main text with real exchange rates only or nominal exchange rates only on both sides of the regression estimations

Robustness of table 1A – full table of table 1A with real exchange rates on both sides of regressions

Estimation result of $\Delta q_{j,t} = \alpha_j + \beta_1 q_{j,t-1} + \beta_2(\Delta\tilde{\eta}_{j,t}) + \beta_3(\Delta i^R_{j,t}) + \beta_4(\tilde{\eta}_{j,t-1}) + \beta_5(i^R_{j,t-1}) + u_{j,t}$

	$q_{j,t-1}$	$\Delta\tilde{\eta}_{j,t}$	$\Delta i^R_{j,t}$	$\tilde{\eta}_{j,t-1}$	$i^R_{j,t-1}$	constant	N	R2_within
AUD	-0.0280***	-5.2808***	-5.7719***	0.2796	-0.2817***	0.0124***	2043	0.1850
	(0.0073)	(0.7342)	(0.5483)	(0.4404)	(0.1074)	(0.0041)		
CAD	-0.0244***	-4.6322***	-5.4419***	0.4694	-0.2444**	0.0060**	2050	0.1633
	(0.0063)	(0.6411)	(0.5059)	(0.3920)	(0.0995)	(0.0025)		
EUR	-0.0187***	-4.7080***	-5.0380***	-0.0553	-0.1667*	-0.0047**	2050	0.1412
	(0.0059)	(0.5218)	(0.4116)	(0.3131)	(0.0889)	(0.0021)		
JPY	-0.0369***	-4.3784***	-6.3494***	2.1603***	-0.0740	0.1816***	2050	0.1668
	(0.0102)	(0.9564)	(0.7390)	(0.5790)	(0.1224)	(0.0477)		
NZD	-0.0254***	-6.4265***	-6.0499***	0.1261	-0.0877	0.0113*	2043	0.1944
	(0.0083)	(0.7362)	(0.6158)	(0.4390)	(0.1234)	(0.0059)		
NOK	-0.0169**	-4.2863***	-5.0364***	0.6300	-0.1657*	0.0351**	2050	0.1582
	(0.0069)	(0.6275)	(0.4992)	(0.4000)	(0.0961)	(0.0142)		
SEK	-0.0205***	-4.5858***	-4.6016***	-0.3178	-0.0947	0.0408***	2050	0.1281
	(0.0063)	(0.5866)	(0.4690)	(0.3595)	(0.0980)	(0.0132)		
CHF	-0.0113*	-2.2507***	-2.7679***	0.6901	-0.1981*	0.0001	2050	0.0480
	(0.0065)	(0.7200)	(0.5613)	(0.4305)	(0.1018)	(0.0032)		
GBP	-0.0200***	-3.3262***	-5.3780***	0.7598*	-0.3324***	-0.0066**	2050	0.1275
	(0.0068)	(0.6743)	(0.5278)	(0.4151)	(0.0996)	(0.0033)		
USD	-0.0106	-6.7341***	-4.9568***	-1.3935***	-0.0467	-0.0187	2050	0.1773
	(0.0069)	(0.7250)	(0.5736)	(0.4399)	(0.1051)	(0.0144)		

The table reports the OLS estimates of the coefficient of the panel fixed effect regression listed above. The 10 currencies used are Australian Dollar (AUD), Canadian Dollar (CAD), Euro (EUR), Japanese Yen (JPY), New Zealand Dollar (NZD), Norwegian Krone (NOK), Swedish Krona (SEK), Swiss Franc (CHF), British Pound (GBP) and United States Dollar (USD). Each row represents a regression estimation using the first column currency as the home currency and the other 9 currencies as foreign currency j. $s_{j,t}$ is the nominal exchange rate between home and foreign country j, defined as home currency price of foreign currency, $q_{j,t}$ is the real exchange rate. $\tilde{\eta}_{j,t}$ is a measure of the treasury liquidity, $i^R_{j,t}$ is the home minus foreign interest rates. Δ is a difference operator. The sample period is 1999M1-2018M1.

Standard errors in parentheses are standard errors adjusted for cross-sectional correlation. *, **, and *** indicate that the alternative model significantly different from zero at 10%, 5%, and 1% significance level, respectively, based on standard normal critical values for the two-sided test.

Robustness of table 1A – full table of table 1A with nominal exchange rates on both sides of regressions

Estimation result of $\Delta s_{j,t} = \alpha_j + \beta_1 s_{j,t-1} + \beta_2(\Delta\tilde{\eta}_{j,t}) + \beta_3(\Delta i^R_{j,t}) + \beta_4(\tilde{\eta}_{j,t-1}) + \beta_5(i^R_{j,t-1}) + u_{j,t}$

	$s_{j,t-1}$	$\Delta\tilde{\eta}_{j,t}$	$\Delta i^R_{j,t}$	$\tilde{\eta}_{j,t-1}$	$i^R_{j,t-1}$	constant	N	R2_within
AUD	-0.0237***	-5.3633***	-5.7211***	0.0786	-0.2335**	0.0102**	2052	0.1858
	(0.0089)	(0.7197)	(0.5390)	(0.4200)	(0.1018)	(0.0043)		
CAD	-0.0288***	-4.6938***	-5.4336***	0.3836	-0.2166**	0.0065***	2052	0.1721
	(0.0072)	(0.6237)	(0.4915)	(0.3814)	(0.0915)	(0.0025)		
EUR	-0.0232***	-4.6716***	-4.9958***	-0.1015	-0.1615*	-0.0054**	2052	0.1441
	(0.0067)	(0.5160)	(0.4100)	(0.3063)	(0.0841)	(0.0023)		
JPY	-0.0305***	-4.5475***	-6.1840***	1.8056***	0.0757	0.1523***	2052	0.1608
	(0.0108)	(0.9595)	(0.7449)	(0.5726)	(0.1078)	(0.0501)		
NZD	-0.0201**	-6.3074***	-5.9606***	0.1187	-0.0467	0.0083	2052	0.1909
	(0.0095)	(0.7317)	(0.6122)	(0.4359)	(0.1154)	(0.0061)		
NOK	-0.0220***	-4.0410***	-4.8326***	0.5207	-0.1588*	0.0448***	2052	0.1539
	(0.0077)	(0.6121)	(0.4879)	(0.3851)	(0.0902)	(0.0155)		
SEK	-0.0274***	-4.5156***	-4.5788***	-0.3614	-0.1164	0.0552***	2052	0.1333
	(0.0072)	(0.5772)	(0.4627)	(0.3518)	(0.0923)	(0.0149)		
CHF	-0.0198**	-2.3232***	-2.7311***	0.6513	-0.2142**	0.0022	2052	0.0537
	(0.0077)	(0.7090)	(0.5544)	(0.4133)	(0.0954)	(0.0032)		
GBP	-0.0242***	-3.4007***	-5.2168***	0.7013*	-0.3016***	-0.0088**	2052	0.1271
	(0.0075)	(0.6652)	(0.5219)	(0.4052)	(0.0917)	(0.0037)		
USD	-0.0149*	-6.4486***	-4.7487***	-1.2456***	-0.0737	-0.0283*	2052	0.1701
	(0.0081)	(0.7181)	(0.5691)	(0.4352)	(0.1011)	(0.0167)		

The table reports the OLS estimates of the coefficient of the panel fixed effect regression listed above. The 10 currencies used are Australian Dollar (AUD), Canadian Dollar (CAD), Euro (EUR), Japanese Yen (JPY), New Zealand Dollar (NZD), Norwegian Krone (NOK), Swedish Krona (SEK), Swiss Franc (CHF), British Pound (GBP) and United States Dollar (USD). Each row represents a regression estimation using the first column currency as the home currency and the other 9 currencies as foreign currency j. $s_{j,t}$ is the nominal exchange rate between home and foreign country j, defined as home currency price of foreign currency, $q_{j,t}$ is the real exchange rate. $\tilde{\eta}_{j,t}$ is a measure of the treasury liquidity, $i^R_{j,t}$ is the home minus foreign interest rates. Δ is a difference operator. The sample period is 1999M1-2018M1.

Standard errors in parentheses are standard errors adjusted for cross-sectional correlation. *, **, and *** indicate that the alternative model significantly different from zero at 10%, 5%, and 1% significance level, respectively, based on standard normal critical values for the two-sided test.

Robustness of table 1B – full table of table 1B with real exchange rates on both sides of regressions

Estimation result of $\Delta q_{j,t} = \alpha_j + \beta_1 q_{j,t-1} + \beta_2(\Delta i^R_{j,t}) + \beta_3(i^R_{j,t-1}) + u_{j,t}$

	$q_{j,t-1}$	$\Delta i^R_{j,t}$	$i^R_{j,t-1}$	constant	N	R2_within
AUD	-0.0312***	-4.0999***	-0.2896***	0.0134***	2043	0.1111
	(0.0075)	(0.5238)	(0.1113)	(0.0043)		
CAD	-0.0255***	-4.5241***	-0.2327**	0.0051**	2050	0.1102
	(0.0065)	(0.4809)	(0.1012)	(0.0023)		
EUR	-0.0210***	-3.8378***	-0.1785**	-0.0049**	2050	0.0870
	(0.0060)	(0.3867)	(0.0908)	(0.0021)		
JPY	-0.0309***	-5.3606***	-0.1008	0.1429***	2050	0.0988
	(0.0105)	(0.7272)	(0.1297)	(0.0487)		
NZD	-0.0284***	-2.6422***	-0.0654	0.0119*	2043	0.0529
	(0.0095)	(0.6027)	(0.1355)	(0.0067)		
NOK	-0.0156**	-3.5742***	-0.1077	0.0309**	2050	0.0801
	(0.0072)	(0.4840)	(0.0981)	(0.0145)		
SEK	-0.0246***	-3.1896***	-0.1109	0.0497***	2050	0.0670
	(0.0064)	(0.4408)	(0.0999)	(0.0133)		
CHF	-0.0081	-2.0299***	-0.2073**	-0.0041*	2050	0.0226
	(0.0062)	(0.5213)	(0.1038)	(0.0023)		
GBP	-0.0198***	-3.8803***	-0.3213***	-0.0071**	2050	0.0872
	(0.0068)	(0.4952)	(0.1004)	(0.0034)		
USD	-0.0134*	-3.8489***	-0.1179	-0.0265*	2050	0.0706
	(0.0076)	(0.5911)	(0.1141)	(0.0159)		

The table reports the OLS estimates of the coefficient of the panel fixed effect regression listed above. The 10 currencies used are Australian Dollar (AUD), Canadian Dollar (CAD), Euro (EUR), Japanese Yen (JPY), New Zealand Dollar (NZD), Norwegian Krone (NOK), Swedish Krona (SEK), Swiss Franc (CHF), British Pound (GBP) and United States Dollar (USD). Each row represents a regression estimation using the first column currency as the home currency and the other 9 currencies as foreign currency j. $s_{j,t}$ is the nominal exchange rate between home and foreign country j, defined as home currency price of foreign currency, $q_{j,t}$ is the real exchange rate. $\tilde{\eta}_{j,t}$ is a measure of the treasury liquidity, $i^R_{j,t}$ is the home minus foreign interest rates. Δ is a difference operator. The sample period is 1999M1-2018M1.

Standard errors in parentheses are standard errors adjusted for cross-sectional correlation. *, **, and *** indicate that the alternative model significantly different from zero at 10%, 5%, and 1% significance level, respectively, based on standard normal critical values for the two-sided test.

Robustness of table 1B – full table of table 1B with nominal exchange rates on both sides of regressions
Estimation result of $\Delta s_{j,t} = \alpha_j + \beta_1 s_{j,t-1} + \beta_2(\Delta i^R_{j,t}) + \beta_3(i^R_{j,t-1}) + u_{j,t}$

	$s_{j,t-1}$	$\Delta i^R_{j,t}$	$i^R_{j,t-1}$	constant	N	R2_within
AUD	-0.0286***	-4.0396***	-0.2565**	0.0120***	2052	0.1111
	(0.0095)	(0.5155)	(0.1062)	(0.0046)		
CAD	-0.0312***	-4.5105***	-0.2077**	0.0060**	2052	0.1173
	(0.0074)	(0.4683)	(0.0936)	(0.0023)		
EUR	-0.0259***	-3.8068***	-0.1708**	-0.0056**	2052	0.0905
	(0.0070)	(0.3847)	(0.0862)	(0.0023)		
JPY	-0.0298***	-5.2081***	0.0252	0.1393***	2052	0.0969
	(0.0113)	(0.7291)	(0.1139)	(0.0522)		
NZD	-0.0245**	-2.6140***	-0.0272	0.0097	2052	0.0525
	(0.0108)	(0.5979)	(0.1273)	(0.0068)		
NOK	-0.0223***	-3.4701***	-0.1141	0.0441***	2052	0.0834
	(0.0081)	(0.4690)	(0.0922)	(0.0161)		
SEK	-0.0320***	-3.1980***	-0.1334	0.0651***	2052	0.0733
	(0.0075)	(0.4342)	(0.0944)	(0.0154)		
CHF	-0.0169**	-1.9801***	-0.2356**	-0.0019	2052	0.0270
	(0.0076)	(0.5153)	(0.0991)	(0.0023)		
GBP	-0.0249***	-3.7020***	-0.2996***	-0.0096**	2052	0.0852
	(0.0077)	(0.4905)	(0.0933)	(0.0038)		
USD	-0.0172*	-3.6744***	-0.1330	-0.0350*	2052	0.0691
	(0.0090)	(0.5814)	(0.1090)	(0.0184)		

The table reports the OLS estimates of the coefficient of the panel fixed effect regression listed above. The 10 currencies used are Australian Dollar (AUD), Canadian Dollar (CAD), Euro (EUR), Japanese Yen (JPY), New Zealand Dollar (NZD), Norwegian Krone (NOK), Swedish Krona (SEK), Swiss Franc (CHF), British Pound (GBP) and United States Dollar (USD). Each row represents a regression estimation using the first column currency as the home currency and the other 9 currencies as foreign currency j. $s_{j,t}$ is the nominal exchange rate between home and foreign country j, defined as home currency price of foreign currency, $q_{j,t}$ is the real exchange rate. $\tilde{\eta}_{j,t}$ is a measure of the treasury liquidity, $i^R_{j,t}$ is the home minus foreign interest rates. Δ is a difference operator. The sample period is 1999M1-2018M1.
Standard errors in parentheses are standard errors adjusted for cross-sectional correlation. *, **, and *** indicate that the alternative model significantly different from zero at 10%, 5%, and 1% significance level, respectively, based on standard normal critical values for the two-sided test

Robustness of table 1C – full table of table 1C 1999M1-2007M12 with real exchange rates on both sides of regressions

Estimation result of $\Delta q_{j,t} = \alpha_j + \beta_1 q_{j,t-1} + \beta_2(\Delta\tilde{\eta}_{j,t}) + \beta_3(\Delta i^R_{j,t}) + \beta_4(\tilde{\eta}_{j,t-1}) + \beta_5(i^R_{j,t-1}) + u_{j,t}$

	$q_{j,t-1}$	$\Delta\tilde{\eta}_{j,t}$	$\Delta i^R_{j,t}$	$\tilde{\eta}_{j,t-1}$	$i^R_{j,t-1}$	constant	N	R2_within
AUD	-0.0446**	-3.6947***	-3.2181***	-0.2731	-0.1467	0.0173**	972	0.0990
	(0.0176)	(1.2306)	(0.8008)	(0.7622)	(0.1732)	(0.0071)		
CAD	-0.0309*	-2.7151**	-3.0882***	-0.1167	-0.3193*	0.0066	972	0.0915
	(0.0161)	(1.1173)	(0.7691)	(0.6574)	(0.1631)	(0.0053)		
EUR	-0.0236*	-2.9133***	-2.0719***	-0.4467	-0.1770	-0.0058*	972	0.0447
	(0.0135)	(0.8537)	(0.5482)	(0.5675)	(0.1302)	(0.0030)		
JPY	-0.0450**	-1.2690	-1.7333*	0.7925	0.1156	0.2250**	972	0.0411
	(0.0199)	(1.3233)	(0.8956)	(0.8524)	(0.1835)	(0.0982)		
NZD	-0.0498***	-4.4889***	-3.5506***	-0.9927	-0.1421	0.0299***	972	0.0980
	(0.0174)	(1.1293)	(0.8775)	(0.6827)	(0.1694)	(0.0103)		
NOK	-0.0262*	-3.7653***	-2.8374***	0.1317	-0.0953	0.0504	972	0.0906
	(0.0157)	(1.0260)	(0.6549)	(0.6835)	(0.1357)	(0.0309)		
SEK	-0.0388***	-3.2415***	-2.3670***	-1.8654***	0.0115	0.0776**	972	0.0744
	(0.0140)	(0.9280)	(0.6193)	(0.5927)	(0.1395)	(0.0302)		
CHF	-0.0262*	-1.0109	-0.9998	-0.2636	-0.2114	0.0030	972	0.0281
	(0.0149)	(1.0324)	(0.6645)	(0.6929)	(0.1421)	(0.0071)		
GBP	-0.0353***	-4.0676***	-3.0539***	0.0276	-0.1883	-0.0181**	972	0.0998
	(0.0132)	(0.9125)	(0.5918)	(0.6173)	(0.1289)	(0.0076)		
USD	-0.0006	-4.1116***	-2.0521***	-1.4413*	-0.1698	0.0048	972	0.0808
	(0.0121)	(1.1183)	(0.7050)	(0.7448)	(0.1502)	(0.0259)		

The table reports the OLS estimates of the coefficient of the panel fixed effect regression listed above. The 10 currencies used are Australian Dollar (AUD), Canadian Dollar (CAD), Euro (EUR), Japanese Yen (JPY), New Zealand Dollar (NZD), Norwegian Krone (NOK), Swedish Krona (SEK), Swiss Franc (CHF), British Pound (GBP) and United States Dollar (USD). Each row represents a regression estimation using the first column currency as the home currency and the other 9 currencies as foreign currency j. $s_{j,t}$ is the nominal exchange rate between home and foreign country j, defined as home currency price of foreign currency, $q_{j,t}$ is the real exchange rate. $\tilde{\eta}_{j,t}$ is a measure of the treasury liquidity, $i^R_{j,t}$ is the home minus foreign interest rates. Δ is a difference operator. The sample period is 1999M1-2007M12.

Standard errors in parentheses are standard errors adjusted for cross-sectional correlation. *, **, and *** indicate that the alternative model significantly different from zero at 10%, 5%, and 1% significance level, respectively, based on standard normal critical values for the two-sided test.

Robustness of table 1C – full table of table 1C 1999M1-2007M12 with nominal exchange rates on both sides of regressions

Estimation result of $\Delta s_{j,t} = \alpha_j + \beta_1 s_{j,t-1} + \beta_2(\Delta\tilde{\eta}_{j,t}) + \beta_3(\Delta i^R_{j,t}) + \beta_4(\tilde{\eta}_{j,t-1}) + \beta_5(i^R_{j,t-1}) + u_{j,t}$

	$s_{j,t-1}$	$\Delta\tilde{\eta}_{j,t}$	$\Delta i^R_{j,t}$	$\tilde{\eta}_{j,t-1}$	$i^R_{j,t-1}$	constant	N	R2_within
AUD	-0.0398**	-3.6570***	-3.4492***	0.0056	-0.2361	0.0186**	972	0.0845
	(0.0166)	(1.2070)	(0.7825)	(0.7460)	(0.1605)	(0.0074)		
CAD	-0.0284*	-2.7650**	-3.3029***	-0.1085	-0.3363**	0.0054	972	0.0867
	(0.0153)	(1.0901)	(0.7478)	(0.6428)	(0.1583)	(0.0048)		
EUR	-0.0235*	-2.8941***	-2.1413***	-0.3580	-0.2126	-0.0060*	972	0.0473
	(0.0131)	(0.8497)	(0.5483)	(0.5562)	(0.1297)	(0.0033)		
JPY	-0.0158	-0.7731	-1.6623*	1.3044	0.0027	0.0794	972	0.0235
	(0.0167)	(1.3451)	(0.9048)	(0.8650)	(0.1843)	(0.0801)		
NZD	-0.0459***	-4.5199***	-3.5901***	-1.0688	-0.2135	0.0311***	972	0.0954
	(0.0163)	(1.1210)	(0.8711)	(0.6808)	(0.1623)	(0.0101)		
NOK	-0.0222	-3.5589***	-2.7512***	0.0004	-0.1040	0.0425	972	0.0876
	(0.0147)	(0.9971)	(0.6344)	(0.6567)	(0.1312)	(0.0288)		
SEK	-0.0381***	-2.9543***	-2.3417***	-1.9087***	-0.0461	0.0744***	972	0.0724
	(0.0135)	(0.9139)	(0.6087)	(0.5759)	(0.1379)	(0.0283)		
CHF	-0.0321**	-1.1660	-1.1067*	-0.2910	-0.2211	0.0036	972	0.0285
	(0.0137)	(1.0100)	(0.6504)	(0.6643)	(0.1398)	(0.0056)		
GBP	-0.0300**	-4.0928***	-3.0436***	0.1676	-0.2343*	-0.0140*	972	0.0963
	(0.0129)	(0.8862)	(0.5737)	(0.5945)	(0.1247)	(0.0075)		
USD	-0.0033	-3.9845***	-1.9965***	-1.4203*	-0.1879	-0.0019	972	0.0793
	(0.0132)	(1.1128)	(0.7043)	(0.7341)	(0.1482)	(0.0274)		

The table reports the OLS estimates of the coefficient of the panel fixed effect regression listed above. The 10 currencies used are Australian Dollar (AUD), Canadian Dollar (CAD), Euro (EUR), Japanese Yen (JPY), New Zealand Dollar (NZD), Norwegian Krone (NOK), Swedish Krona (SEK), Swiss Franc (CHF), British Pound (GBP) and United States Dollar (USD). Each row represents a regression estimation using the first column currency as the home currency and the other 9 currencies as foreign currency j. $s_{j,t}$ is the nominal exchange rate between home and foreign country j, defined as home currency price of foreign currency, $q_{j,t}$ is the real exchange rate. $\tilde{\eta}_{j,t}$ is a measure of the treasury liquidity, $i^R_{j,t}$ is the home minus foreign interest rates. Δ is a difference operator. The sample period is 1999M1-2007M12.

Standard errors in parentheses are standard errors adjusted for cross-sectional correlation. *, **, and *** indicate that the alternative model significantly different from zero at 10%, 5%, and 1% significance level, respectively, based on standard normal critical values for the two-sided test.

Robustness of table 1C – full table of table 1C 2008M1-2018M1 with real exchange rates on both sides of regressions

Estimation result of $\Delta q_{j,t} = \alpha_j + \beta_1 q_{j,t-1} + \beta_2(\Delta\tilde{\eta}_{j,t}) + \beta_3(\Delta i^R_{j,t}) + \beta_4(\tilde{\eta}_{j,t-1}) + \beta_5(i^R_{j,t-1}) + u_{j,t}$

	$q_{j,t-1}$	$\Delta\tilde{\eta}_{j,t}$	$\Delta i^R_{j,t}$	$\tilde{\eta}_{j,t-1}$	$i^R_{j,t-1}$	constant	N	R2_within
AUD	-0.0470***	-6.0352***	-7.6226***	0.1786	-0.4299**	0.0165**	1071	0.3002
	(0.0138)	(0.8927)	(0.7531)	(0.6182)	(0.2169)	(0.0073)		
CAD	-0.0402***	-5.7126***	-7.8492***	-0.0596	0.1273	0.0044	1078	0.2913
	(0.0110)	(0.7458)	(0.6660)	(0.5077)	(0.1766)	(0.0030)		
EUR	-0.0346***	-5.3779***	-7.4541***	-0.2743	-0.0978	-0.0111***	1078	0.2595
	(0.0104)	(0.6571)	(0.6077)	(0.4598)	(0.1845)	(0.0038)		
JPY	-0.0542***	-5.6465***	-11.2605***	2.0872**	-0.0793	0.2563***	1078	0.3308
	(0.0177)	(1.2394)	(1.1294)	(0.8921)	(0.2962)	(0.0803)		
NZD	-0.0512***	-7.1671***	-8.0791***	0.2807	0.1149	0.0090	1071	0.3220
	(0.0142)	(0.9642)	(0.8866)	(0.6598)	(0.2472)	(0.0094)		
NOK	-0.0293***	-5.2234***	-8.2771***	0.7820	-0.1070	0.0579***	1078	0.2618
	(0.0112)	(0.7781)	(0.7493)	(0.5585)	(0.1982)	(0.0223)		
SEK	-0.0471***	-5.5394***	-6.5734***	-0.0853	0.0028	0.0914***	1078	0.2377
	(0.0113)	(0.7432)	(0.7081)	(0.4987)	(0.2008)	(0.0225)		
CHF	-0.0239*	-2.8031***	-4.2448***	0.3146	0.2226	-0.0027	1078	0.1761
	(0.0128)	(1.0134)	(0.9299)	(0.7273)	(0.2267)	(0.0057)		
GBP	-0.0442***	-3.4178***	-8.0737***	0.7458	-0.2589	-0.0170***	1078	0.2089
	(0.0144)	(0.9215)	(0.8559)	(0.6355)	(0.2419)	(0.0064)		
USD	-0.0459***	-7.4838***	-9.8596***	-1.1229*	0.0316	-0.0869***	1078	0.3256
	(0.0128)	(0.8681)	(0.8195)	(0.5909)	(0.2214)	(0.0254)		

The table reports the OLS estimates of the coefficient of the panel fixed effect regression listed above. The 10 currencies used are Australian Dollar (AUD), Canadian Dollar (CAD), Euro (EUR), Japanese Yen (JPY), New Zealand Dollar (NZD), Norwegian Krone (NOK), Swedish Krona (SEK), Swiss Franc (CHF), British Pound (GBP) and United States Dollar (USD). Each row represents a regression estimation using the first column currency as the home currency and the other 9 currencies as foreign currency j. $s_{j,t}$ is the nominal exchange rate between home and foreign country j, defined as home currency price of foreign currency, $q_{j,t}$ is the real exchange rate. $\tilde{\eta}_{j,t}$ is a measure of the treasury liquidity, $i^R_{j,t}$ is the home minus foreign interest rates. Δ is a difference operator. The sample period is 2008M1-2018M1.

Standard errors in parentheses are standard errors adjusted for cross-sectional correlation. *, **, and *** indicate that the alternative model significantly different from zero at 10%, 5%, and 1% significance level, respectively, based on standard normal critical values for the two-sided test.

Robustness of table 1C – full table of table 1C 2008M1-2018M1 with nominal exchange rates on both sides of regressions

Estimation result of $\Delta s_{j,t} = \alpha_j + \beta_1 s_{j,t-1} + \beta_2(\Delta\tilde{\eta}_{j,t}) + \beta_3(\Delta i^R_{j,t}) + \beta_4(\tilde{\eta}_{j,t-1}) + \beta_5(i^R_{j,t-1}) + u_{j,t}$

	$s_{j,t-1}$	$\Delta\tilde{\eta}_{j,t}$	$\Delta i^R_{j,t}$	$\tilde{\eta}_{j,t-1}$	$i^R_{j,t-1}$	constant	N	R2_within
AUD	-0.0492***	-5.9909***	-7.4202***	0.2291	-0.3337	0.0131*	1080	0.2959
	(0.0156)	(0.8779)	(0.7400)	(0.6052)	(0.2095)	(0.0072)		
CAD	-0.0521***	-5.7511***	-7.6897***	0.0112	0.1015	0.0062**	1080	0.2953
	(0.0119)	(0.7265)	(0.6457)	(0.4996)	(0.1702)	(0.0031)		
EUR	-0.0413***	-5.3178***	-7.3974***	-0.2630	-0.1253	-0.0121***	1080	0.2591
	(0.0117)	(0.6482)	(0.6033)	(0.4547)	(0.1857)	(0.0040)		
JPY	-0.0586***	-5.8506***	-11.2549***	1.8963**	0.0145	0.2787***	1080	0.3286
	(0.0188)	(1.2388)	(1.1283)	(0.8933)	(0.2861)	(0.0860)		
NZD	-0.0556***	-6.9970***	-8.0703***	0.3636	0.1691	0.0089	1080	0.3218
	(0.0154)	(0.9483)	(0.8712)	(0.6509)	(0.2351)	(0.0094)		
NOK	-0.0434***	-4.9075***	-8.0550***	0.8204	-0.1823	0.0853***	1080	0.2617
	(0.0127)	(0.7663)	(0.7375)	(0.5484)	(0.1963)	(0.0251)		
SEK	-0.0600***	-5.6607***	-6.6391***	-0.1650	-0.1090	0.1188***	1080	0.2313
	(0.0129)	(0.7264)	(0.6946)	(0.4896)	(0.1972)	(0.0259)		
CHF	-0.0407**	-2.8807***	-4.1192***	0.2668	0.1272	-0.0010	1080	0.0985
	(0.0160)	(1.0049)	(0.9224)	(0.7229)	(0.2266)	(0.0056)		
GBP	-0.0556***	-3.5000***	-7.9158***	0.7427	-0.3191	-0.0226***	1080	0.2104
	(0.0161)	(0.9183)	(0.8555)	(0.6337)	(0.2368)	(0.0072)		
USD	-0.0517***	-7.1658***	-9.6362***	-0.8298	-0.0262	-0.1006***	1080	0.3266
	(0.0142)	(0.8602)	(0.8173)	(0.5846)	(0.2257)	(0.0285)		

The table reports the OLS estimates of the coefficient of the panel fixed effect regression listed above. The 10 currencies used are Australian Dollar (AUD), Canadian Dollar (CAD), Euro (EUR), Japanese Yen (JPY), New Zealand Dollar (NZD), Norwegian Krone (NOK), Swedish Krona (SEK), Swiss Franc (CHF), British Pound (GBP) and United States Dollar (USD). Each row represents a regression estimation using the first column currency as the home currency and the other 9 currencies as foreign currency j. $s_{j,t}$ is the nominal exchange rate between home and foreign country j, defined as home currency price of foreign currency, $q_{j,t}$ is the real exchange rate. $\tilde{\eta}_{j,t}$ is a measure of the treasury liquidity, $i^R_{j,t}$ is the home minus foreign interest rates. Δ is a difference operator. The sample period is 2008M1-2018M1

Standard errors in parentheses are standard errors adjusted for cross-sectional correlation. *, **, and *** indicate that the alternative model significantly different from zero at 10%, 5%, and 1% significance level, respectively, based on standard normal critical values for the two-sided test.

Robustness of table 1D – full table of table 1D with real exchange rates on both sides of regressions

Estimation result of $\Delta q_{j,t} = \alpha_j + \beta_1 q_{j,t-1} + \beta_2(\Delta\tilde{\eta}_{j,t}) + \beta_3(\Delta i^R_{j,t}) + \beta_4(\tilde{\eta}_{j,t-1}) + \beta_5(i^R_{j,t-1}) + u_{j,t}$

	$q_{j,t-1}$	$\Delta\tilde{\eta}_{j,t}$	$\Delta i^R_{j,t}$	$\tilde{\eta}_{j,t-1}$	$i^R_{j,t-1}$	constant	N	R2_within
AUD	-0.0229***	-5.0522***	-4.8797***	0.1741	-0.3015***	0.0113***	1710	0.1236
	(0.0072)	(0.9443)	(0.6388)	(0.5073)	(0.1094)	(0.0041)		
CAD	-0.0208***	-4.8367***	-4.5880***	0.2761	-0.3080***	0.0056**	1717	0.1188
	(0.0061)	(0.8026)	(0.5692)	(0.4355)	(0.0972)	(0.0025)		
EUR	-0.0158***	-5.3561***	-3.8352***	-0.4470	-0.1758*	-0.0050**	1717	0.0909
	(0.0059)	(0.7110)	(0.5009)	(0.3724)	(0.0952)	(0.0022)		
JPY	-0.0324***	-2.3328*	-3.5115***	2.0169***	-0.0577	0.1603***	1717	0.0560
	(0.0102)	(1.2231)	(0.8861)	(0.6228)	(0.1228)	(0.0475)		
NZD	-0.0204**	-5.9190***	-4.4553***	-0.4956	-0.1198	0.0103*	1710	0.1057
	(0.0083)	(0.9612)	(0.7356)	(0.5542)	(0.1263)	(0.0059)		
NOK	-0.0123*	-4.5710***	-4.2430***	0.4987	-0.1920*	0.0260*	1717	0.1103
	(0.0071)	(0.8557)	(0.5944)	(0.4792)	(0.1019)	(0.0148)		
SEK	-0.0154**	-4.3551***	-3.3927***	-0.3887	-0.1323	0.0299**	1717	0.0759
	(0.0062)	(0.7868)	(0.5623)	(0.4149)	(0.1026)	(0.0131)		
CHF	-0.0071	-2.2652**	-0.8951	0.1187	-0.2441**	-0.0041	1717	0.0207
	(0.0064)	(0.8948)	(0.6355)	(0.4694)	(0.1008)	(0.0034)		
GBP	-0.0134**	-4.6233***	-4.0156***	0.1198	-0.2669***	-0.0052*	1717	0.0773
	(0.0066)	(0.8747)	(0.6057)	(0.4723)	(0.0983)	(0.0031)		
USD	-0.0076	-7.2607***	-4.3986***	-1.3723***	-0.1022	-0.0124	1717	0.1256
	(0.0069)	(0.9681)	(0.6759)	(0.4899)	(0.1068)	(0.0147)		

The table reports the OLS estimates of the coefficient of the panel fixed effect regression listed above. The 10 currencies used are Australian Dollar (AUD), Canadian Dollar (CAD), Euro (EUR), Japanese Yen (JPY), New Zealand Dollar (NZD), Norwegian Krone (NOK), Swedish Krona (SEK), Swiss Franc (CHF), British Pound (GBP) and United States Dollar (USD). Each row represents a regression estimation using the first column currency as the home currency and the other 9 currencies as foreign currency j. $s_{j,t}$ is the nominal exchange rate between home and foreign country j, defined as home currency price of foreign currency, $q_{j,t}$ is the real exchange rate. $\tilde{\eta}_{j,t}$ is a measure of the treasury liquidity, $i^R_{j,t}$ is the home minus foreign interest rates. Δ is a difference operator. The sample period is 1999M1-2018M1 but excludes 2007-2009.

Standard errors in parentheses are standard errors adjusted for cross-sectional correlation. *, **, and *** indicate that the alternative model significantly different from zero at 10%, 5%, and 1% significance level, respectively, based on standard normal critical values for the two-sided test.

Robustness of table 1D – full table of table 1D with nominal exchange rates on both sides of regressions

Estimation result of $\Delta s_{j,t} = \alpha_j + \beta_1 s_{j,t-1} + \beta_2(\Delta\tilde{\eta}_{j,t}) + \beta_3(\Delta i^R_{j,t}) + \beta_4(\tilde{\eta}_{j,t-1}) + \beta_5(i^R_{j,t-1}) + u_{j,t}$

	$s_{j,t-1}$	$\Delta\tilde{\eta}_{j,t}$	$\Delta i^R_{j,t}$	$\tilde{\eta}_{j,t-1}$	$i^R_{j,t-1}$	constant	N	R2_within
AUD	-0.0189**	-5.1127***	-4.8669***	-0.0612	-0.2541**	0.0090**	1719	0.1245
	(0.0087)	(0.9233)	(0.6278)	(0.4760)	(0.1018)	(0.0042)		
CAD	-0.0236***	-4.8339***	-4.6051***	0.1296	-0.2716***	0.0057**	1719	0.1258
	(0.0069)	(0.7771)	(0.5489)	(0.4178)	(0.0882)	(0.0025)		
EUR	-0.0208***	-5.1822***	-3.7190***	-0.5389	-0.1662*	-0.0057**	1719	0.0910
	(0.0068)	(0.7010)	(0.4964)	(0.3602)	(0.0885)	(0.0023)		
JPY	-0.0253**	-2.3721*	-3.3384***	1.5299**	0.0649	0.1266**	1719	0.0471
	(0.0107)	(1.2211)	(0.8911)	(0.6098)	(0.1045)	(0.0493)		
NZD	-0.0162*	-5.8911***	-4.4334***	-0.5663	-0.0842	0.0079	1719	0.1046
	(0.0097)	(0.9535)	(0.7318)	(0.5461)	(0.1176)	(0.0061)		
NOK	-0.0161**	-4.2369***	-4.1005***	0.3273	-0.1756*	0.0331**	1719	0.1065
	(0.0079)	(0.8456)	(0.5898)	(0.4622)	(0.0956)	(0.0161)		
SEK	-0.0216***	-4.1729***	-3.3421***	-0.4857	-0.1447	0.0430***	1719	0.0793
	(0.0072)	(0.7731)	(0.5549)	(0.4037)	(0.0959)	(0.0149)		
CHF	-0.0133*	-2.1600**	-0.8602	0.0490	-0.2522***	-0.0022	1719	0.0227
	(0.0075)	(0.8807)	(0.6279)	(0.4437)	(0.0932)	(0.0033)		
GBP	-0.0169**	-4.7814***	-3.9481***	0.0519	-0.2429***	-0.0069**	1719	0.0811
	(0.0072)	(0.8624)	(0.5991)	(0.4578)	(0.0901)	(0.0035)		
USD	-0.0106	-7.1340***	-4.2981***	-1.4504***	-0.1036	-0.0191	1719	0.1262
	(0.0082)	(0.9572)	(0.6707)	(0.4813)	(0.1017)	(0.0170)		

The table reports the OLS estimates of the coefficient of the panel fixed effect regression listed above. The 10 currencies used are Australian Dollar (AUD), Canadian Dollar (CAD), Euro (EUR), Japanese Yen (JPY), New Zealand Dollar (NZD), Norwegian Krone (NOK), Swedish Krona (SEK), Swiss Franc (CHF), British Pound (GBP) and United States Dollar (USD). Each row represents a regression estimation using the first column currency as the home currency and the other 9 currencies as foreign currency j. $s_{j,t}$ is the nominal exchange rate between home and foreign country j, defined as home currency price of foreign currency, $q_{j,t}$ is the real exchange rate. $\tilde{\eta}_{j,t}$ is a measure of the treasury liquidity, $i^R_{j,t}$ is the home minus foreign interest rates. Δ is a difference operator. The sample period is 1999M1-2018M1 but excludes 2007-2009.

Standard errors in parentheses are standard errors adjusted for cross-sectional correlation. *, **, and *** indicate that the alternative model significantly different from zero at 10%, 5%, and 1% significance level, respectively, based on standard normal critical values for the two-sided test.

Robustness of table 1E – full table of table 1E with real exchange rates on both sides of regressions
Estimation result of $\Delta q_{j,t} = \alpha_j + \beta_1 q_{j,t-1} + \beta_2(\Delta\tilde{\eta}_{j,t}) + \beta_3(\Delta i^R_{j,t}) + \beta_4(\tilde{\eta}_{j,t-1}) + \beta_5(i^R_{j,t-1}) + u_{j,t}$

	$q_{j,t-1}$	$\Delta\tilde{\eta}_{j,t}$	$\Delta i^R_{j,t}$	$\tilde{\eta}_{j,t-1}$	$i^R_{j,t-1}$	constant	N	R2_within
AUD	-0.0321***	-4.7731***	-5.6412***	0.5921	-0.2819**	-0.0529***	1816	0.1796
	(0.0079)	(0.7297)	(0.5391)	(0.4499)	(0.1105)	(0.0136)		
CAD	-0.0298***	-4.3079***	-5.3884***	0.8721**	-0.2842***	-0.0535***	1822	0.1670
	(0.0074)	(0.6691)	(0.5189)	(0.4181)	(0.1063)	(0.0135)		
EUR	-0.0239***	-4.3915***	-4.9432***	0.3868	-0.2005**	-0.0531***	1822	0.1380
	(0.0063)	(0.5383)	(0.4112)	(0.3307)	(0.0912)	(0.0140)		
JPY	-0.0405***	-4.7771***	-6.6848***	2.3985***	-0.0453	0.1141***	1822	0.1781
	(0.0114)	(1.0095)	(0.7736)	(0.6256)	(0.1291)	(0.0298)		
NZD	-0.0303***	-6.0543***	-5.9772***	0.3219	-0.0945	-0.0490***	1816	0.1912
	(0.0089)	(0.7311)	(0.6098)	(0.4373)	(0.1273)	(0.0137)		
NOK	-0.0209***	-3.6933***	-5.0691***	0.9499**	-0.2238**	0.0007	1822	0.1562
	(0.0073)	(0.6173)	(0.4912)	(0.3944)	(0.0973)	(0.0016)		
SEK	-0.0269***	-4.0112***	-4.4930***	0.1425	-0.1451	0.0417***	1822	0.1197
	(0.0065)	(0.5775)	(0.4580)	(0.3545)	(0.0990)	(0.0100)		
CHF	-0.0138*	-1.7683**	-2.6962***	1.0109**	-0.1906*	-0.0268**	1822	0.0464
	(0.0071)	(0.7424)	(0.5728)	(0.4544)	(0.1075)	(0.0135)		
GBP	-0.0214***	-3.3774***	-5.4686***	1.0772**	-0.3620***	-0.0515***	1822	0.1323
	(0.0074)	(0.7139)	(0.5526)	(0.4428)	(0.1096)	(0.0184)		

The table reports the OLS estimates of the coefficient of the panel fixed effect regression listed above. The 9 currencies used are Australian Dollar (AUD), Canadian Dollar (CAD), Euro (EUR), Japanese Yen (JPY), New Zealand Dollar (NZD), Norwegian Krone (NOK), Swedish Krona (SEK), Swiss Franc (CHF) and British Pound (GBP). We exclude United States Dollar (USD) from all the regressions. Each row represents a regression estimation using the first column currency as the home currency and the other 9 currencies as foreign currency j. $s_{j,t}$ is the nominal exchange rate between home and foreign country j, defined as home currency price of foreign currency, $q_{j,t}$ is the real exchange rate. $\tilde{\eta}_{j,t}$ is a measure of the treasury liquidity, $i^R_{j,t}$ is the home minus foreign interest rates. Δ is a difference operator. The sample period is 1999M1-2018M1.

Standard errors in parentheses are standard errors adjusted for cross-sectional correlation. *, **, and *** indicate that the alternative model significantly different from zero at 10%, 5%, and 1% significance level, respectively, based on standard normal critical values for the two-sided test.

Robustness of table 1E – full table of table 1E with nominal exchange rates on both sides of regressions

Estimation result of $\Delta q_{j,t} = \alpha_j + \beta_1 q_{j,t-1} + \beta_2(\Delta\tilde{\eta}_{j,t}) + \beta_3(\Delta i^R_{j,t}) + \beta_4(\tilde{\eta}_{j,t-1}) + \beta_5(i^R_{j,t-1}) + u_{j,t}$

	$q_{j,t-1}$	$\Delta\tilde{\eta}_{j,t}$	$\Delta i^R_{j,t}$	$\tilde{\eta}_{j,t-1}$	$i^R_{j,t-1}$	constant	N	R2_within
AUD	-0.0271***	-4.9043***	-5.6080***	0.3072	-0.2301**	-0.0446***	1824	0.1803
	(0.0091)	(0.7164)	(0.5309)	(0.4293)	(0.1031)	(0.0156)		
CAD	-0.0336***	-4.4372***	-5.3892***	0.7112*	-0.2408**	-0.0612***	1824	0.1767
	(0.0079)	(0.6502)	(0.5034)	(0.4046)	(0.0965)	(0.0144)		
EUR	-0.0268***	-4.3696***	-4.9121***	0.2718	-0.1717**	-0.0599***	1824	0.1406
	(0.0070)	(0.5320)	(0.4094)	(0.3212)	(0.0860)	(0.0155)		
JPY	-0.0317***	-4.9460***	-6.4697***	1.9784***	0.1174	0.0918***	1824	0.1698
	(0.0113)	(1.0136)	(0.7801)	(0.6153)	(0.1149)	(0.0297)		
NZD	-0.0234**	-5.9704***	-5.8733***	0.2578	-0.0342	-0.0388**	1824	0.1879
	(0.0098)	(0.7268)	(0.6067)	(0.4310)	(0.1174)	(0.0153)		
NOK	-0.0257***	-3.5405***	-4.8812***	0.7592**	-0.1999**	-0.0005	1824	0.1531
	(0.0079)	(0.6027)	(0.4808)	(0.3779)	(0.0904)	(0.0016)		
SEK	-0.0321***	-4.0314***	-4.4846***	0.0550	-0.1471	0.0495***	1824	0.1258
	(0.0073)	(0.5682)	(0.4519)	(0.3452)	(0.0919)	(0.0114)		
CHF	-0.0222***	-1.8984***	-2.6791***	0.9076**	-0.1916*	-0.0425***	1824	0.0516
	(0.0082)	(0.7307)	(0.5656)	(0.4339)	(0.1004)	(0.0156)		
GBP	-0.0250***	-3.4953***	-5.3796***	0.9851**	-0.3202***	-0.0611***	1824	0.1338
	(0.0080)	(0.7053)	(0.5474)	(0.4307)	(0.0986)	(0.0199)		

The table reports the OLS estimates of the coefficient of the panel fixed effect regression listed above. The 9 currencies used are Australian Dollar (AUD), Canadian Dollar (CAD), Euro (EUR), Japanese Yen (JPY), New Zealand Dollar (NZD), Norwegian Krone (NOK), Swedish Krona (SEK), Swiss Franc (CHF) and British Pound (GBP). We exclude United States Dollar (USD) from all the regressions. Each row represents a regression estimation using the first column currency as the home currency and the other 9 currencies as foreign currency j. $s_{j,t}$ is the nominal exchange rate between home and foreign country j, defined as home currency price of foreign currency, $q_{j,t}$ is the real exchange rate. $\tilde{\eta}_{j,t}$ is a measure of the treasury liquidity, $i^R_{j,t}$ is the home minus foreign interest rates. Δ is a difference operator. The sample period is 1999M1-2018M1.

Standard errors in parentheses are standard errors adjusted for cross-sectional correlation. *, **, and *** indicate that the alternative model significantly different from zero at 10%, 5%, and 1% significance level, respectively, based on standard normal critical values for the two-sided test.

Robustness of table 1F – full table of table 1F with real exchange rates on both sides of regressions

Estimation result of $\Delta q_{j,t} = \alpha_j + \beta_1 q_{j,t-1} + \beta_2(\Delta\tilde{\eta}_{j,t}) + \beta_3(\Delta i^R_{j,t}) + \beta_4(\tilde{\eta}_{j,t-1}) + \beta_5(i^R_{j,t-1}) + u_{j,t}$

	$q_{j,t-1}$	$\Delta\tilde{\eta}_{j,t}$	$\Delta i^R_{j,t}$	$\tilde{\eta}_{j,t-1}$	$i^R_{j,t-1}$	constant	N	R2_within
AUD	-0.0532**	-8.2425	-24.1151	-9.8448	-3.0785	0.0121	360	0.0513
	(0.0261)	(10.7255)	(15.0846)	(12.2280)	(3.1098)	(0.0119)		
CAD	-0.0277***	-13.9201***	-29.4273***	-10.8506**	0.4895	0.0035	1227	0.0545
	(0.0101)	(4.7626)	(7.4452)	(4.9374)	(1.9228)	(0.0032)		
EUR	-0.0817***	-20.9888***	-27.0912***	-21.2376***	2.4764	-0.0216***	608	0.0984
	(0.0169)	(7.5837)	(9.1983)	(7.4064)	(2.7841)	(0.0053)		
JPY	-0.0986***	-21.4511**	-13.6255	1.1911	-7.9017**	0.5160***	461	0.1295
	(0.0242)	(10.3551)	(11.9705)	(12.4120)	(3.5755)	(0.1192)		
NZD	-0.0314***	-19.5937***	-30.2513***	-12.2364**	1.1698	0.0058	1221	0.0659
	(0.0104)	(4.8945)	(7.0247)	(5.3484)	(1.6065)	(0.0072)		
SEK	-0.0305***	-16.6822***	-16.8925***	-12.1601***	0.2214	0.0767***	1227	0.0456
	(0.0085)	(3.9413)	(5.6739)	(4.1854)	(1.2648)	(0.0185)		
CHF	-0.0573***	-10.4051	8.3720	-13.9700	12.1927***	-0.0060	730	0.0594
	(0.0139)	(9.1014)	(8.6491)	(9.2527)	(3.4866)	(0.0042)		
GBP	-0.0194*	-8.9733*	-20.4977***	-9.3455*	-0.9275	-0.0133**	1227	0.0299
	(0.0116)	(5.0094)	(7.1602)	(5.1057)	(1.7048)	(0.0065)		
USD	-0.0247***	-18.5417***	-16.2520***	-17.6993***	1.5415	-0.0502**	1227	0.0664
	(0.0088)	(4.0163)	(6.2360)	(4.0169)	(1.4493)	(0.0196)		

The table reports the OLS estimates of the coefficient of the panel fixed effect regression listed above. The 10 currencies used are Australian Dollar (AUD), Canadian Dollar (CAD), Euro (EUR), Japanese Yen (JPY), New Zealand Dollar (NZD), Norwegian Krone (NOK), Swedish Krona (SEK), Swiss Franc (CHF), British Pound (GBP) and United States Dollar (USD). Each row represents a regression estimation using the first column currency as the home currency and the other 9 currencies as foreign currency j. $s_{j,t}$ is the nominal exchange rate between home and foreign country j, defined as home currency price of foreign currency, $q_{j,t}$ is the real exchange rate. $\tilde{\eta}_{j,t}$ is a measure of the treasury liquidity, $i^R_{j,t}$ is the home minus foreign interest rates. Δ is a difference operator. The sample period is 1999M1-2018M1.

Standard errors in parentheses are standard errors adjusted for cross-sectional correlation. *, **, and *** indicate that the alternative model significantly different from zero at 10%, 5%, and 1% significance level, respectively, based on standard normal critical values for the two-sided test.

Robustness of table 1F – full table of table 1F with nominal exchange rates on both sides of regressions
Estimation result of $\Delta s_{j,t} = \alpha_j + \beta_1 s_{j,t-1} + \beta_2(\Delta\tilde{\eta}_{j,t}) + \beta_3(\Delta i^R_{j,t}) + \beta_4(\tilde{\eta}_{j,t-1}) + \beta_5(i^R_{j,t-1}) + u_{j,t}$

	$s_{j,t-1}$	$\Delta\tilde{\eta}_{j,t}$	$\Delta i^R_{j,t}$	$\tilde{\eta}_{j,t-1}$	$i^R_{j,t-1}$	constant	N	R2_within
AUD	-0.0420*	-6.1255	-22.9702	-9.2576	-3.7846	-0.0050	360	0.0465
	(0.0249)	(10.6280)	(15.0457)	(11.9021)	(3.5309)	(0.0035)		
CAD	-0.0330***	-13.0088***	-29.0955***	-10.1306**	0.0577	-0.0136***	1228	0.0565
	(0.0111)	(4.6399)	(7.2932)	(4.7910)	(1.8971)	(0.0030)		
EUR	-0.0882***	-18.9649**	-21.2256**	-19.0896***	0.9455	-0.0860***	609	0.0845
	(0.0186)	(7.4816)	(9.0414)	(7.3569)	(2.8330)	(0.0159)		
JPY	-0.1100***	-22.9549**	-13.5040	-0.9211	-8.7010**	0.4847***	462	0.1394
	(0.0258)	(10.0978)	(11.7250)	(12.1154)	(3.6683)	(0.0669)		
NZD	-0.0290***	-18.9129***	-28.1859***	-12.3604**	1.0430	-0.0077***	1228	0.0605
	(0.0105)	(4.8701)	(6.9947)	(5.3371)	(1.5986)	(0.0023)		
SEK	-0.0395***	-15.2212***	-17.2152***	-11.8799***	-0.2303	0.0690***	1228	0.0493
	(0.0090)	(3.8734)	(5.5854)	(4.1150)	(1.2488)	(0.0131)		
CHF	-0.0831***	-10.3270	8.1529	-15.5219*	10.2469***	-0.0547***	731	0.0747
	(0.0161)	(8.8365)	(8.4713)	(8.9880)	(3.4494)	(0.0089)		
GBP	-0.0248*	-8.4546*	-19.3578***	-9.0781*	-1.2418	-0.0292***	1228	0.0308
	(0.0134)	(4.9111)	(7.0492)	(4.9918)	(1.6042)	(0.0080)		
USD	-0.0275***	-17.3643***	-15.3126**	-16.8933***	1.0161	-0.0119***	1228	0.0618
	(0.0095)	(3.9407)	(6.1502)	(3.9631)	(1.4429)	(0.0042)		

The table reports the OLS estimates of the coefficient of the panel fixed effect regression listed above. The 10 currencies used are Australian Dollar (AUD), Canadian Dollar (CAD), Euro (EUR), Japanese Yen (JPY), New Zealand Dollar (NZD), Norwegian Krone (NOK), Swedish Krona (SEK), Swiss Franc (CHF), British Pound (GBP) and United States Dollar (USD). Each row represents a regression estimation using the first column currency as the home currency and the other 9 currencies as foreign currency j. $s_{j,t}$ is the nominal exchange rate between home and foreign country j, defined as home currency price of foreign currency, $q_{j,t}$ is the real exchange rate. $\tilde{\eta}_{j,t}$ is a measure of the treasury liquidity, $i^R_{j,t}$ is the home minus foreign interest rates. Δ is a difference operator. The sample period is 1999M1-2018M1.

Standard errors in parentheses are standard errors adjusted for cross-sectional correlation. *, **, and *** indicate that the alternative model significantly different from zero at 10%, 5%, and 1% significance level, respectively, based on standard normal critical values for the two-sided test.

Robustness of table 1G – full table of table 1G with real exchange rates on both sides of regressions

Estimation result of $\Delta q_{j,t} = \alpha_j + \beta_1 q_{j,t-1} + \beta_2 \Delta\hat{\eta}_{j,t} + \beta_3 \Delta i^R_{j,t} + \beta_4 \hat{\eta}_{j,t-1} + \beta_5 i^R_{j,t-1} + u_{j,t}$

	$q_{j,t-1}$	$\Delta\hat{\eta}_{j,t}$	$\Delta i^R_{j,t}$	$\hat{\eta}_{j,t-1}$	$i^R_{j,t-1}$	constant	N	R2_within
AUD	-0.0277***	-5.7751***	-5.6699***	0.4402	-0.2934***	0.0127***	2019	0.1883
	(0.0072)	(0.7965)	(0.5457)	(0.4127)	(0.1131)	(0.0042)		
CAD	-0.0271***	-3.8495***	-6.2294***	0.6398*	-0.2601**	0.0057**	1834	0.1714
	(0.0069)	(0.7614)	(0.5544)	(0.3810)	(0.1146)	(0.0025)		
EUR	-0.0191***	-3.6097***	-5.0646***	0.1470	-0.1441	-0.0044**	2026	0.1187
	(0.0059)	(0.5813)	(0.4181)	(0.2974)	(0.0939)	(0.0021)		
JPY	-0.0347***	-4.1654***	-6.2198***	1.7668***	-0.2332*	0.1635***	2026	0.1410
	(0.0103)	(1.0244)	(0.7643)	(0.5412)	(0.1356)	(0.0474)		
NZD	-0.0264***	-6.1882***	-5.9097***	0.2401	-0.0913	0.0117*	2019	0.1672
	(0.0087)	(0.8175)	(0.6368)	(0.4070)	(0.1315)	(0.0062)		
NOK	-0.0157**	-3.0530***	-4.5264***	0.4380	-0.1567	0.0316**	2026	0.1226
	(0.0070)	(0.6696)	(0.5129)	(0.3882)	(0.1048)	(0.0143)		
SEK	-0.0215***	-4.2228***	-4.4396***	-0.2548	-0.0638	0.0434***	2026	0.1084
	(0.0063)	(0.6532)	(0.4820)	(0.3490)	(0.1058)	(0.0132)		
CHF	-0.0085	-2.9705***	-3.0542***	0.5812	-0.2002*	-0.0018	2026	0.0469
	(0.0062)	(0.7853)	(0.5617)	(0.3960)	(0.1093)	(0.0025)		
GBP	-0.0180***	-3.9696***	-5.4704***	0.5693	-0.3275***	-0.0066**	2026	0.1321
	(0.0067)	(0.7452)	(0.5315)	(0.3946)	(0.1066)	(0.0033)		
USD	-0.0134*	-6.2974***	-4.9367***	-1.2904***	0.0006	-0.0269*	2026	0.1398
	(0.0072)	(0.8529)	(0.6062)	(0.4349)	(0.1152)	(0.0149)		

The table reports the OLS estimates of the coefficient of the panel fixed effect regression listed above. The 10 currencies used are Australian Dollar (AUD), Canadian Dollar (CAD), Euro (EUR), Japanese Yen (JPY), New Zealand Dollar (NZD), Norwegian Krone (NOK), Swedish Krona (SEK), Swiss Franc (CHF), British Pound (GBP) and United States Dollar (USD). Each row represents a regression estimation using the first column currency as the home currency and the other 9 currencies as foreign currency j. $s_{j,t}$ is the nominal exchange rate between home and foreign country j, defined as home currency price of foreign currency, $q_{j,t}$ is the real exchange rate, $\hat{\eta}_{j,t}$ is a measure of the treasury liquidity, $i^R_{j,t}$ is the home minus foreign interest rates. Δ is a difference operator. The sample period is 1999M1-2018M1.

Standard errors in parentheses are standard errors adjusted for cross-sectional correlation. *, **, and *** indicate that the alternative model significantly different from zero at 10%, 5%, and 1% significance level, respectively, based on standard normal critical values for the two-sided test.

Robustness of table 1G – full table of table 1G with nominal exchange rates on both sides of regressions

Estimation result of $\Delta s_{j,t} = \alpha_j + \beta_1 s_{j,t-1} + \beta_2 \Delta\hat{\eta}_{j,t} + \beta_3 \Delta i^R_{j,t} + \beta_4 \hat{\eta}_{j,t-1} + \beta_5 i^R_{j,t-1} + u_{j,t}$

	$s_{j,t-1}$	$\Delta\hat{\eta}_{j,t}$	$\Delta i^R_{j,t}$	$\hat{\eta}_{j,t-1}$	$i^R_{j,t-1}$	constant	N	R2_within
AUD	-0.0257***	-5.6745***	-5.5987***	0.6116	-0.2746**	0.0116***	2028	0.1909
	(0.0089)	(0.7806)	(0.5354)	(0.4041)	(0.1068)	(0.0044)		
CAD	-0.0344***	-3.6676***	-6.2024***	0.6432*	-0.2459**	0.0069***	1836	0.1793
	(0.0081)	(0.7464)	(0.5413)	(0.3780)	(0.1083)	(0.0026)		
EUR	-0.0238***	-3.4722***	-4.9982***	0.1845	-0.1411	-0.0049**	2028	0.1207
	(0.0069)	(0.5779)	(0.4158)	(0.2977)	(0.0904)	(0.0022)		
JPY	-0.0320***	-4.2433***	-6.0675***	1.6479***	-0.0801	0.1527***	2028	0.1383
	(0.0110)	(1.0243)	(0.7676)	(0.5408)	(0.1202)	(0.0510)		
NZD	-0.0223**	-6.0083***	-5.8285***	0.3361	-0.0618	0.0094	2028	0.1650
	(0.0099)	(0.8126)	(0.6323)	(0.4059)	(0.1244)	(0.0064)		
NOK	-0.0220***	-2.8769***	-4.3672***	0.3995	-0.1573	0.0438***	2028	0.1223
	(0.0080)	(0.6512)	(0.4988)	(0.3790)	(0.0995)	(0.0160)		
SEK	-0.0278***	-4.1445***	-4.4416***	-0.1737	-0.0930	0.0567***	2028	0.1139
	(0.0075)	(0.6445)	(0.4752)	(0.3468)	(0.1014)	(0.0153)		
CHF	-0.0170**	-3.0973***	-3.0510***	0.5991	-0.2264**	0.0005	2028	0.0538
	(0.0076)	(0.7749)	(0.5543)	(0.3922)	(0.1044)	(0.0026)		
GBP	-0.0233***	-4.0538***	-5.3340***	0.6145	-0.3150***	-0.0091**	2028	0.1337
	(0.0076)	(0.7357)	(0.5245)	(0.3912)	(0.1005)	(0.0037)		
USD	-0.0163*	-6.0164***	-4.7338***	-1.1285***	-0.0252	-0.0334*	2028	0.1342
	(0.0085)	(0.8445)	(0.5995)	(0.4304)	(0.1122)	(0.0174)		

The table reports the OLS estimates of the coefficient of the panel fixed effect regression listed above. The 10 currencies used are Australian Dollar (AUD), Canadian Dollar (CAD), Euro (EUR), Japanese Yen (JPY), New Zealand Dollar (NZD), Norwegian Krone (NOK), Swedish Krona (SEK), Swiss Franc (CHF), British Pound (GBP) and United States Dollar (USD). Each row represents a regression estimation using the first column currency as the home currency and the other 9 currencies as foreign currency j. $s_{j,t}$ is the nominal exchange rate between home and foreign country j, defined as home currency price of foreign currency, $q_{j,t}$ is the real exchange rate, $\hat{\eta}_{j,t}$ is a measure of the treasury liquidity, $i^R_{j,t}$ is the home minus foreign interest rates. Δ is a difference operator. The sample period is 1999M1-2018M1.

Standard errors in parentheses are standard errors adjusted for cross-sectional correlation. *, **, and *** indicate that the alternative model significantly different from zero at 10%, 5%, and 1% significance level, respectively, based on standard normal critical values for the two-sided test.

Robustness of table 2A – full table of table 2A, full sample, no default risk, with real exchange rates on both sides of regressions

Estimation result of $\Delta q_{j,t} = \alpha_j + \beta_1 q_{j,t-1} + \beta_2 \Delta\lambda_{j,t} + \beta_3 \Delta\tau_{j,t} + \beta_4 \Delta l^R_{j,t} + \beta_5 \Delta i^R_{j,t} + \beta_6 \lambda_{j,t-1} + \beta_7 \tau_{j,t-1} + \beta_8 l^R_{j,t-1} + \beta_9 i^R_{j,t-1} + u_{j,t}$

	$q_{j,t-1}$	$\Delta\lambda_{j,t}$	$\Delta\tau_{j,t}$	$\Delta i^R_{j,t}$	$\lambda_{j,t-1}$	$\tau_{j,t-1}$	$i^R_{j,t-1}$	constant	N	R2_within
AUD	-0.0269***	-6.1125***	-3.1154**	-5.9027***	0.3805	-0.2541	-0.2998***	0.0127***	2019	0.1956
	(0.0074)	(0.8081)	(1.2520)	(0.5487)	(0.4370)	(0.7782)	(0.1135)	(0.0042)		
CAD	-0.0262***	-4.7578***	-5.0606***	-6.1798***	0.5135	-0.2924	-0.2885**	0.0053**	1834	0.1966
	(0.0069)	(0.7419)	(1.1586)	(0.5425)	(0.4118)	(0.7321)	(0.1132)	(0.0026)		
EUR	-0.0171***	-4.7713***	-4.9377***	-5.0710***	-0.0752	-0.5204	-0.1569*	-0.0053**	2026	0.1453
	(0.0059)	(0.5726)	(0.8733)	(0.4109)	(0.3147)	(0.5385)	(0.0908)	(0.0022)		
JPY	-0.0367***	-4.1337***	-5.0325***	-6.4433***	2.1405***	2.0365**	-0.0931	0.1800***	2026	0.1708
	(0.0102)	(1.0046)	(1.5941)	(0.7475)	(0.5800)	(0.9654)	(0.1343)	(0.0478)		
NZD	-0.0267***	-6.7612***	-5.9030***	-6.2988***	0.1569	-0.6276	-0.1350	0.0132**	2019	0.2004
	(0.0080)	(0.8064)	(1.3145)	(0.6201)	(0.4379)	(0.7935)	(0.1285)	(0.0058)		
NOK	-0.0168**	-4.0928***	-5.5236***	-5.0670***	0.6073	0.6625	-0.1637	0.0350**	2026	0.1624
	(0.0070)	(0.6672)	(1.0670)	(0.4988)	(0.4064)	(0.7048)	(0.1009)	(0.0145)		
SEK	-0.0195***	-4.4841***	-5.1720***	-4.5787***	-0.2946	-0.6172	-0.0998	0.0381***	2026	0.1292
	(0.0064)	(0.6520)	(0.9988)	(0.4740)	(0.3669)	(0.6449)	(0.1043)	(0.0136)		
CHF	-0.0111*	-2.8827***	-1.2675	-3.0160***	0.6630	0.6845	-0.1749	0.0002	2026	0.0508
	(0.0066)	(0.7813)	(1.2110)	(0.5584)	(0.4264)	(0.7576)	(0.1088)	(0.0035)		
GBP	-0.0190***	-4.1011***	-1.5710	-5.6397***	0.7323*	0.4878	-0.3269***	-0.0066**	2026	0.1357
	(0.0069)	(0.7560)	(1.1410)	(0.5325)	(0.4223)	(0.7082)	(0.1077)	(0.0033)		
USD	-0.0108	-6.5855***	-7.1197***	-4.9650***	-1.4400***	-1.2587*	-0.0382	-0.0194	2026	0.1789
	(0.0070)	(0.8278)	(1.2047)	(0.5845)	(0.4483)	(0.7295)	(0.1115)	(0.0149)		

The table reports the OLS estimates of the coefficient of the panel fixed effect regression listed above. The 10 currencies used are Australian Dollar (AUD), Canadian Dollar (CAD), Euro (EUR), Japanese Yen (JPY), New Zealand Dollar (NZD), Norwegian Krone (NOK), Swedish Krona (SEK), Swiss Franc (CHF), British Pound (GBP) and United States Dollar (USD). Each row represents a regression estimation using the first column currency as the home currency and the other 9 currencies as foreign currency j. $s_{j,t}$ is the nominal exchange rate between home and foreign country j, defined as home currency price of foreign currency, $q_{j,t}$ is the real exchange rate. $\tau_{j,t}$ is a measure of currency derivative friction, $l^R_{j,t}$ is a measure of home minus foreign default risk, $\lambda_{j,t}$ is a measure of the treasury liquidity after adjusting for derivative market friction and default risk, $i^R_{j,t}$ is the home minus foreign interest rates. Δ is a difference operator. The sample period is 1999M1-2018M1.

Standard errors in parentheses are standard errors adjusted for cross-sectional correlation. *, **, and *** indicate that the alternative model significantly different from zero at 10%, 5%, and 1% significance level, respectively, based on standard normal critical values for the two-sided test.

Robustness of table 2A – full table of table 2A, full sample, no default risk, with nominal exchange rates on both sides of regressions

Estimation result of $\Delta s_{j,t} = \alpha_j + \beta_1 s_{j,t-1} + \beta_2 \Delta\lambda_{j,t} + \beta_3 \Delta\tau_{j,t} + \beta_4 \Delta l^R_{j,t} + \beta_5 \Delta i^R_{j,t} + \beta_6 \lambda_{j,t-1} + \beta_7 \tau_{j,t-1} + \beta_8 l^R_{j,t-1} + \beta_9 i^R_{j,t-1} + u_{j,t}$

	$s_{j,t-1}$	$\Delta\lambda_{j,t}$	$\Delta\tau_{j,t}$	$\Delta i^R_{j,t}$	$\lambda_{j,t-1}$	$\tau_{j,t-1}$	$i^R_{j,t-1}$	constant	N	R2_within
AUD	-0.0293***	-6.1153***	-3.3934***	-5.8207***	0.3300	-1.0130	-0.3173***	0.0139***	2028	0.2002
	(0.0085)	(0.7901)	(1.2181)	(0.5373)	(0.4255)	(0.7283)	(0.1091)	(0.0044)		
CAD	-0.0340***	-4.6422***	-5.4011***	-6.1473***	0.4646	-0.4723	-0.2886***	0.0065**	1836	0.2083
	(0.0079)	(0.7234)	(1.1216)	(0.5273)	(0.4006)	(0.7003)	(0.1096)	(0.0026)		
EUR	-0.0227***	-4.6702***	-5.0325***	-4.9995***	-0.1083	-0.6544	-0.1630*	-0.0063***	2028	0.1486
	(0.0067)	(0.5670)	(0.8619)	(0.4083)	(0.3087)	(0.5186)	(0.0884)	(0.0024)		
JPY	-0.0308***	-4.2212***	-5.3680***	-6.2586***	1.8793***	1.3745	0.0210	0.1518***	2028	0.1652
	(0.0108)	(1.0079)	(1.5977)	(0.7535)	(0.5767)	(0.9537)	(0.1258)	(0.0497)		
NZD	-0.0279***	-6.6545***	-6.0965***	-6.2321***	0.1273	-1.1984	-0.1498	0.0145**	2028	0.2001
	(0.0090)	(0.7975)	(1.2964)	(0.6142)	(0.4312)	(0.7672)	(0.1242)	(0.0062)		
NOK	-0.0216***	-3.8634***	-5.2116***	-4.8596***	0.5095	0.4263	-0.1622*	0.0438***	2028	0.1575
	(0.0077)	(0.6519)	(1.0383)	(0.4880)	(0.3948)	(0.6645)	(0.0973)	(0.0154)		
SEK	-0.0275***	-4.4120***	-5.2121***	-4.5315***	-0.2852	-1.1030*	-0.1513	0.0539***	2028	0.1354
	(0.0072)	(0.6414)	(0.9796)	(0.4666)	(0.3611)	(0.6147)	(0.1021)	(0.0150)		
CHF	-0.0189**	-3.0251***	-1.2444	-3.0125***	0.6560	0.5159	-0.1998*	0.0021	2028	0.0570
	(0.0075)	(0.7705)	(1.1869)	(0.5511)	(0.4155)	(0.7024)	(0.1062)	(0.0033)		
GBP	-0.0234***	-4.2066***	-1.5885	-5.4765***	0.6976*	0.2243	-0.3141***	-0.0090**	2028	0.1367
	(0.0075)	(0.7460)	(1.1200)	(0.5259)	(0.4142)	(0.6801)	(0.1044)	(0.0038)		
USD	-0.0151*	-6.2921***	-6.8514***	-4.7590***	-1.2806***	-1.1215	-0.0658	-0.0288*	2028	0.1718
	(0.0082)	(0.8215)	(1.1837)	(0.5799)	(0.4466)	(0.7037)	(0.1109)	(0.0168)		

The table reports the OLS estimates of the coefficient of the panel fixed effect regression listed above. The 10 currencies used are Australian Dollar (AUD), Canadian Dollar (CAD), Euro (EUR), Japanese Yen (JPY), New Zealand Dollar (NZD), Norwegian Krone (NOK), Swedish Krona (SEK), Swiss Franc (CHF), British Pound (GBP) and United States Dollar (USD). Each row represents a regression estimation using the first column currency as the home currency and the other 9 currencies as foreign currency j. $s_{j,t}$ is the nominal exchange rate between home and foreign country j, defined as home currency price of foreign currency, $q_{j,t}$ is the real exchange rate. $\tau_{j,t}$ is a measure of currency derivative friction, $l^R_{j,t}$ is a measure of home minus foreign default risk, $\lambda_{j,t}$ is a measure of the treasury liquidity after adjusting for derivative market friction and default risk, $i^R_{j,t}$ is the home minus foreign interest rates. Δ is a difference operator. The sample period is 1999M1-2018M1.

Standard errors in parentheses are standard errors adjusted for cross-sectional correlation. *, **, and *** indicate that the alternative model significantly different from zero at 10%, 5%, and 1% significance level, respectively, based on standard normal critical values for the two-sided test.

Robustness of table 2A – full table of table 2A, post 2008, with default risk, with real exchange rates on both sides of regressions

Estimation result of $\Delta q_{j,t} = \alpha_j + \beta_1 q_{j,t-1} + \beta_2 \Delta\lambda_{j,t} + \beta_3 \Delta\tau_{j,t} + \beta_4 \Delta l^R_{j,t} + \beta_5 \Delta i^R_{j,t} + \beta_6 \lambda_{j,t-1} + \beta_7 \tau_{j,t-1} + \beta_8 l^R_{j,t-1} + \beta_9 i^R_{j,t-1} + u_{j,t}$

	$q_{j,t-1}$	$\Delta\lambda_{j,t}$	$\Delta\tau_{j,t}$	$\Delta l^R_{j,t}$	$\Delta i^R_{j,t}$	$\lambda_{j,t-1}$	$\tau_{j,t-1}$	$l^R_{j,t-1}$	$i^R_{j,t-1}$	N	R2_within
AUD	-0.0500***	-6.9905***	-3.2537**	13.9603***	-7.3647***	-0.2514	-0.3967	0.0704	-0.4035*	946	0.2877
	(0.0161)	(1.1544)	(1.5895)	(2.4229)	(0.8265)	(0.6792)	(1.2372)	(1.4657)	(0.2212)		
CAD	-0.0375***	-8.5976***	-6.4680***	7.5185***	-9.5496***	-0.4895	-3.8675***	-0.7664	0.3320	397	0.3046
	(0.0127)	(1.6347)	(2.0021)	(2.8412)	(1.2465)	(0.9194)	(1.1732)	(1.6863)	(0.2739)		
EUR	-0.0441***	-6.3260***	-3.8591***	7.9316***	-7.9929***	-0.0368	-0.8180	2.0960**	-0.0394	964	0.2592
	(0.0108)	(0.8082)	(0.9578)	(1.6943)	(0.6267)	(0.4774)	(0.7231)	(1.0633)	(0.1767)		
JPY	-0.0591***	-6.8276***	-4.2662**	10.0638***	-11.3810***	2.0644**	3.1155**	0.1625	0.0191	964	0.3372
	(0.0178)	(1.3788)	(1.8635)	(3.1921)	(1.1352)	(0.8133)	(1.4265)	(2.0052)	(0.2798)		
NZD	-0.0534***	-8.0860***	-5.9783***	12.5350***	-8.0470***	0.5891	0.3525	0.2115	0.2131	934	0.3123
	(0.0140)	(1.1602)	(1.5135)	(2.5481)	(0.9202)	(0.7084)	(1.2478)	(1.4474)	(0.2537)		
NOK	-0.0388***	-5.5007***	-5.9573***	4.2082**	-8.1254***	0.5270	0.6183	1.6778	-0.0826	964	0.2670
	(0.0112)	(0.8186)	(1.2155)	(1.9775)	(0.7404)	(0.5385)	(0.9116)	(1.2826)	(0.1960)		
SEK	-0.0460***	-5.4898***	-4.2737***	7.3440***	-6.1670***	0.0279	-0.9114	-0.0626	-0.0083	964	0.1980
	(0.0115)	(0.9057)	(1.1731)	(1.9522)	(0.7384)	(0.5190)	(0.8715)	(1.1734)	(0.1950)		
CHF	-0.0236*	-3.0688**	-1.4029	5.2727**	-1.1023	-0.3194	0.3271	1.8528	0.2218	886	0.0312
	(0.0126)	(1.5060)	(1.8328)	(2.6419)	(1.0836)	(0.7739)	(1.1767)	(1.4893)	(0.2359)		
GBP	-0.0468***	-6.0848***	-0.5898	5.6774**	-9.1657***	0.4693	2.0281*	1.0813	-0.0513	964	0.2330
	(0.0137)	(1.1178)	(1.4178)	(2.3574)	(0.8805)	(0.6587)	(1.0387)	(1.4895)	(0.2373)		
USD	-0.0553***	-9.3364***	-3.5274***	13.0448***	-10.5412***	-1.2093*	0.0704	1.2208	0.1490	811	0.3843
	(0.0140)	(1.1279)	(1.3005)	(2.1895)	(0.8953)	(0.6417)	(0.9708)	(1.3843)	(0.2284)		

The table reports the OLS estimates of the coefficient of the panel fixed effect regression listed above. The 10 currencies used are Australian Dollar (AUD), Canadian Dollar (CAD), Euro (EUR), Japanese Yen (JPY), New Zealand Dollar (NZD), Norwegian Krone (NOK), Swedish Krona (SEK), Swiss Franc (CHF), British Pound (GBP) and United States Dollar (USD). Each row represents a regression estimation using the first column currency as the home currency and the other 9 currencies as foreign currency j. $s_{j,t}$ is the nominal exchange rate between home and foreign country j, defined as home currency price of foreign currency, $q_{j,t}$ is the real exchange rate. $\tau_{j,t}$ is a measure of currency derivative friction, $l^R_{j,t}$ is a measure of home minus foreign default risk, $\lambda_{j,t}$ is a measure of the treasury liquidity after adjusting for derivative market friction and default risk, $i^R_{j,t}$ is the home minus foreign interest rates. Δ is a difference operator. The sample period is 2008M1-2018M1.

Standard errors in parentheses are standard errors adjusted for cross-sectional correlation. *, **, and *** indicate that the alternative model significantly different from zero at 10%, 5%, and 1% significance level, respectively, based on standard normal critical values for the two-sided test.

Robustness of table 2A – full table of table 2A, post 2008, with default risk, with nominal exchange rates on both sides of regressions

Estimation result of $\Delta s_{j,t} = \alpha_j + \beta_1 s_{j,t-1} + \beta_2 \Delta\lambda_{j,t} + \beta_3 \Delta\tau_{j,t} + \beta_4 \Delta l^R_{j,t} + \beta_5 \Delta i^R_{j,t} + \beta_6 \lambda_{j,t-1} + \beta_7 \tau_{j,t-1} + \beta_8 l^R_{j,t-1} + \beta_9 i^R_{j,t-1} + u_{j,t}$

	$s_{j,t-1}$	$\Delta\lambda_{j,t}$	$\Delta\tau_{j,t}$	$\Delta l^R_{j,t}$	$\Delta i^R_{j,t}$	$\lambda_{j,t-1}$	$\tau_{j,t-1}$	$l^R_{j,t-1}$	$i^R_{j,t-1}$	N	R2_within
AUD	-0.0561***	-6.9234***	-3.0928**	14.5433***	-7.0818***	-0.2219	-0.5739	0.4607	-0.3511	955	0.2905
	(0.0171)	(1.1179)	(1.5349)	(2.3556)	(0.7989)	(0.6625)	(1.1915)	(1.4263)	(0.2175)		
CAD	-0.0452***	-8.7478***	-6.8539***	8.2598***	-8.9245***	-0.5903	-3.6899***	-0.5421	0.3553	399	0.3095
	(0.0155)	(1.5103)	(1.7874)	(2.5604)	(1.1076)	(0.8476)	(1.0582)	(1.5414)	(0.2520)		
EUR	-0.0561***	-6.1346***	-3.9516***	8.4379***	-7.8268***	-0.0649	-0.8720	2.4586**	-0.0988	966	0.2626
	(0.0123)	(0.7976)	(0.9435)	(1.6765)	(0.6184)	(0.4718)	(0.7110)	(1.0576)	(0.1801)		
JPY	-0.0650***	-6.8812***	-4.5365**	10.4251***	-11.2611***	2.0921**	2.5341*	0.2363	0.0396	966	0.3381
	(0.0192)	(1.3812)	(1.8549)	(3.1878)	(1.1344)	(0.8183)	(1.4283)	(2.0116)	(0.2789)		
NZD	-0.0578***	-7.8690***	-5.9201***	12.5630***	-8.0042***	0.6155	0.2007	0.3171	0.2458	943	0.3147
	(0.0159)	(1.1425)	(1.4861)	(2.5156)	(0.9045)	(0.6991)	(1.2257)	(1.4519)	(0.2459)		
NOK	-0.0556***	-5.1392***	-5.8378***	4.2726**	-7.9138***	0.5503	0.3971	1.8382	-0.1758	966	0.2651
	(0.0130)	(0.8053)	(1.1951)	(1.9521)	(0.7288)	(0.5305)	(0.8934)	(1.2767)	(0.1976)		
SEK	-0.0625***	-5.6128***	-4.1807***	7.6208***	-6.1712***	-0.0062	-1.2239	0.2801	-0.1383	966	0.2102
	(0.0134)	(0.8799)	(1.1420)	(1.8930)	(0.7177)	(0.5105)	(0.8454)	(1.1431)	(0.1939)		
CHF	-0.0429***	-3.1797**	-1.2316	5.7305**	-0.9602	-0.5137	0.0141	2.3253	0.1572	888	0.0423
	(0.0156)	(1.4839)	(1.7978)	(2.5929)	(1.0661)	(0.7682)	(1.1504)	(1.4810)	(0.2330)		
GBP	-0.0566***	-6.1559***	-0.6474	5.7833**	-8.9778***	0.4620	1.6963*	1.2768	-0.1226	966	0.2306
	(0.0158)	(1.1167)	(1.4103)	(2.3582)	(0.8789)	(0.6578)	(1.0290)	(1.5065)	(0.2380)		
USD	-0.0620***	-8.9441***	-3.3469***	12.5068***	-10.2297***	-0.9105	0.0934	0.8905	0.0817	813	0.3760
	(0.0158)	(1.1130)	(1.2514)	(2.1606)	(0.8861)	(0.6266)	(0.9398)	(1.3678)	(0.2366)		

The table reports the OLS estimates of the coefficient of the panel fixed effect regression listed above. The 10 currencies used are Australian Dollar (AUD), Canadian Dollar (CAD), Euro (EUR), Japanese Yen (JPY), New Zealand Dollar (NZD), Norwegian Krone (NOK), Swedish Krona (SEK), Swiss Franc (CHF), British Pound (GBP) and United States Dollar (USD). Each row represents a regression estimation using the first column currency as the home currency and the other 9 currencies as foreign currency j. $s_{j,t}$ is the nominal exchange rate between home and foreign country j, defined as home currency price of foreign currency, $q_{j,t}$ is the real exchange rate. $\tau_{j,t}$ is a measure of currency derivative friction, $l^R_{j,t}$ is a measure of home minus foreign default risk, $\lambda_{j,t}$ is a measure of the treasury liquidity after adjusting for derivative market friction and default risk, $i^R_{j,t}$ is the home minus foreign interest rates. Δ is a difference operator. The sample period is 2008M1-2018M1.

Standard errors in parentheses are standard errors adjusted for cross-sectional correlation. *, **, and *** indicate that the alternative model significantly different from zero at 10%, 5%, and 1% significance level, respectively, based on standard normal critical values for the two-sided test.

Robustness of table 2B – full table of table 2B for $\lambda_{j,t}$ with real exchange rates on both sides of regressions

Estimation result of $\Delta q_{j,t} = \alpha_j + \beta_1 q_{j,t-1} + \beta_2 \Delta\lambda_{j,t} + \beta_3 \Delta i^R_{j,t} + \beta_4 \lambda_{j,t-1} + \beta_5 i^R_{j,t-1} + u_{j,t}$

	$q_{j,t-1}$	$\Delta\lambda_{j,t}$	$\Delta i^R_{j,t}$	$\lambda_{j,t-1}$	$i^R_{j,t-1}$	constant	N	R2_within
AUD	-0.0534***	-4.3739***	-6.5096***	0.0997	-0.4144*	0.0177**	946	0.2127
	(0.0164)	(1.1082)	(0.8622)	(0.5894)	(0.2368)	(0.0080)		
CAD	-0.0417***	-3.7888***	-8.5852***	1.1051	0.4062	0.0047	397	0.2494
	(0.0134)	(1.4655)	(1.2578)	(0.7903)	(0.2887)	(0.0036)		
EUR	-0.0388***	-3.4389***	-7.7765***	0.7446*	-0.0085	-0.0125***	964	0.2181
	(0.0107)	(0.7464)	(0.6335)	(0.4171)	(0.1848)	(0.0037)		
JPY	-0.0636***	-4.9737***	-10.8616***	1.7369***	-0.2885	0.2901***	964	0.2780
	(0.0183)	(1.3654)	(1.1818)	(0.6563)	(0.2953)	(0.0828)		
NZD	-0.0515***	-5.1729***	-6.9011***	0.9073	0.2786	0.0059	934	0.2198
	(0.0163)	(1.1498)	(0.9819)	(0.6777)	(0.2765)	(0.0103)		
NOK	-0.0320***	-4.4965***	-7.3775***	0.8098*	-0.0473	0.0599***	964	0.2168
	(0.0113)	(0.7858)	(0.7615)	(0.4551)	(0.2065)	(0.0223)		
SEK	-0.0486***	-3.9759***	-5.9093***	0.0752	0.0733	0.0941***	964	0.1551
	(0.0114)	(0.8385)	(0.7441)	(0.4719)	(0.2026)	(0.0227)		
CHF	-0.0206*	-1.7830	-0.9819	0.0818	0.2107	-0.0043	886	0.0178
	(0.0120)	(1.3401)	(1.0761)	(0.6575)	(0.2374)	(0.0037)		
GBP	-0.0428***	-4.9667***	-8.3456***	0.2093	-0.1122	-0.0180***	964	0.2134
	(0.0135)	(1.0282)	(0.8663)	(0.5513)	(0.2399)	(0.0062)		
USD	-0.0573***	-5.4277***	-10.3205***	-0.9251	0.2120	-0.1111***	811	0.2864
	(0.0166)	(1.1358)	(0.9772)	(0.6452)	(0.2609)	(0.0327)		

The table reports the OLS estimates of the coefficient of the panel fixed effect regression listed above. The 10 currencies used are Australian Dollar (AUD), Canadian Dollar (CAD), Euro (EUR), Japanese Yen (JPY), New Zealand Dollar (NZD), Norwegian Krone (NOK), Swedish Krona (SEK), Swiss Franc (CHF), British Pound (GBP) and United States Dollar (USD). Each row represents a regression estimation using the first column currency as the home currency and the other 9 currencies as foreign currency j. $s_{j,t}$ is the nominal exchange rate between home and foreign country j, defined as home currency price of foreign currency, $q_{j,t}$ is the real exchange rate. $\tau_{j,t}$ is a measure of currency derivative friction, $l^R_{j,t}$ is a measure of home minus foreign default risk, $\lambda_{j,t}$ is a measure of the treasury liquidity after adjusting for derivative market friction and default risk, $i^R_{j,t}$ is the home minus foreign interest rates. Δ is a difference operator. The sample period is 1999M1-2018M1. Regressions involving default risk $\hat{l}^R_{j,t}$ are only estimated through 2008M1-2018M1 period.

Standard errors in parentheses are standard errors adjusted for cross-sectional correlation. *, **, and *** indicate that the alternative model significantly different from zero at 10%, 5%, and 1% significance level, respectively, based on standard normal critical values for the two-sided test.

Robustness of table 2B – full table of table 2B for $\tau_{j,t}$ with real exchange rates on both sides of regressions

Estimation result of $\Delta q_{j,t} = \alpha_j + \beta_1 q_{j,t-1} + \beta_2 \Delta\tau_{j,t} + \beta_3 \Delta i^R_{j,t} + \beta_4 \tau_{j,t-1} + \beta_5 i^R_{j,t-1} + u_{j,t}$

	$q_{j,t-1}$	$\Delta\tau_{j,t}$	$\Delta i^R_{j,t}$	$\tau_{j,t-1}$	$i^R_{j,t-1}$	constant	N	R2_within
AUD	-0.0306***	-1.5580	-4.2340***	-0.3559	-0.3044***	0.0138***	2019	0.1146
	(0.0077)	(1.3011)	(0.5264)	(0.7647)	(0.1169)	(0.0044)		
CAD	-0.0266***	-4.1632***	-5.3026***	-0.8095	-0.2918***	0.0043*	1834	0.1604
	(0.0070)	(1.1573)	(0.5126)	(0.6645)	(0.1125)	(0.0024)		
EUR	-0.0188***	-3.1431***	-3.6503***	-0.5212	-0.1804**	-0.0056**	2026	0.1007
	(0.0059)	(0.8809)	(0.3771)	(0.4858)	(0.0909)	(0.0022)		
JPY	-0.0309***	-5.8410***	-5.6309***	0.6750	-0.0575	0.1444***	2026	0.1273
	(0.0103)	(1.6410)	(0.7081)	(0.9162)	(0.1354)	(0.0482)		
NZD	-0.0284***	-4.1545***	-2.8570***	-0.3922	-0.0823	0.0125*	2019	0.0730
	(0.0089)	(1.4344)	(0.5912)	(0.7932)	(0.1380)	(0.0064)		
NOK	-0.0153**	-3.3299***	-3.7231***	0.1104	-0.1082	0.0306**	2026	0.0956
	(0.0072)	(1.0869)	(0.4805)	(0.6810)	(0.1006)	(0.0148)		
SEK	-0.0224***	-4.5149***	-3.2503***	-0.5409	-0.1366	0.0442***	2026	0.0827
	(0.0065)	(1.0079)	(0.4331)	(0.6124)	(0.1027)	(0.0137)		
CHF	-0.0096	-1.5690	-2.0432***	0.4203	-0.1742	-0.0029	2026	0.0268
	(0.0063)	(1.2161)	(0.5133)	(0.7098)	(0.1069)	(0.0028)		
GBP	-0.0192***	-0.8562	-3.9284***	-0.3696	-0.3375***	-0.0072**	2026	0.0897
	(0.0070)	(1.1545)	(0.4956)	(0.6809)	(0.1073)	(0.0034)		
USD	-0.0114	-6.4723***	-3.8889***	-0.9843	-0.1586	-0.0206	2026	0.1045
	(0.0076)	(1.2571)	(0.5748)	(0.7087)	(0.1154)	(0.0162)		

The table reports the OLS estimates of the coefficient of the panel fixed effect regression listed above. The 10 currencies used are Australian Dollar (AUD), Canadian Dollar (CAD), Euro (EUR), Japanese Yen (JPY), New Zealand Dollar (NZD), Norwegian Krone (NOK), Swedish Krona (SEK), Swiss Franc (CHF), British Pound (GBP) and United States Dollar (USD). Each row represents a regression estimation using the first column currency as the home currency and the other 9 currencies as foreign currency j. $s_{j,t}$ is the nominal exchange rate between home and foreign country j, defined as home currency price of foreign currency, $q_{j,t}$ is the real exchange rate. $\tau_{j,t}$ is a measure of currency derivative friction, $l^R_{j,t}$ is a measure of home minus foreign default risk, $\lambda_{j,t}$ is a measure of the treasury liquidity after adjusting for derivative market friction and default risk, $i^R_{j,t}$ is the home minus foreign interest rates. Δ is a difference operator. The sample period is 1999M1-2018M1. Regressions involving default risk $\hat{l}^R_{j,t}$ are only estimated through 2008M1-2018M1 period.

Standard errors in parentheses are standard errors adjusted for cross-sectional correlation. *, **, and *** indicate that the alternative model significantly different from zero at 10%, 5%, and 1% significance level, respectively, based on standard normal critical values for the two-sided test.

Robustness of table 2B – full table of table 2B for $l_{j,t}^{R}$ with real exchange rates on both sides of regressions

Estimation result of $\Delta q_{j,t} = \alpha_j + \beta_1 q_{j,t-1} + \beta_2 \Delta l_{j,t}^{R} + \beta_3 \Delta i_{j,t}^{R} + \beta_4 l_{j,t-1}^{R} + \beta_5 i_{j,t-1}^{R} + u_{j,t}$

	$q_{j,t-1}$	$\Delta l_{j,t}^{R}$	$\Delta i_{j,t}^{R}$	$l_{j,t-1}^{R}$	$i_{j,t-1}^{R}$	constant	N	R2_within
AUD	-0.0557***	9.5842***	-5.8544***	0.5459	-0.4645**	0.0199***	946	0.2106
	(0.0167)	(2.2739)	(0.7789)	(1.3563)	(0.2265)	(0.0077)		
CAD	-0.0359***	0.1895	-7.5258***	1.4216	0.5160*	0.0024	397	0.2107
	(0.0135)	(2.5282)	(1.1956)	(1.5294)	(0.2702)	(0.0037)		
EUR	-0.0475***	1.5135	-6.1494***	2.3604**	-0.0327	-0.0132***	964	0.1828
	(0.0111)	(1.5723)	(0.5837)	(0.9697)	(0.1860)	(0.0038)		
JPY	-0.0562***	4.4139	-9.8760***	2.1216	0.0010	0.2537***	964	0.2392
	(0.0194)	(3.1174)	(1.1446)	(1.8890)	(0.3094)	(0.0873)		
NZD	-0.0648***	4.4994*	-5.7978***	2.0931	0.3272	0.0070	934	0.1550
	(0.0163)	(2.6259)	(0.9824)	(1.4705)	(0.2809)	(0.0104)		
NOK	-0.0415***	-1.5135	-5.2312***	2.9458**	-0.0437	0.0810***	964	0.1354
	(0.0123)	(1.9833)	(0.7324)	(1.1982)	(0.2222)	(0.0245)		
SEK	-0.0529***	3.0654*	-4.2163***	1.1342	0.0647	0.1033***	964	0.1180
	(0.0121)	(1.8408)	(0.6777)	(1.1156)	(0.2005)	(0.0240)		
CHF	-0.0228*	2.3077	-0.3057	1.6418	0.1830	-0.0047	886	0.0165
	(0.0125)	(2.3223)	(0.9909)	(1.3364)	(0.2311)	(0.0033)		
GBP	-0.0467***	0.8943	-6.0613***	1.5762	-0.1343	-0.0191***	964	0.1657
	(0.0145)	(2.2250)	(0.8301)	(1.2965)	(0.2472)	(0.0067)		
USD	-0.0539***	5.3278**	-9.0747***	-0.3014	0.1945	-0.1033***	811	0.2592
	(0.0170)	(2.1713)	(0.9298)	(1.3941)	(0.2596)	(0.0337)		

The table reports the OLS estimates of the coefficient of the panel fixed effect regression listed above. The 10 currencies used are Australian Dollar (AUD), Canadian Dollar (CAD), Euro (EUR), Japanese Yen (JPY), New Zealand Dollar (NZD), Norwegian Krone (NOK), Swedish Krona (SEK), Swiss Franc (CHF), British Pound (GBP) and United States Dollar (USD). Each row represents a regression estimation using the first column currency as the home currency and the other 9 currencies as foreign currency j. $s_{j,t}$ is the nominal exchange rate between home and foreign country j, defined as home currency price of foreign currency, $q_{j,t}$ is the real exchange rate. $\tau_{j,t}$ is a measure of currency derivative friction, $l_{j,t}^{R}$ is a measure of home minus foreign default risk, $\lambda_{j,t}$ is a measure of the treasury liquidity after adjusting for derivative market friction and default risk, $i_{j,t}^{R}$ is the home minus foreign interest rates. Δ is a difference operator. The sample period is 1999M1-2018M1. Regressions involving default risk $\hat{l}_{j,t}^{R}$ are only estimated through 2008M1-2018M1 period.

Standard errors in parentheses are standard errors adjusted for cross-sectional correlation. *, **, and *** indicate that the alternative model significantly different from zero at 10%, 5%, and 1% significance level, respectively, based on standard normal critical values for the two-sided test.

Robustness of table 2B – full table of table 2B for $(\eta + l^R)_{j,t}$ with real exchange rates on both sides of regressions

Estimation result of $\Delta q_{j,t} = \alpha_j + \beta_1 q_{j,t-1} + \beta_2 \Delta(\eta + l^R)_{j,t} + \beta_3 \Delta i^R_{j,t} + \beta_4 (\eta + l^R)_{j,t-1} + \beta_5 i^R_{j,t-1} + u_{j,t}$

	$q_{j,t-1}$	$\Delta(\eta+l^R)_{j,t}$	$\Delta i^R_{j,t}$	$(\eta+l^R)_{j,t-1}$	$i^R_{j,t-1}$	constant	N	R2_within
AUD	-0.0510***	-4.3330***	-6.8168***	-0.0988	-0.3855*	0.0168**	946	0.2224
	(0.0164)	(0.9813)	(0.8744)	(0.6628)	(0.2341)	(0.0078)		
CAD	-0.0320**	-5.3497***	-8.8092***	-0.5048	0.5908**	0.0022	397	0.2540
	(0.0128)	(1.3506)	(1.2660)	(0.8605)	(0.2785)	(0.0038)		
EUR	-0.0367***	-3.9413***	-7.4480***	0.3598	-0.0061	-0.0104***	964	0.2291
	(0.0107)	(0.6257)	(0.6064)	(0.4234)	(0.1794)	(0.0039)		
JPY	-0.0625***	-4.4920***	-11.1699***	2.4222***	-0.1201	0.2949***	964	0.3137
	(0.0180)	(1.1395)	(1.1205)	(0.7912)	(0.2922)	(0.0815)		
NZD	-0.0490***	-5.4003***	-7.4684***	0.9618	0.3324	0.0026	934	0.2631
	(0.0154)	(0.9280)	(0.9399)	(0.6675)	(0.2608)	(0.0097)		
NOK	-0.0344***	-5.0701***	-7.9508***	0.9347**	-0.0651	0.0673***	964	0.2599
	(0.0108)	(0.6722)	(0.7199)	(0.4411)	(0.1945)	(0.0216)		
SEK	-0.0462***	-4.1494***	-6.0740***	-0.0862	0.0640	0.0896***	964	0.1725
	(0.0115)	(0.6960)	(0.7218)	(0.4672)	(0.1972)	(0.0228)		
CHF	-0.0213*	-1.5999	-0.7741	0.1657	0.1943	-0.0036	886	0.0221
	(0.0120)	(1.0840)	(1.0277)	(0.6311)	(0.2346)	(0.0048)		
GBP	-0.0426***	-3.3640***	-8.0299***	0.9588*	-0.1576	-0.0171***	964	0.2075
	(0.0139)	(0.8676)	(0.8606)	(0.5704)	(0.2385)	(0.0064)		
USD	-0.0582***	-4.8651***	-9.7742***	-1.0721*	0.1731	-0.1106***	811	0.3030
	(0.0159)	(0.8745)	(0.9304)	(0.5963)	(0.2522)	(0.0315)		

The table reports the OLS estimates of the coefficient of the panel fixed effect regression listed above. The 10 currencies used are Australian Dollar (AUD), Canadian Dollar (CAD), Euro (EUR), Japanese Yen (JPY), New Zealand Dollar (NZD), Norwegian Krone (NOK), Swedish Krona (SEK), Swiss Franc (CHF), British Pound (GBP) and United States Dollar (USD). Each row represents a regression estimation using the first column currency as the home currency and the other 9 currencies as foreign currency j. $s_{j,t}$ is the nominal exchange rate between home and foreign country j, defined as home currency price of foreign currency, $q_{j,t}$ is the real exchange rate. $\tau_{j,t}$ is a measure of currency derivative friction, $l^R_{j,t}$ is a measure of home minus foreign default risk, $\lambda_{j,t}$ is a measure of the treasury liquidity after adjusting for derivative market friction and default risk, $i^R_{j,t}$ is the home minus foreign interest rates. Δ is a difference operator. The sample period is 1999M1-2018M1. Regressions involving default risk $\hat{l}^R_{j,t}$ are only estimated through 2008M1-2018M1 period.

Standard errors in parentheses are standard errors adjusted for cross-sectional correlation. *, **, and *** indicate that the alternative model significantly different from zero at 10%, 5%, and 1% significance level, respectively, based on standard normal critical values for the two-sided test.

Robustness of table 2B – full table of table 2B for $(\tau - l^R)_{j,t}$ with real exchange rates on both sides of regressions

Estimation result of $\Delta s_{j,t} = \alpha_j + \beta_1 q_{j,t-1} + \beta_2 \Delta(\tau - l^R)_{j,t} + \beta_3 \Delta i^R_{j,t} + \beta_4 (\tau - l^R)_{j,t-1} + \beta_5 i^R_{j,t-1} + u_{j,t}$

	$q_{j,t-1}$	$\Delta(\tau - l^R)_{j,t}$	$\Delta i^R_{j,t}$	$(\tau - l^R)_{j,t-1}$	$i^R_{j,t-1}$	constant	N	R2_within
AUD	-0.0544***	-4.6485***	-6.0675***	-0.9573	-0.5285**	0.0218***	946	0.2053
	(0.0165)	(1.3342)	(0.8128)	(0.8864)	(0.2430)	(0.0084)		
CAD	-0.0415***	-1.4134	-7.4779***	-1.8776**	0.3391	0.0010	397	0.2301
	(0.0135)	(1.5977)	(1.1781)	(0.8608)	(0.2726)	(0.0037)		
EUR	-0.0448***	-2.1385***	-5.7709***	-1.5086***	-0.1106	-0.0178***	964	0.1911
	(0.0108)	(0.8262)	(0.5806)	(0.5440)	(0.1836)	(0.0043)		
JPY	-0.0501***	-6.0067***	-10.0991***	0.2014	0.0658	0.2277***	964	0.2693
	(0.0187)	(1.6490)	(1.1207)	(1.0903)	(0.3108)	(0.0838)		
NZD	-0.0542***	-5.3081***	-6.2437***	-0.7509	0.2669	0.0075	934	0.1879
	(0.0163)	(1.3981)	(0.9651)	(0.9459)	(0.2771)	(0.0103)		
NOK	-0.0314***	-3.3808***	-5.1824***	-1.3813*	-0.0505	0.0578**	964	0.1360
	(0.0120)	(1.1076)	(0.7473)	(0.7373)	(0.2246)	(0.0234)		
SEK	-0.0517***	-3.7575***	-4.1713***	-1.0157	-0.0031	0.0984***	964	0.1343
	(0.0117)	(1.0152)	(0.6759)	(0.6546)	(0.1994)	(0.0232)		
CHF	-0.0198*	-2.1756	-0.0573	-0.3278	0.1774	-0.0052	886	0.0192
	(0.0119)	(1.4756)	(0.9995)	(0.8623)	(0.2311)	(0.0043)		
GBP	-0.0470***	-0.5878	-6.0992***	-0.1266	-0.1690	-0.0187***	964	0.1632
	(0.0141)	(1.2057)	(0.8406)	(0.7522)	(0.2530)	(0.0066)		
USD	-0.0566***	-4.9275***	-8.8790***	-0.6179	0.1045	-0.1072***	811	0.2777
	(0.0164)	(1.2004)	(0.9218)	(0.8523)	(0.2543)	(0.0322)		

The table reports the OLS estimates of the coefficient of the panel fixed effect regression listed above. The 10 currencies used are Australian Dollar (AUD), Canadian Dollar (CAD), Euro (EUR), Japanese Yen (JPY), New Zealand Dollar (NZD), Norwegian Krone (NOK), Swedish Krona (SEK), Swiss Franc (CHF), British Pound (GBP) and United States Dollar (USD). Each row represents a regression estimation using the first column currency as the home currency and the other 9 currencies as foreign currency j. $s_{j,t}$ is the nominal exchange rate between home and foreign country j, defined as home currency price of foreign currency, $q_{j,t}$ is the real exchange rate. $\tau_{j,t}$ is a measure of currency derivative friction, $l^R_{j,t}$ is a measure of home minus foreign default risk, $\lambda_{j,t}$ is a measure of the treasury liquidity after adjusting for derivative market friction and default risk, $i^R_{j,t}$ is the home minus foreign interest rates. Δ is a difference operator. The sample period is 1999M1-2018M1. Regressions involving default risk $\hat{l}^R_{j,t}$ are only estimated through 2008M1-2018M1 period.

Standard errors in parentheses are standard errors adjusted for cross-sectional correlation. *, **, and *** indicate that the alternative model significantly different from zero at 10%, 5%, and 1% significance level, respectively, based on standard normal critical values for the two-sided test.

Robustness of table 2B – full table of table 2B for $\lambda_{j,t}$ with nominal exchange rates on both sides of regressions

Estimation result of $\Delta s_{j,t} = \alpha_j + \beta_1 s_{j,t-1} + \beta_2 \Delta\lambda_{j,t} + \beta_3 \Delta i^R_{j,t} + \beta_4 \lambda_{j,t-1} + \beta_5 i^R_{j,t-1} + u_{j,t}$

	$s_{j,t-1}$	$\Delta\lambda_{j,t}$	$\Delta i^R_{j,t}$	$\lambda_{j,t-1}$	$i^R_{j,t-1}$	constant	N	R2_within
AUD	-0.0590***	-4.2368***	-6.2444***	0.2449	-0.3457	0.0154*	955	0.2109
	(0.0177)	(1.0806)	(0.8405)	(0.5866)	(0.2336)	(0.0079)		
CAD	-0.0490***	-3.5511***	-7.9123***	1.0562	0.4060	0.0059	399	0.2440
	(0.0161)	(1.3298)	(1.1303)	(0.7125)	(0.2670)	(0.0039)		
EUR	-0.0477***	-3.1006***	-7.5862***	0.7900*	-0.0539	-0.0142***	966	0.2164
	(0.0121)	(0.7402)	(0.6290)	(0.4149)	(0.1889)	(0.0039)		
JPY	-0.0729***	-4.9654***	-10.8168***	1.9380***	-0.2287	0.3363***	966	0.2810
	(0.0196)	(1.3595)	(1.1771)	(0.6566)	(0.2899)	(0.0893)		
NZD	-0.0546***	-4.9534***	-6.8799***	0.9760	0.3157	0.0056	943	0.2227
	(0.0173)	(1.1303)	(0.9666)	(0.6669)	(0.2668)	(0.0103)		
NOK	-0.0483***	-4.1381***	-7.2070***	0.8925**	-0.1439	0.0918***	966	0.2164
	(0.0130)	(0.7709)	(0.7477)	(0.4500)	(0.2064)	(0.0256)		
SEK	-0.0630***	-4.0957***	-6.0086***	0.1026	-0.0504	0.1244***	966	0.1657
	(0.0135)	(0.8153)	(0.7240)	(0.4651)	(0.2013)	(0.0270)		
CHF	-0.0384***	-1.7289	-0.7926	0.0104	0.1453	-0.0026	888	0.0282
	(0.0148)	(1.3206)	(1.0593)	(0.6496)	(0.2354)	(0.0035)		
GBP	-0.0536***	-4.9932***	-8.2041***	0.3304	-0.1841	-0.0236***	966	0.2121
	(0.0154)	(1.0261)	(0.8641)	(0.5606)	(0.2395)	(0.0071)		
USD	-0.0645***	-5.1997***	-10.0205***	-0.7124	0.1317	-0.1272***	813	0.2799
	(0.0184)	(1.1099)	(0.9636)	(0.6255)	(0.2667)	(0.0366)		

The table reports the OLS estimates of the coefficient of the panel fixed effect regression listed above. The 10 currencies used are Australian Dollar (AUD), Canadian Dollar (CAD), Euro (EUR), Japanese Yen (JPY), New Zealand Dollar (NZD), Norwegian Krone (NOK), Swedish Krona (SEK), Swiss Franc (CHF), British Pound (GBP) and United States Dollar (USD). Each row represents a regression estimation using the first column currency as the home currency and the other 9 currencies as foreign currency j. $s_{j,t}$ is the nominal exchange rate between home and foreign country j, defined as home currency price of foreign currency, $q_{j,t}$ is the real exchange rate. $\tau_{j,t}$ is a measure of currency derivative friction, $l^R_{j,t}$ is a measure of home minus foreign default risk, $\lambda_{j,t}$ is a measure of the treasury liquidity after adjusting for derivative market friction and default risk, $i^R_{j,t}$ is the home minus foreign interest rates. Δ is a difference operator. The sample period is 1999M1-2018M1. Regressions involving default risk $\hat{l}^R_{j,t}$ are only estimated through 2008M1-2018M1 period.

Standard errors in parentheses are standard errors adjusted for cross-sectional correlation. *, **, and *** indicate that the alternative model significantly different from zero at 10%, 5%, and 1% significance level, respectively, based on standard normal critical values for the two-sided test.

Robustness of table 2B – full table of table 2B for $\tau_{j,t}$ with nominal exchange rates on both sides of regressions

Estimation result of $\Delta s_{j,t} = \alpha_j + \beta_1 s_{j,t-1} + \beta_2 \Delta\tau_{j,t} + \beta_3 \Delta i^R_{j,t} + \beta_4 \tau_{j,t-1} + \beta_5 i^R_{j,t-1} + u_{j,t}$

	$s_{j,t-1}$	$\Delta\tau_{j,t}$	$\Delta i^R_{j,t}$	$\tau_{j,t-1}$	$i^R_{j,t-1}$	constant	N	R2_within
AUD	-0.0345***	-1.9094	-4.1470***	-1.2390*	-0.3375***	0.0158***	2028	0.1180
	(0.0090)	(1.2705)	(0.5166)	(0.7223)	(0.1131)	(0.0046)		
CAD	-0.0359***	-4.5162***	-5.2931***	-0.9604	-0.2998***	0.0059**	1836	0.1732
	(0.0080)	(1.1220)	(0.4975)	(0.6466)	(0.1090)	(0.0024)		
EUR	-0.0249***	-3.2810***	-3.6089***	-0.6452	-0.1861**	-0.0067***	2028	0.1055
	(0.0069)	(0.8708)	(0.3739)	(0.4749)	(0.0886)	(0.0024)		
JPY	-0.0289***	-6.0544***	-5.4636***	0.2067	0.0248	0.1358***	2028	0.1247
	(0.0110)	(1.6384)	(0.7110)	(0.9079)	(0.1274)	(0.0508)		
NZD	-0.0300***	-4.3844***	-2.8557***	-0.9886	-0.1053	0.0143**	2028	0.0751
	(0.0102)	(1.4156)	(0.5851)	(0.7793)	(0.1336)	(0.0068)		
NOK	-0.0216***	-3.1209***	-3.6053***	-0.0206	-0.1184	0.0426***	2028	0.0970
	(0.0080)	(1.0513)	(0.4663)	(0.6435)	(0.0968)	(0.0159)		
SEK	-0.0314***	-4.5926***	-3.2172***	-1.0937*	-0.1917*	0.0619***	2028	0.0896
	(0.0074)	(0.9890)	(0.4259)	(0.5867)	(0.1004)	(0.0152)		
CHF	-0.0176**	-1.5296	-1.9983***	0.3017	-0.2028*	-0.0010	2028	0.0307
	(0.0073)	(1.1968)	(0.5073)	(0.6710)	(0.1049)	(0.0027)		
GBP	-0.0247***	-0.8436	-3.7322***	-0.6089	-0.3355***	-0.0101***	2028	0.0881
	(0.0078)	(1.1388)	(0.4908)	(0.6617)	(0.1049)	(0.0039)		
USD	-0.0164*	-6.2485***	-3.7134***	-0.9035	-0.1768	-0.0316*	2028	0.1021
	(0.0088)	(1.2288)	(0.5663)	(0.6748)	(0.1137)	(0.0180)		

The table reports the OLS estimates of the coefficient of the panel fixed effect regression listed above. The 10 currencies used are Australian Dollar (AUD), Canadian Dollar (CAD), Euro (EUR), Japanese Yen (JPY), New Zealand Dollar (NZD), Norwegian Krone (NOK), Swedish Krona (SEK), Swiss Franc (CHF), British Pound (GBP) and United States Dollar (USD). Each row represents a regression estimation using the first column currency as the home currency and the other 9 currencies as foreign currency j. $s_{j,t}$ is the nominal exchange rate between home and foreign country j, defined as home currency price of foreign currency, $q_{j,t}$ is the real exchange rate. $\tau_{j,t}$ is a measure of currency derivative friction, $l^R_{j,t}$ is a measure of home minus foreign default risk, $\lambda_{j,t}$ is a measure of the treasury liquidity after adjusting for derivative market friction and default risk, $i^R_{j,t}$ is the home minus foreign interest rates. Δ is a difference operator. The sample period is 1999M1-2018M1. Regressions involving default risk $\hat{l}^R_{j,t}$ are only estimated through 2008M1-2018M1 period.

Standard errors in parentheses are standard errors adjusted for cross-sectional correlation. *, **, and *** indicate that the alternative model significantly different from zero at 10%, 5%, and 1% significance level, respectively, based on standard normal critical values for the two-sided test.

Robustness of table 2B – full table of table 2B for $l^R_{j,t}$ with nominal exchange rates on both sides of regressions

Estimation result of $\Delta s_{j,t} = \alpha_j + \beta_1 s_{j,t-1} + \beta_2 \Delta l^R_{j,t} + \beta_3 \Delta i^R_{j,t} + \beta_4 l^R_{j,t-1} + \beta_5 i^R_{j,t-1} + u_{j,t}$

	$s_{j,t-1}$	$\Delta l^R_{j,t}$	$\Delta i^R_{j,t}$	$l^R_{j,t-1}$	$i^R_{j,t-1}$	constant	N	R2_within
AUD	-0.0614***	10.1942***	-5.5983***	0.9575	-0.3848*	0.0172**	955	0.2125
	(0.0178)	(2.2184)	(0.7563)	(1.3342)	(0.2207)	(0.0075)		
CAD	-0.0430***	0.7942	-6.9043***	1.4441	0.5067**	0.0036	399	0.2058
	(0.0162)	(2.2663)	(1.0756)	(1.3637)	(0.2448)	(0.0040)		
EUR	-0.0574***	2.2288	-6.0698***	2.6641***	-0.0724	-0.0150***	966	0.1880
	(0.0129)	(1.5516)	(0.5769)	(0.9624)	(0.1899)	(0.0040)		
JPY	-0.0628***	4.7410	-9.8144***	2.2184	0.0849	0.2869***	966	0.2399
	(0.0207)	(3.1073)	(1.1420)	(1.8900)	(0.2967)	(0.0942)		
NZD	-0.0689***	4.7585*	-5.8371***	2.1691	0.3667	0.0071	943	0.1614
	(0.0183)	(2.5898)	(0.9655)	(1.4758)	(0.2705)	(0.0105)		
NOK	-0.0591***	-1.0564	-5.2035***	3.0798***	-0.1318	0.1150***	966	0.1428
	(0.0142)	(1.9423)	(0.7147)	(1.1881)	(0.2220)	(0.0283)		
SEK	-0.0686***	3.2242*	-4.2413***	1.5259	-0.0595	0.1363***	966	0.1259
	(0.0142)	(1.7932)	(0.6633)	(1.0912)	(0.2006)	(0.0284)		
CHF	-0.0425***	2.6141	-0.1369	1.8040	0.1082	-0.0028	888	0.0284
	(0.0155)	(2.2824)	(0.9769)	(1.3189)	(0.2288)	(0.0030)		
GBP	-0.0588***	1.0319	-5.8955***	1.8902	-0.2035	-0.0252***	966	0.1623
	(0.0168)	(2.2302)	(0.8311)	(1.3320)	(0.2462)	(0.0077)		
USD	-0.0601***	5.1038**	-8.7622***	-0.3906	0.1390	-0.1176***	813	0.2539
	(0.0189)	(2.1210)	(0.9109)	(1.3654)	(0.2646)	(0.0377)		

The table reports the OLS estimates of the coefficient of the panel fixed effect regression listed above. The 10 currencies used are Australian Dollar (AUD), Canadian Dollar (CAD), Euro (EUR), Japanese Yen (JPY), New Zealand Dollar (NZD), Norwegian Krone (NOK), Swedish Krona (SEK), Swiss Franc (CHF), British Pound (GBP) and United States Dollar (USD). Each row represents a regression estimation using the first column currency as the home currency and the other 9 currencies as foreign currency j. $s_{j,t}$ is the nominal exchange rate between home and foreign country j, defined as home currency price of foreign currency, $q_{j,t}$ is the real exchange rate. $\tau_{j,t}$ is a measure of currency derivative friction, $l^R_{j,t}$ is a measure of home minus foreign default risk, $\lambda_{j,t}$ is a measure of the treasury liquidity after adjusting for derivative market friction and default risk, $i^R_{j,t}$ is the home minus foreign interest rates. Δ is a difference operator. The sample period is 1999M1-2018M1. Regressions involving default risk $\hat{l}^R_{j,t}$ are only estimated through 2008M1-2018M1 period.

Standard errors in parentheses are standard errors adjusted for cross-sectional correlation. *, **, and *** indicate that the alternative model significantly different from zero at 10%, 5%, and 1% significance level, respectively, based on standard normal critical values for the two-sided test.

Robustness of table 2B – full table of table 2B for $(\eta + l^R)_{j,t}$ with nominal exchange rates on both sides of regressions

Estimation result of $\Delta s_{j,t} = \alpha_j + \beta_1 s_{j,t-1} + \beta_2 \Delta(\eta + l^R)_{j,t} + \beta_3 \Delta i^R_{j,t} + \beta_4 (\eta + l^R)_{j,t-1} + \beta_5 i^R_{j,t-1} + u_{j,t}$

	$s_{j,t-1}$	$\Delta(\eta+l^R)_{j,t}$	$\Delta i^R_{j,t}$	$(\eta+l^R)_{j,t-1}$	$i^R_{j,t-1}$	constant	N	R2_within
AUD	-0.0551***	-4.1786***	-6.5414***	-0.0379	-0.2985	0.0139*	955	0.2188
	(0.0176)	(0.9546)	(0.8533)	(0.6497)	(0.2300)	(0.0077)		
CAD	-0.0372**	-5.2590***	-8.1842***	-0.4818	0.5854**	0.0032	399	0.2525
	(0.0153)	(1.2234)	(1.1341)	(0.7696)	(0.2540)	(0.0040)		
EUR	-0.0436***	-3.7517***	-7.3482***	0.4040	-0.0345	-0.0115***	966	0.2292
	(0.0121)	(0.6175)	(0.6022)	(0.4191)	(0.1828)	(0.0041)		
JPY	-0.0675***	-4.6016***	-11.1431***	2.2662***	-0.0091	0.3209***	966	0.3131
	(0.0191)	(1.1404)	(1.1224)	(0.7924)	(0.2804)	(0.0873)		
NZD	-0.0516***	-5.2227***	-7.4423***	0.9851	0.3715	0.0021	943	0.2646
	(0.0165)	(0.9141)	(0.9256)	(0.6567)	(0.2517)	(0.0098)		
NOK	-0.0495***	-4.7408***	-7.7634***	0.9719**	-0.1401	0.0965***	966	0.2571
	(0.0124)	(0.6618)	(0.7101)	(0.4345)	(0.1942)	(0.0246)		
SEK	-0.0596***	-4.2090***	-6.1225***	-0.1391	-0.0442	0.1178***	966	0.1819
	(0.0133)	(0.6766)	(0.7035)	(0.4571)	(0.1956)	(0.0267)		
CHF	-0.0388***	-1.5085	-0.5730	0.0520	0.1303	-0.0023	888	0.0312
	(0.0147)	(1.0673)	(1.0133)	(0.6200)	(0.2325)	(0.0047)		
GBP	-0.0536***	-3.3666***	-7.8781***	0.9942*	-0.2251	-0.0225***	966	0.2044
	(0.0157)	(0.8659)	(0.8614)	(0.5777)	(0.2359)	(0.0072)		
USD	-0.0658***	-4.6510***	-9.5203***	-0.8913	0.0951	-0.1279***	813	0.2957
	(0.0177)	(0.8523)	(0.9201)	(0.5739)	(0.2574)	(0.0353)		

The table reports the OLS estimates of the coefficient of the panel fixed effect regression listed above. The 10 currencies used are Australian Dollar (AUD), Canadian Dollar (CAD), Euro (EUR), Japanese Yen (JPY), New Zealand Dollar (NZD), Norwegian Krone (NOK), Swedish Krona (SEK), Swiss Franc (CHF), British Pound (GBP) and United States Dollar (USD). Each row represents a regression estimation using the first column currency as the home currency and the other 9 currencies as foreign currency j. $s_{j,t}$ is the nominal exchange rate between home and foreign country j, defined as home currency price of foreign currency, $q_{j,t}$ is the real exchange rate. $\tau_{j,t}$ is a measure of currency derivative friction, $l^R_{j,t}$ is a measure of home minus foreign default risk, $\lambda_{j,t}$ is a measure of the treasury liquidity after adjusting for derivative market friction and default risk, $i^R_{j,t}$ is the home minus foreign interest rates. Δ is a difference operator. The sample period is 1999M1-2018M1. Regressions involving default risk $\hat{l}^R_{j,t}$ are only estimated through 2008M1-2018M1 period.

Standard errors in parentheses are standard errors adjusted for cross-sectional correlation. *, **, and *** indicate that the alternative model significantly different from zero at 10%, 5%, and 1% significance level, respectively, based on standard normal critical values for the two-sided test.

Robustness of table 2B – full table of table 2B for $(\tau - l^R)_{j,t}$ with nominal exchange rates on both sides of regressions

Estimation result of $\Delta s_{j,t} = \alpha_j + \beta_1 s_{j,t-1} + \beta_2 \Delta(\tau - l^R)_{j,t} + \beta_3 \Delta i^R_{j,t} + \beta_4 (\tau - l^R)_{j,t-1} + \beta_5 i^R_{j,t-1} + u_{j,t}$

	$s_{j,t-1}$	$\Delta(\tau - l^R)_{j,t}$	$\Delta i^R_{j,t}$	$(\tau - l^R)_{j,t-1}$	$i^R_{j,t-1}$	constant	N	R2_within
AUD	-0.0599***	-4.7368***	-5.7959***	-1.2388	-0.4624*	0.0197**	955	0.2044
	(0.0181)	(1.3034)	(0.7928)	(0.8795)	(0.2404)	(0.0083)		
CAD	-0.0515***	-1.8440	-6.8437***	-1.8067**	0.3296	0.0027	399	0.2268
	(0.0165)	(1.4316)	(1.0629)	(0.7791)	(0.2480)	(0.0039)		
EUR	-0.0550***	-2.4649***	-5.6618***	-1.6118***	-0.1652	-0.0201***	966	0.1974
	(0.0125)	(0.8134)	(0.5728)	(0.5410)	(0.1884)	(0.0046)		
JPY	-0.0551***	-6.2777***	-9.9786***	-0.1479	0.0977	0.2521***	966	0.2704
	(0.0202)	(1.6417)	(1.1176)	(1.1036)	(0.3042)	(0.0909)		
NZD	-0.0584***	-5.3074***	-6.2658***	-0.8499	0.2932	0.0079	943	0.1937
	(0.0180)	(1.3752)	(0.9475)	(0.9518)	(0.2697)	(0.0105)		
NOK	-0.0482***	-3.4671***	-5.1417***	-1.5500**	-0.1634	0.0904***	966	0.1448
	(0.0138)	(1.0796)	(0.7270)	(0.7325)	(0.2256)	(0.0269)		
SEK	-0.0679***	-3.7679***	-4.1573***	-1.3394**	-0.1408	0.1316***	966	0.1427
	(0.0138)	(0.9892)	(0.6611)	(0.6441)	(0.1999)	(0.0274)		
CHF	-0.0384***	-2.1231	0.1012	-0.5429	0.1039	-0.0041	888	0.0298
	(0.0148)	(1.4497)	(0.9858)	(0.8548)	(0.2290)	(0.0040)		
GBP	-0.0568***	-0.6345	-5.8886***	-0.4046	-0.2362	-0.0242***	966	0.1589
	(0.0163)	(1.2057)	(0.8416)	(0.7701)	(0.2549)	(0.0077)		
USD	-0.0631***	-4.7205***	-8.5966***	-0.5507	0.0471	-0.1224***	813	0.2715
	(0.0185)	(1.1673)	(0.9027)	(0.8431)	(0.2630)	(0.0367)		

The table reports the OLS estimates of the coefficient of the panel fixed effect regression listed above. The 10 currencies used are Australian Dollar (AUD), Canadian Dollar (CAD), Euro (EUR), Japanese Yen (JPY), New Zealand Dollar (NZD), Norwegian Krone (NOK), Swedish Krona (SEK), Swiss Franc (CHF), British Pound (GBP) and United States Dollar (USD). Each row represents a regression estimation using the first column currency as the home currency and the other 9 currencies as foreign currency j. $s_{j,t}$ is the nominal exchange rate between home and foreign country j, defined as home currency price of foreign currency, $q_{j,t}$ is the real exchange rate. $\tau_{j,t}$ is a measure of currency derivative friction, $l^R_{j,t}$ is a measure of home minus foreign default risk, $\lambda_{j,t}$ is a measure of the treasury liquidity after adjusting for derivative market friction and default risk, $i^R_{j,t}$ is the home minus foreign interest rates. Δ is a difference operator. The sample period is 1999M1-2018M1. Regressions involving default risk $\hat{l}^R_{j,t}$ are only estimated through 2008M1-2018M1 period.

Standard errors in parentheses are standard errors adjusted for cross-sectional correlation. *, **, and *** indicate that the alternative model significantly different from zero at 10%, 5%, and 1% significance level, respectively, based on standard normal critical values for the two-sided test.

Robustness of table 3A – full table of table 3A with real exchange rates on both sides of regressions

IV Estimation result of $\Delta q_{j,t} = \alpha_j + \beta_1 q_{j,t-1} + \beta_2(\Delta\eta^{IV}_{j,t}) + \beta_3(\Delta i^R_{j,t}) + \beta_4(\eta^{IV}_{j,t-1}) + \beta_5(i^R_{j,t-1}) + u_{j,t}$

	$q_{j,t-1}$	$\Delta\eta^{IV}_{j,t}$	$\eta^{IV}_{j,t-1}$	$\Delta i^R_{j,t}$	$i^R_{j,t-1}$	constant	N
AUD	-0.0188**	-16.9494***	-2.1130	-8.7934***	-0.1285	0.0083*	1974
	(0.0085)	(3.9392)	(2.2485)	(1.2089)	(0.1578)	(0.0047)	
CAD	-0.0263***	-5.9707	1.3475	-5.8983***	-0.2849***	0.0087**	1974
	(0.0071)	(3.8570)	(1.3527)	(0.9113)	(0.1045)	(0.0043)	
EUR	-0.0252***	3.9389	-0.0278	-3.6544***	-0.2191**	-0.0062	1890
	(0.0074)	(4.4194)	(1.8096)	(1)	(0.1064)	(0.0049)	
JPY	-0.0394***	-9.8198***	2.2023	-7.5643***	-0.1272	0.1928***	1974
	(0.0113)	(2.5906)	(1.8195)	(0.8694)	(0.1253)	(0.0567)	
NZD	-0.0228***	-7.4363**	1.4009*	-7.1435***	-0.1589	0.0107*	1974
	(0.0086)	(3.0545)	(0.8084)	(1.5292)	(0.1258)	(0.0060)	
NOK	-0.0269***	-3.3250**	2.3594**	-5.5000***	-0.3232**	0.0595***	1890
	(0.0084)	(1.4726)	(1.0331)	(0.6697)	(0.1265)	(0.0184)	
SEK	-0.0164**	-10.2930***	-0.7042	-6.4207***	-0.0810	0.0321**	1974
	(0.0070)	(2.6379)	(0.7724)	(0.9825)	(0.1106)	(0.0150)	
CHF	-0.0231***	0.6916	2.6045***	-2.2478***	-0.1766*	0.0126**	1974
	(0.0074)	(2.2780)	(0.8053)	(0.8337)	(0.1054)	(0.0051)	
GBP	-0.0293***	-1.8175	4.5890**	-6.2075***	-0.4882***	-0.0070*	1890
	(0.0088)	(3.2408)	(2.1108)	(1.2788)	(0.1352)	(0.0037)	
USD	-0.0124*	-10.0589***	-4.2861***	-5.0548***	0.0717	-0.0181	1974
	(0.0072)	(2.3512)	(0.9456)	(0.7891)	(0.1166)	(0.0149)	

The table reports the OLS estimates of the coefficient of the panel fixed effect regression listed above. The 10 currencies used are Australian Dollar (AUD), Canadian Dollar (CAD), Euro (EUR), Japanese Yen (JPY), New Zealand Dollar (NZD), Norwegian Krone (NOK), Swedish Krona (SEK), Swiss Franc (CHF), British Pound (GBP) and United States Dollar (USD). Each row represents a regression estimation using the first column currency as the home currency and the other 9 currencies as foreign currency j. $s_{j,t}$ is the nominal exchange rate between home and foreign country j, defined as home currency price of foreign currency, $q_{j,t}$ is the real exchange rate. $\eta^{IV}_{j,t}$ is a measure of the treasury liquidity, $i^R_{j,t}$ is the home minus foreign interest rates. Δ is a difference operator. The sample period is 1999M1-2018M1.

Standard errors in parentheses are standard errors adjusted for cross-sectional correlation. *, **, and *** indicate that the alternative model significantly different from zero at 10%, 5%, and 1% significance level, respectively, based on standard normal critical values for the two-sided test.

Robustness of table 3A – full table of table 3A with nominal exchange rates on both sides of regressions

IV Estimation result of $\Delta s_{j,t} = \alpha_j + \beta_1 s_{j,t-1} + \beta_2(\Delta\eta^{IV}_{j,t}) + \beta_3(\Delta i^R_{j,t}) + \beta_4(\eta^{IV}_{j,t-1}) + \beta_5(i^R_{j,t-1}) + u_{j,t}$

	$s_{j,t-1}$	$\Delta\eta^{IV}_{j,t}$	$\eta^{IV}_{j,t-1}$	$\Delta i^R_{j,t}$	$i^R_{j,t-1}$	constant	N
AUD	-0.0197*	-17.6450***	-2.7378	-8.8706***	-0.0927	0.0081*	1974
	(0.0103)	(3.8627)	(2.3466)	(1.2036)	(0.1449)	(0.0048)	
CAD	-0.0276***	-6.7310*	1.2273	-6.0501***	-0.2496***	0.0084**	1974
	(0.0078)	(3.7894)	(1.3153)	(0.8932)	(0.0941)	(0.0039)	
EUR	-0.0300***	3.3946	0.4917	-3.7973***	-0.2048**	-0.0056	1890
	(0.0078)	(4.4416)	(2.0098)	(0.9959)	(0.0972)	(0.0058)	
JPY	-0.0331***	-11.0226***	0.6570	-7.5189***	-0.0033	0.1577***	1974
	(0.0111)	(2.6292)	(1.7322)	(0.8835)	(0.1179)	(0.0527)	
NZD	-0.0153	-7.0085**	1.4809*	-6.9377***	-0.1220	0.0069	1974
	(0.0101)	(3.0352)	(0.8198)	(1.5219)	(0.1171)	(0.0064)	
NOK	-0.0307***	-3.2727**	2.1447**	-5.3318***	-0.2958***	0.0660***	1890
	(0.0086)	(1.4317)	(0.9613)	(0.6503)	(0.1141)	(0.0180)	
SEK	-0.0228***	-9.7286***	-0.6001	-6.2683***	-0.1069	0.0458***	1974
	(0.0077)	(2.5804)	(0.7620)	(0.9641)	(0.1031)	(0.0161)	
CHF	-0.0306***	-0.0270	2.2601***	-2.3517***	-0.1609*	0.0130***	1974
	(0.0083)	(2.2419)	(0.7262)	(0.8229)	(0.0971)	(0.0047)	
GBP	-0.0328***	-0.9711	6.0046***	-5.9836***	-0.4370***	-0.0082*	1890
	(0.0087)	(3.3489)	(2.1903)	(1.2956)	(0.1153)	(0.0043)	
USD	-0.0191**	-9.1545***	-3.7740***	-4.8166***	0.0148	-0.0331*	1974
	(0.0086)	(2.3326)	(1.0027)	(0.7873)	(0.1134)	(0.0175)	

The table reports the OLS estimates of the coefficient of the panel fixed effect regression listed above. The 10 currencies used are Australian Dollar (AUD), Canadian Dollar (CAD), Euro (EUR), Japanese Yen (JPY), New Zealand Dollar (NZD), Norwegian Krone (NOK), Swedish Krona (SEK), Swiss Franc (CHF), British Pound (GBP) and United States Dollar (USD). Each row represents a regression estimation using the first column currency as the home currency and the other 9 currencies as foreign currency j. $s_{j,t}$ is the nominal exchange rate between home and foreign country j, defined as home currency price of foreign currency, $q_{j,t}$ is the real exchange rate. $\eta^{IV}_{j,t}$ is a measure of the treasury liquidity, $i^R_{j,t}$ is the home minus foreign interest rates. Δ is a difference operator. The sample period is 1999M1-2018M1.

Standard errors in parentheses are standard errors adjusted for cross-sectional correlation. *, **, and *** indicate that the alternative model significantly different from zero at 10%, 5%, and 1% significance level, respectively, based on standard normal critical values for the two-sided test.

Robustness of table 3B – full table of table 3B with real exchange rates on both sides of regressions

IV Estimation result of $\Delta q_{j,t} = \alpha_j + \beta_1 q_{j,t-1} + \beta_2 \Delta\lambda_{j,t}^{IV} + \beta_3 \Delta i_{j,t}^{R} + \beta_4 \Delta\tau_{j,t} + \beta_5 \lambda_{j,t-1}^{IV} + \beta_6 i_{j,t-1}^{R} + \beta_7 \tau_{j,t-1} + u_{j,t}$

	$q_{j,t-1}$	$\Delta\lambda_{j,t}^{IV}$	$\lambda_{j,t-1}^{IV}$	$\Delta\tau_{j,t}$	$\tau_{j,t-1}$	$\Delta i_{j,t}^{R}$	$i_{j,t-1}^{R}$	N
AUD	-0.0119	-24.6697***	-4.1232	-8.0341***	-3.0484	-9.8431***	0.1100	1950
	(0.0093)	(4.9702)	(3.2542)	(2.0796)	(1.9777)	(1.2920)	(0.2588)	
CAD	-0.0309***	2.3048	0.6215	-3.6721**	-0.4405	-5.0195***	-0.3887***	1797
	(0.0081)	(6.2203)	(1.2962)	(1.6701)	(1.2817)	(1.2548)	(0.1377)	
EUR	-0.0168**	-13.1441***	-1.0358	-8.1550***	-1.4654	-7.4239***	-0.1726	1879
	(0.0069)	(4.9583)	(1.2630)	(2.0125)	(1.2382)	(1.3075)	(0.1060)	
JPY	-0.0426***	-12.1202***	2.8877	-4.6374***	2.5610*	-8.0469***	-0.1551	1950
	(0.0110)	(3.9033)	(1.9346)	(1.7097)	(1.3099)	(1.0575)	(0.1573)	
NZD	-0.0253***	-5.4835*	1.4853*	-5.3057***	0.5301	-6.3191***	-0.2318*	1950
	(0.0082)	(3.3314)	(0.8003)	(1.4833)	(0.9825)	(1.5625)	(0.1336)	
NOK	-0.0257***	-3.5471**	2.4267**	-5.0639***	1.8324*	-5.6316***	-0.3553***	1879
	(0.0081)	(1.4637)	(1.0310)	(1.3250)	(1.0234)	(0.6542)	(0.1359)	
SEK	-0.0172**	-9.2160***	-0.6237	-5.8000***	-0.7483	-6.0396***	-0.0667	1950
	(0.0069)	(2.9531)	(0.6991)	(1.1303)	(0.7248)	(1.0303)	(0.1199)	
CHF	-0.0179**	-2.2156	2.4307***	-0.8884	1.3830*	-3.1328**	-0.2029*	1950
	(0.0071)	(3.6863)	(0.8555)	(1.2495)	(0.8240)	(1.2275)	(0.1202)	
GBP	-0.0240***	-12.5547***	3.9070**	-2.4798	3.7504**	-9.7440***	-0.4108***	1879
	(0.0088)	(4.5072)	(1.7893)	(1.5581)	(1.6111)	(1.6839)	(0.1553)	
USD	-0.0127*	-14.5776***	-4.5484***	-8.1210***	-2.1308**	-6.0207***	0.1832	1950
	(0.0075)	(3.2136)	(1.1178)	(1.2765)	(0.8800)	(0.9322)	(0.1414)	

The table reports the OLS estimates of the coefficient of the panel fixed effect regression listed above. The 10 currencies used are Australian Dollar (AUD), Canadian Dollar (CAD), Euro (EUR), Japanese Yen (JPY), New Zealand Dollar (NZD), Norwegian Krone (NOK), Swedish Krona (SEK), Swiss Franc (CHF), British Pound (GBP) and United States Dollar (USD). Each row represents a regression estimation using the first column currency as the home currency and the other 9 currencies as foreign currency j. $s_{j,t}$ is the nominal exchange rate between home and foreign country j, defined as home currency price of foreign currency, $q_{j,t}$ is the real exchange rate. $\lambda_{j,t}^{IV}$ is a measure of the treasury liquidity, $i_{j,t}^{R}$ is the home minus foreign interest rates. Δ is a difference operator. The sample period is 1999M1-2018M1.

Standard errors in parentheses are standard errors adjusted for cross-sectional correlation. *, **, and *** indicate that the alternative model significantly different from zero at 10%, 5%, and 1% significance level, respectively, based on standard normal critical values for the two-sided test

Robustness of table 3B – full table of table 3B with nominal exchange rates on both sides of regressions

IV Estimation result of $\Delta s_{j,t} = \alpha_j + \beta_1 s_{j,t-1} + \beta_2 \Delta\lambda_{j,t}^{IV} + \beta_3 \Delta i_{j,t}^{R} + \beta_4 \Delta\tau_{j,t} + \beta_5 \lambda_{j,t-1}^{IV} + \beta_6 i_{j,t-1}^{R} + \beta_7 \tau_{j,t-1} + u_{j,t}$

	$s_{j,t-1}$	$\Delta\lambda_{j,t}^{IV}$	$\lambda_{j,t-1}^{IV}$	$\Delta\tau_{j,t}$	$\tau_{j,t-1}$	$\Delta i_{j,t}^{R}$	$i_{j,t-1}^{R}$	N
AUD	-0.0135	-24.6326***	-3.5395	-8.0307***	-2.9879	-9.8565***	0.0639	1950
	(0.0105)	(4.9372)	(3.3014)	(2.0342)	(1.9771)	(1.2835)	(0.2526)	
CAD	-0.0391***	2.7476	0.4849	-3.9604**	-0.7178	-4.9393***	-0.3852***	1797
	(0.0091)	(6.1382)	(1.2380)	(1.6297)	(1.2153)	(1.2363)	(0.1307)	
EUR	-0.0240***	-13.2605***	-1.0566	-8.3051***	-1.5709	-7.4234***	-0.1828*	1879
	(0.0075)	(4.9543)	(1.3468)	(2.0042)	(1.2975)	(1.3085)	(0.1027)	
JPY	-0.0354***	-13.5375***	1.3435	-5.3485***	1.2643	-8.0324***	0.0100	1950
	(0.0112)	(3.9665)	(1.8866)	(1.7208)	(1.2715)	(1.0705)	(0.1462)	
NZD	-0.0244***	-5.1467	1.4430*	-5.3664***	0.0736	-6.1438***	-0.2353*	1950
	(0.0095)	(3.2770)	(0.8008)	(1.4530)	(0.9697)	(1.5383)	(0.1285)	
NOK	-0.0299***	-3.3749**	2.2177**	-4.8272***	1.4324	-5.4131***	-0.3384***	1879
	(0.0084)	(1.4259)	(0.9723)	(1.2856)	(0.9188)	(0.6361)	(0.1283)	
SEK	-0.0244***	-8.6838***	-0.5003	-5.7771***	-1.1379*	-5.8709***	-0.1211	1950
	(0.0079)	(2.8942)	(0.6923)	(1.1014)	(0.6905)	(1.0123)	(0.1176)	
CHF	-0.0252***	-3.2948	2.2833***	-0.9160	0.9877	-3.3957***	-0.2131*	1950
	(0.0080)	(3.6583)	(0.8287)	(1.2256)	(0.7537)	(1.2187)	(0.1170)	
GBP	-0.0271***	-13.1141***	4.4749**	-2.3910	3.9832**	-9.8244***	-0.3819***	1879
	(0.0091)	(4.5474)	(1.8423)	(1.5739)	(1.6064)	(1.6907)	(0.1480)	
USD	-0.0166*	-13.2471***	-3.9538***	-7.7129***	-1.9305**	-5.7155***	0.1168	1950
	(0.0088)	(3.1756)	(1.1580)	(1.2512)	(0.8926)	(0.9286)	(0.1422)	

The table reports the OLS estimates of the coefficient of the panel fixed effect regression listed above. The 10 currencies used are Australian Dollar (AUD), Canadian Dollar (CAD), Euro (EUR), Japanese Yen (JPY), New Zealand Dollar (NZD), Norwegian Krone (NOK), Swedish Krona (SEK), Swiss Franc (CHF), British Pound (GBP) and United States Dollar (USD). Each row represents a regression estimation using the first column currency as the home currency and the other 9 currencies as foreign currency j. $s_{j,t}$ is the nominal exchange rate between home and foreign country j, defined as home currency price of foreign currency, $q_{j,t}$ is the real exchange rate. $\lambda_{j,t}^{IV}$ is a measure of the treasury liquidity, $i_{j,t}^{R}$ is the home minus foreign interest rates. Δ is a difference operator. The sample period is 1999M1-2018M1.

Standard errors in parentheses are standard errors adjusted for cross-sectional correlation. *, **, and *** indicate that the alternative model significantly different from zero at 10%, 5%, and 1% significance level, respectively, based on standard normal critical values for the two-sided test.

Robustness of table 3C – full table of table 3C with real exchange rates on both sides of regressions

IV Estimation result of $\Delta q_{j,t} = \alpha_j + \beta_1 q_{j,t-1} + \beta_2 \Delta\lambda_{j,t}^{IV} + \beta_3 \Delta\tau_{j,t} + \beta_4 \Delta l_{j,t}^{R} + \beta_5 \Delta i_{j,t}^{R} + \beta_6 \lambda_{j,t-1}^{IV} + \beta_7 \tau_{j,t-1} + \beta_8 l_{j,t-1}^{R} + \beta_9 i_{j,t-1}^{R} + u_{j,t}$

	$q_{j,t-1}$	$\Delta\lambda_{j,t}^{IV}$	$\lambda_{j,t-1}^{IV}$	$\Delta i_{j,t}^{R}$	$i_{j,t-1}^{R}$	$\Delta\tau_{j,t}$	$\tau_{j,t-1}$	$\Delta l_{j,t}^{R}$	$l_{j,t-1}^{R}$	N
AUD	-0.0468***	-12.6984***	-0.0774	-8.4784***	-0.3514	-3.6134**	0.2533	17.5882***	-0.8276	919
	(0.0173)	(4.2449)	(2.0610)	(1.1609)	(0.2976)	(1.7118)	(1.5832)	(3.9735)	(2.3889)	
CAD	-0.0304*	-19.6128*	-2.0326	-11.9151***	0.5462	-10.7661***	-4.5744**	17.4561*	0.2257	363
	(0.0177)	(10.2209)	(2.9105)	(2.7118)	(0.4180)	(4.0252)	(2.1178)	(9.2865)	(3.3491)	
EUR	-0.0470***	-11.7576***	-0.0487	-9.9020***	-0.1167	-5.0773***	-0.3770	13.7949***	2.2913	930
	(0.0121)	(4.3731)	(1.3878)	(1.5569)	(0.1866)	(1.4215)	(1.2634)	(4.8971)	(1.6776)	
JPY	-0.0635***	-9.2416**	3.5935*	-11.8006***	-0.1687	-3.2785	3.9180**	11.9352***	-1.1379	930
	(0.0181)	(4.1736)	(2.1201)	(1.3927)	(0.3346)	(1.9946)	(1.6619)	(4.5872)	(2.6286)	
NZD	-0.0408***	-8.5899***	2.8811**	-8.3645***	0.0984	-5.5862***	1.5735	12.6553***	-1.4675	907
	(0.0148)	(3.0672)	(1.3681)	(1.0974)	(0.2799)	(1.5374)	(1.3908)	(3.9433)	(1.7122)	
NOK	-0.0424***	-4.9438***	-0.5201	-7.5413***	-0.1837	-6.0795***	-0.2884	4.0680*	3.2919*	930
	(0.0116)	(1.3759)	(0.9654)	(0.9710)	(0.2088)	(1.2956)	(1.1248)	(2.3067)	(1.7026)	
SEK	-0.0425***	-10.3108***	-0.3786	-7.7378***	0.0100	-4.0136***	-0.6754	11.6648***	-0.3609	930
	(0.0123)	(3.4979)	(0.8156)	(1.3675)	(0.2270)	(1.2531)	(0.9587)	(3.6930)	(1.3702)	
CHF	-0.0257*	13.7126**	-0.1098	4.4750**	-0.0322	-4.9585**	0.1530	-10.8390*	1.7968	852
	(0.0135)	(5.3526)	(1.2977)	(2.0365)	(0.2968)	(2.2019)	(1.2884)	(5.6121)	(1.9965)	
GBP	-0.0411***	-12.5672***	1.4199	-12.3670***	-0.0417	-0.9781	3.3151**	10.3152**	-0.3886	930
	(0.0157)	(4.2420)	(1.7972)	(2.0640)	(0.2554)	(1.5238)	(1.5541)	(4.0682)	(2.2855)	
USD	-0.0571***	-19.8062***	-2.0055	-12.8908***	0.0114	-2.2209	1.6242	21.7824***	2.5564	777
	(0.0160)	(3.5534)	(1.2812)	(1.2760)	(0.2495)	(1.4498)	(1.1614)	(3.5511)	(1.7118)	

The table reports the OLS estimates of the coefficient of the panel fixed effect regression listed above. The 10 currencies used are Australian Dollar (AUD), Canadian Dollar (CAD), Euro (EUR), Japanese Yen (JPY), New Zealand Dollar (NZD), Norwegian Krone (NOK), Swedish Krona (SEK), Swiss Franc (CHF), British Pound (GBP) and United States Dollar (USD). Each row represents a regression estimation using the first column currency as the home currency and the other 9 currencies as foreign currency j. $s_{j,t}$ is the nominal exchange rate between home and foreign country j, defined as home currency price of foreign currency, $q_{j,t}$ is the real exchange rate. $\lambda_{j,t}^{IV}$ is a measure of the treasury liquidity, $i_{j,t}^{R}$ is the home minus foreign interest rates. Δ is a difference operator. The sample period is 2008M1-2018M1.

Standard errors in parentheses are standard errors adjusted for cross-sectional correlation. *, **, and *** indicate that the alternative model significantly different from zero at 10%, 5%, and 1% significance level, respectively, based on standard normal critical values for the two-sided test.

Robustness of table 3C – full table of table 3C with nominal exchange rates on both sides of regressions

IV Estimation result of $\Delta s_{j,t} = \alpha_j + \beta_1 s_{j,t-1} + \beta_2 \Delta\lambda^{IV}_{j,t} + \beta_3 \Delta\tau_{j,t} + \beta_4 \Delta l^R_{j,t} + \beta_5 \Delta i^R_{j,t} + \beta_6 \lambda^{IV}_{j,t-1} + \beta_7 \tau_{j,t-1} + \beta_8 l^R_{j,t-1} + \beta_9 i^R_{j,t-1} + u_{j,t}$

	$s_{j,t-1}$	$\Delta\lambda^{IV}_{j,t}$	$\lambda^{IV}_{j,t-1}$	$\Delta i^R_{j,t}$	$i^R_{j,t-1}$	$\Delta\tau_{j,t}$	$\tau_{j,t-1}$	$\Delta l^R_{j,t}$	$l^R_{j,t-1}$	N
AUD	-0.0538***	-12.6844***	0.9082	-8.3348***	-0.4198	-3.3232**	0.5467	18.0129***	-1.3161	919
	(0.0182)	(4.1600)	(1.9757)	(1.1411)	(0.2928)	(1.6754)	(1.5415)	(3.9067)	(2.3200)	
CAD	-0.0344*	-20.9739**	-2.0834	-11.7061***	0.5739	-11.4445***	-4.2914**	19.2211**	0.2320	363
	(0.0203)	(9.0602)	(2.6896)	(2.3981)	(0.4024)	(3.6682)	(1.9059)	(8.2626)	(3.0563)	
EUR	-0.0588***	-11.0246**	0.3400	-9.6135***	-0.1723	-4.9192***	-0.1461	13.7601***	2.2903	930
	(0.0134)	(4.3460)	(1.3138)	(1.5439)	(0.1890)	(1.4029)	(1.2333)	(4.8764)	(1.6370)	
JPY	-0.0699***	-10.1198**	3.8777*	-11.8162***	-0.1521	-3.2763*	3.5187**	12.9353***	-1.3067	930
	(0.0198)	(4.1945)	(2.1256)	(1.4016)	(0.3449)	(1.9897)	(1.6469)	(4.6090)	(2.6259)	
NZD	-0.0428**	-8.4859***	2.9228**	-8.3856***	0.0918	-5.5156***	1.4837	12.7015***	-1.5764	907
	(0.0168)	(3.0205)	(1.3745)	(1.0832)	(0.2747)	(1.5171)	(1.3880)	(3.8978)	(1.7383)	
NOK	-0.0590***	-4.4980***	-0.3959	-7.2974***	-0.2600	-5.9084***	-0.4694	4.0141*	3.3335**	930
	(0.0133)	(1.3465)	(0.9469)	(0.9521)	(0.2113)	(1.2683)	(1.0983)	(2.2721)	(1.6861)	
SEK	-0.0595***	-10.8048***	-0.4352	-7.8516***	-0.1081	-3.8804***	-0.9498	12.2850***	-0.0060	930
	(0.0141)	(3.3925)	(0.8026)	(1.3342)	(0.2238)	(1.2302)	(0.9418)	(3.5970)	(1.3506)	
CHF	-0.0491***	13.5475**	-0.2830	4.5878**	-0.0930	-4.7855**	-0.1490	-10.2838*	2.3589	852
	(0.0169)	(5.3098)	(1.2901)	(2.0186)	(0.2939)	(2.1784)	(1.2658)	(5.5546)	(1.9969)	
GBP	-0.0493***	-12.6585***	1.7311	-12.2721***	-0.1038	-0.9247	3.3012**	10.3548**	-0.5556	930
	(0.0178)	(4.2616)	(1.7779)	(2.0713)	(0.2551)	(1.5237)	(1.5695)	(4.0891)	(2.3083)	
USD	-0.0631***	-18.6096***	-1.1405	-12.6401***	-0.1127	-2.0216	1.6244	20.5667***	1.7123	777
	(0.0169)	(3.4468)	(1.2067)	(1.2408)	(0.2529)	(1.3974)	(1.1302)	(3.4551)	(1.6271)	

The table reports the OLS estimates of the coefficient of the panel fixed effect regression listed above. The 10 currencies used are Australian Dollar (AUD), Canadian Dollar (CAD), Euro (EUR), Japanese Yen (JPY), New Zealand Dollar (NZD), Norwegian Krone (NOK), Swedish Krona (SEK), Swiss Franc (CHF), British Pound (GBP) and United States Dollar (USD). Each row represents a regression estimation using the first column currency as the home currency and the other 9 currencies as foreign currency j. $s_{j,t}$ is the nominal exchange rate between home and foreign country j, defined as home currency price of foreign currency, $q_{j,t}$ is the real exchange rate. $\lambda^{IV}_{j,t}$ is a measure of the treasury liquidity, $i^R_{j,t}$ is the home minus foreign interest rates. Δ is a difference operator. The sample period is 2008M1-2018M1.

Standard errors in parentheses are standard errors adjusted for cross-sectional correlation. *, **, and *** indicate that the alternative model significantly different from zero at 10%, 5%, and 1% significance level, respectively, based on standard normal critical values for the two-sided test.

Robustness of table 4A – full table of table 4A with real exchange rates on both sides of regressions

Estimation result of $\Delta q_{j,t} = \alpha_j + \beta_1 q_{j,t-1} + \beta_2 \Delta\tau_{j,t} + \beta_3 \Delta\gamma_t + \beta_4 \Delta\gamma^*_{j,t} + \beta_5 \Delta i^R_{j,t} + \beta_6 \gamma_{t-1} + \beta_7 \gamma^*_{j,t-1} + \beta_8 i^R_{j,t-1} + u_{j,t}$

	$q_{j,t-1}$	$\Delta\gamma^*_{j,t}$	$\Delta\gamma_t$	$\Delta\tau_{j,t}$	$\Delta i^R_{j,t}$	$\gamma^*_{j,t-1}$	γ_{t-1}	$\tau_{j,t-1}$	$i^R_{j,t-1}$	constant	N	R2 within
AUD	-0.0267***	5.4282***	-6.7391***	-2.8717**	-5.8718***	-0.2414	0.5035	-0.2808	-0.2951***	0.0115**	2019	0.2134
	(0.0073)	(0.6989)	(1.2378)	(1.2348)	(0.5490)	(0.3771)	(0.6155)	(0.7812)	(0.1134)	(0.0047)		
CAD	-0.0261***	4.5638***	-6.3743***	-5.1167***	-6.2022***	-0.5507	-0.4400	-0.4321	-0.2823**	0.0074**	1834	0.1974
	(0.0069)	(0.7008)	(2.0361)	(1.1584)	(0.5404)	(0.4096)	(1.2821)	(0.7461)	(0.1130)	(0.0036)		
EUR	-0.0172***	4.6420***	-5.2236***	-5.2164***	-5.0760***	0.0752	-0.1639	-0.5683	-0.1587*	-0.0051**	2026	0.1453
	(0.0059)	(0.5655)	(1.0935)	(0.9110)	(0.4114)	(0.3168)	(0.5350)	(0.5786)	(0.0924)	(0.0025)		
JPY	-0.0365***	4.2326***	-2.2114	-4.8667***	-6.4200***	-2.1214***	1.6876	2.0357**	-0.0885	0.1794***	2026	0.1720
	(0.0101)	(0.9895)	(5.1846)	(1.5906)	(0.7483)	(0.5748)	(2.4872)	(0.9655)	(0.1345)	(0.0474)		
NZD	-0.0297***	6.1267***	-6.9512***	-5.6387***	-6.3253***	1.0141*	0.1682	-0.8634	-0.1330	0.0095	2019	0.2154
	(0.0077)	(0.8714)	(0.9067)	(1.3022)	(0.6189)	(0.5209)	(0.4333)	(0.7846)	(0.1280)	(0.0063)		
NOK	-0.0148**	5.7564***	-3.5732***	-5.4628***	-5.2565***	-0.2195	0.7117	0.5658	-0.1556	0.0289**	2026	0.1716
	(0.0069)	(0.7496)	(0.7776)	(1.0629)	(0.5025)	(0.4231)	(0.4956)	(0.7000)	(0.1010)	(0.0144)		
SEK	-0.0193***	5.0373***	-3.6774***	-5.2317***	-4.6433***	0.5315	0.0047	-0.7085	-0.1087	0.0352***	2026	0.1359
	(0.0064)	(0.6410)	(1.2354)	(0.9998)	(0.4724)	(0.3853)	(0.4961)	(0.6489)	(0.1041)	(0.0137)		
CHF	-0.0141**	2.9468***	-2.5001	-1.3164	-3.0334***	-0.5529	1.5591	0.5841	-0.1730	-0.0002	2026	0.0536
	(0.0072)	(0.7557)	(1.9085)	(1.2066)	(0.5588)	(0.4383)	(1.1170)	(0.7692)	(0.1085)	(0.0035)		
GBP	-0.0183***	4.9239***	-3.3655***	-1.2412	-5.5986***	-0.6562	0.8722	0.5135	-0.3281***	-0.0071*	2026	0.1398
	(0.0070)	(0.7148)	(1.0952)	(1.1286)	(0.5333)	(0.4099)	(0.5923)	(0.7070)	(0.1080)	(0.0037)		
USD	-0.0118*	6.4787***	-6.1135***	-6.8490***	-5.2149***	0.2363	-2.1369***	-0.3064	-0.0037	-0.0150	2026	0.1962
	(0.0070)	(0.8114)	(1.3825)	(1.2181)	(0.5828)	(0.4571)	(0.5777)	(0.7439)	(0.1118)	(0.0147)		

The table reports the OLS estimates of the coefficient of the panel fixed effect regression listed above. The 10 currencies used are Australian Dollar (AUD), Canadian Dollar (CAD), Euro (EUR), Japanese Yen (JPY), New Zealand Dollar (NZD), Norwegian Krone (NOK), Swedish Krona (SEK), Swiss Franc (CHF), British Pound (GBP) and United States Dollar (USD). Each row represents a regression estimation using the first column currency as the home currency and the other 9 currencies as foreign currency j. $s_{j,t}$ is the nominal exchange rate between home and foreign country j, defined as home currency price of foreign currency, $q_{j,t}$ is the real exchange rate. $\tau_{j,t}$ is a measure of currency derivative friction, $\gamma^*_{j,t}$ is a measure of foreign treasury liquidity, $\gamma_{j,t}$ is a measure of the home treasury liquidity, $i^R_{j,t}$ is the home minus foreign interest rates. Δ is a difference operator. The sample period is 1999M1-2018M1.

Standard errors in parentheses are standard errors adjusted for cross-sectional correlation. *, **, and *** indicate that the alternative model significantly different from zero at 10%, 5%, and 1% significance level, respectively, based on standard normal critical values for the two-sided test.

Robustness of table 4A – full table of table 4A with nominal exchange rates on both sides of regressions

Estimation result of $\Delta s_{j,t} = \alpha_j + \beta_1 s_{j,t-1} + \beta_2 \Delta\tau_{j,t} + \beta_3 \Delta\gamma_t + \beta_4 \Delta\gamma^*_{j,t} + \beta_5 \Delta i^R_{j,t} + \beta_6 \gamma_{t-1} + \beta_7 \gamma^*_{j,t-1} + \beta_8 i^R_{j,t-1} + u_{j,t}$

	$s_{j,t-1}$	$\Delta\gamma^*_{j,t}$	$\Delta\gamma_t$	$\Delta\tau_{j,t}$	$\Delta i^R_{j,t}$	$\gamma^*_{j,t-1}$	γ_{t-1}	$\tau_{j,t-1}$	$i^R_{j,t-1}$	constant	N	R2 within
AUD	-0.0299***	5.4375***	-6.7016***	-3.1545***	-5.7743***	-0.1259	0.5188	-1.0400	-0.3189***	0.0125***	2028	0.2030
	(0.0084)	(0.6838)	(1.2095)	(1.2018)	(0.5372)	(0.3661)	(0.6014)	(0.7299)	(0.1091)	(0.0048)		
CAD	-0.0351***	4.4677***	-6.0910***	-5.4676***	-6.1643***	-0.5081	-0.4865	-0.6167	-0.2873***	0.0088**	1836	0.2103
	(0.0079)	(0.6848)	(1.9728)	(1.1210)	(0.5256)	(0.3981)	(1.2421)	(0.7133)	(0.1094)	(0.0036)		
EUR	-0.0233***	4.5724***	-5.0079***	-5.2792***	-4.9931***	0.0997	-0.3333	-0.8159	-0.1699*	-0.0060**	2028	0.1489
	(0.0067)	(0.5578)	(1.0918)	(0.8994)	(0.4087)	(0.3111)	(0.5275)	(0.5534)	(0.0909)	(0.0026)		
JPY	-0.0312***	4.3278***	-1.8465	-5.1748***	-6.2563***	-1.8910***	2.0154	1.3894	0.0227	0.1539***	2028	0.1658
	(0.0110)	(0.9917)	(5.2345)	(1.5931)	(0.7537)	(0.5734)	(2.5487)	(0.9522)	(0.1263)	(0.0500)		
NZD	-0.0323***	6.1592***	-6.8200***	-5.9324***	-6.2455***	1.1145**	0.1224	-1.5591**	-0.1537	0.0115*	2028	0.2079
	(0.0088)	(0.8596)	(0.8971)	(1.2849)	(0.6129)	(0.5014)	(0.4244)	(0.7484)	(0.1233)	(0.0065)		
NOK	-0.0194**	5.6143***	-3.3276***	-5.1365***	-5.0536***	-0.1630	0.5877	0.3513	-0.1532	0.0377**	2028	0.1641
	(0.0076)	(0.7350)	(0.7594)	(1.0344)	(0.4915)	(0.4139)	(0.4826)	(0.6593)	(0.0974)	(0.0154)		
SEK	-0.0269***	4.7323***	-3.9786***	-5.2370***	-4.5729***	0.4500	-0.0859	-1.1534*	-0.1555	0.0512***	2028	0.1364
	(0.0072)	(0.6304)	(1.2187)	(0.9822)	(0.4657)	(0.3788)	(0.4877)	(0.6201)	(0.1021)	(0.0149)		
CHF	-0.0230***	3.0804***	-2.6574	-1.3391	-3.0266***	-0.5239	1.6395	0.3283	-0.1956*	0.0015	2028	0.0591
	(0.0080)	(0.7448)	(1.8807)	(1.1845)	(0.5513)	(0.4299)	(1.0763)	(0.7316)	(0.1059)	(0.0034)		
GBP	-0.0228***	4.7660***	-3.7016***	-1.3531	-5.4467***	-0.6326	0.8127	0.2650	-0.3138***	-0.0094**	2028	0.1379
	(0.0077)	(0.7056)	(1.0830)	(1.1105)	(0.5271)	(0.4016)	(0.5879)	(0.6854)	(0.1048)	(0.0041)		
USD	-0.0148*	6.2155***	-5.8200***	-6.6182***	-5.0111***	0.1152	-1.9332***	-0.2274	-0.0298	-0.0221	2028	0.1875
	(0.0081)	(0.8046)	(1.3724)	(1.1985)	(0.5778)	(0.4512)	(0.5733)	(0.7132)	(0.1114)	(0.0166)		

The table reports the OLS estimates of the coefficient of the panel fixed effect regression listed above. The 10 currencies used are Australian Dollar (AUD), Canadian Dollar (CAD), Euro (EUR), Japanese Yen (JPY), New Zealand Dollar (NZD), Norwegian Krone (NOK), Swedish Krona (SEK), Swiss Franc (CHF), British Pound (GBP) and United States Dollar (USD). Each row represents a regression estimation using the first column currency as the home currency and the other 9 currencies as foreign currency j. $s_{j,t}$ is the nominal exchange rate between home and foreign country j, defined as home currency price of foreign currency, $q_{j,t}$ is the real exchange rate. $\tau_{j,t}$ is a measure of currency derivative friction, $\gamma^*_{j,t}$ is a measure of foreign treasury liquidity, $\gamma_{j,t}$ is a measure of the home treasury liquidity, $i^R_{j,t}$ is the home minus foreign interest rates. Δ is a difference operator. The sample period is 1999M1-2018M1.

Standard errors in parentheses are standard errors adjusted for cross-sectional correlation. *, **, and *** indicate that the alternative model significantly different from zero at 10%, 5%, and 1% significance level, respectively, based on standard normal critical values for the two-sided test.

B.5 Supplmentary Appendix B

Liquidity and Exchange Rates: An Empirical Investigation

Charles Engel and Steve Pak Yeung Wu

April 16, 2020

Supplementary Appendix B

1. The Model

The equations of the model are:

(1) $i_t^{*m} + E_t s_{t+1} - s_t - i_t^m = r_t$,

(2) $\eta_t = \gamma_t - \gamma_t^* = \left(i_t^m - i_t\right) - \left(i_t^{m*} - i_t^*\right) = \left(i_t^m - i_t^{m*}\right) - \left(i_t - i_t^*\right)$.

(3) $i_t^* + E_t s_{t+1} - s_t - i_t = \eta_t + r_t$.

(4) $\eta_t = \alpha\left(i_t - i_t^*\right) + v_t$, $\alpha > 0$.

(5) $\pi_t - \pi_t^* = \theta q_{t-1} + E_{t-1} s_t - s_{t-1}$.

(6) $i_t - i_t^* = \sigma\left(\pi_t - \pi_t^*\right) - \psi\eta_t + u_t - u_t^*$.

(7) $u_t - u_t^* = \delta\left(u_{t-1} - u_{t-1}^*\right) + \xi_t$, $0 \le \delta < 1$

(8) $v_t = \rho v_{t-1} + \varepsilon_t$,

(9) $r_t = \varsigma r_{t-1} + \omega_t$, $0 \le \varsigma < 1$.

2. Derivation of solution for q_t

As a first step, using (6) and (4), we have

$i_t - i_t^* = \sigma\left(\pi_t - \pi_t^*\right) - \psi\left(\alpha\left(i_t - i_t^*\right) + v_t\right) + u_t - u_t^*$, so

(10) $i_t - i_t^* = \dfrac{\sigma}{1+\alpha\psi}\left(\pi_t - \pi_t^*\right) - \dfrac{\psi}{1+\alpha\psi} v_t + \dfrac{1}{1+\alpha\psi}\left(u_t - u_t^*\right)$

We can solve the model by the method of undetermined coefficients. We guess a solution of the form:

(11) $q_t = a\left(\pi_t - \pi_t^*\right) + b\left(u_t - u_t^*\right) + c v_t + f r_t$,

where *a*, *b*, *c* and *f* are undetermined coefficients to be solved for.

We have:

(12)
$$\begin{aligned} E_t q_{t+1} &= aE_t\left(\pi_{t+1}-\pi^*_{t+1}\right)+bE_t\left(u_{t+1}-u^*_{t+1}\right)+cE_t v_{t+1}+fE_t r_{t+1} \\ &= aE_t\left(\pi_{t+1}-\pi^*_{t+1}\right)+b\delta\left(u_t-u^*_t\right)+c\rho v_t+f\varsigma r_t \end{aligned}$$

Now,

(13)
$$\begin{aligned} E_t\left(\pi_{t+1}-\pi^*_{t+1}\right) &= E_t s_{t+1}-s_t-\left(E_t q_{t+1}-q_t\right)=E_t s_{t+1}-s_t+\theta q_t \\ &= i_t-i^*_t+\eta_t+r_t+\theta q_t=\left(1+\alpha\right)\left(i_t-i^*_t\right)+v_t+r_t+\theta q_t \\ &= \theta q_t+\frac{\sigma\left(1+\alpha\right)}{1+\alpha\psi}\left(\pi_t-\pi^*_t\right)+\frac{1+\alpha}{1+\alpha\psi}\left(u_t-u^*_t\right)+\frac{1-\psi}{1+\alpha\psi}v_t+r_t \end{aligned}$$

where we have used, from (5) that $E_t q_{t+1}-q_t=-\theta q_t$.

Substituting from (13) into (12), we get:

(14)

$$\begin{aligned} E_t q_{t+1} &= a\left[\theta q_t+\frac{\sigma\left(1+\alpha\right)}{1+\alpha\psi}\left(\pi_t-\pi^*_t\right)+\frac{1+\alpha}{1+\alpha\psi}\left(u_t-u^*_t\right)+\frac{1-\psi}{1+\alpha\psi}v_t+r_t\right]+b\delta\left(u_t-u^*_t\right)+c\rho v_t+f\varsigma r_t \\ &= a\theta q_t+\frac{a\sigma\left(1+\alpha\right)}{1+\alpha\psi}\left(\pi_t-\pi^*_t\right)+\left[\frac{a\left(1+\alpha\right)+b\delta\left(1+\alpha\psi\right)}{1+\alpha\psi}\right]\left(u_t-u^*_t\right)+\left[\frac{a\left(1-\psi\right)+c\rho\left(1+\alpha\psi\right)}{1+\alpha\psi}\right]v_t+\left[a+f\varsigma\right]r_t \\ &= a\theta\left[a\left(\pi_t-\pi^*_t\right)+b\left(u_t-u^*_t\right)+cv_t+fr_t\right]+ \\ &\quad \frac{a\sigma\left(1+\alpha\right)}{1+\alpha\psi}\left(\pi_t-\pi^*_t\right)+\left[\frac{a\left(1+\alpha\right)+b\delta\left(1+\alpha\psi\right)}{1+\alpha\psi}\right]\left(u_t-u^*_t\right)+\left[\frac{a\left(1-\psi\right)+c\rho\left(1+\alpha\psi\right)}{1+\alpha\psi}\right]v_t+\left[a+f\varsigma\right]r_t \\ &= \frac{a\left[\sigma\left(1+\alpha\right)+a\theta\left(1+\alpha\psi\right)\right]}{1+\alpha\psi}\left(\pi_t-\pi^*_t\right)+\frac{\left[a\left(1+\alpha\right)+b\left(\delta+a\theta\right)\left(1+\alpha\psi\right)\right]}{1+\alpha\psi}\left(u_t-u^*_t\right) \\ &\quad +\frac{\left[a\left(1-\psi\right)+c\left(\rho+a\theta\right)\left(1+\alpha\psi\right)\right]}{1+\alpha\psi}v_t+\left[a+f\varsigma+fa\theta\right]r_t \end{aligned}$$

But, also, using from (5) that $E_t q_{t+1}=\left(1-\theta\right)q_t$, we have from (11):

(15) $$E_t q_{t+1}=a\left(1-\theta\right)\left(\pi_t-\pi^*_t\right)+b\left(1-\theta\right)\left(u_t-u^*_t\right)+c\left(1-\theta\right)v_t+f\left(1-\theta\right)r_t.$$

Now, equating the right-hand sides of (14) and (15), we get:

$$\frac{a\left[\sigma(1+\alpha)+a\theta(1+\alpha\psi)\right]}{1+\alpha\psi}=a(1-\theta)$$

from which we derive:

$$a=\frac{-\left[\sigma(1+\alpha)-(1-\theta)(1+\alpha\psi)\right]}{\theta(1+\alpha\psi)}.$$

Then, from (14) and (15), we get:

$$a(1+\alpha)=b(1-\theta)(1+\alpha\psi)-b(\delta+a\theta)(1+\alpha\psi).$$

Substituting in the solution for *a*, we get:

$$b=\frac{-(1+\alpha)\left[\sigma(1+\alpha)-(1-\theta)(1+\alpha\psi)\right]}{\theta(1+\alpha\psi)\left(\sigma(1+\alpha)-\delta(1+\alpha\psi)\right)}.$$

From (14) and (15), we also get:

$$\frac{\left[a(1-\psi)+c(\rho+a\theta)(1+\alpha\psi)\right]}{1+\alpha\psi}=c(1-\theta)$$, from which we derive

$$c=\frac{-(1-\psi)\left[\sigma(1+\alpha)-(1-\theta)(1+\alpha\psi)\right]}{\theta(1+\alpha\psi)\left[\sigma(1+\alpha)-\rho(1+\alpha\psi)\right]}$$

And, finally, from (14) and (15), we get:

$a+f\varsigma+fa\theta=f(1-\theta)$, which gives us:

$$f=\frac{-\left[\sigma(1+\alpha)-(1-\theta)(1+\alpha\psi)\right]}{\theta\left[\sigma(1+\alpha)-\zeta(1+\alpha\psi)\right]}$$

We can therefore write solution for the real exchange rate as:

(16)

$$q_t = -\left(\frac{\sigma(1+\alpha)-(1-\theta)(1+\alpha\psi)}{\theta(1+\alpha\psi)}\right)(\pi_t - \pi_t^*) - \left(\frac{(1+\alpha)\left[\sigma(1+\alpha)-(1-\theta)(1+\alpha\psi)\right]}{\theta(1+\alpha\psi)(\sigma(1+\alpha)-\delta(1+\alpha\psi))}\right)(u_t - u_t^*)$$
$$-\left(\frac{(1-\psi)\left[\sigma(1+\alpha)-(1-\theta)(1+\alpha\psi)\right]}{\theta(1+\alpha\psi)\left[\sigma(1+\alpha)-\rho(1+\alpha\psi)\right]}\right)v_t - \left(\frac{\sigma(1+\alpha)-(1-\theta)(1+\alpha\psi)}{\theta\left[\sigma(1+\alpha)-\zeta(1+\alpha\psi)\right]}\right)r_t .$$

3. <u>**Derivation of solution for**</u> $s_t - s_{t-1}$

Use (10) to write $u_t - u_t^* = (1+\alpha\psi)(i_t - i_t^*) - \sigma(\pi_t - \pi_t^*) + \psi v_t$, and substitute this into (16):

$$q_t = -\left(\frac{\sigma(1+\alpha)-(1-\theta)(1+\alpha\psi)}{\theta(1+\alpha\psi)}\right)(\pi_t - \pi_t^*)$$
$$-\left(\frac{(1+\alpha)\left[\sigma(1+\alpha)-(1-\theta)(1+\alpha\psi)\right]}{\theta(1+\alpha\psi)(\sigma(1+\alpha)-\delta(1+\alpha\psi))}\right)\left((1+\alpha\psi)(i_t - i_t^*) - \sigma(\pi_t - \pi_t^*) + \psi v_t\right)$$
$$-\left(\frac{(1-\psi)\left[\sigma(1+\alpha)-(1-\theta)(1+\alpha\psi)\right]}{\theta(1+\alpha\psi)\left[\sigma(1+\alpha)-\rho(1+\alpha\psi)\right]}\right)v_t - \left(\frac{\sigma(1+\alpha)-(1-\theta)(1+\alpha\psi)}{\theta\left[\sigma(1+\alpha)-\zeta(1+\alpha\psi)\right]}\right)r_t$$

The coefficients on $\pi_t - \pi_t^*$ are

$$-\left(\frac{\sigma(1+\alpha)-(1-\theta)(1+\alpha\psi)}{\theta(1+\alpha\psi)}\right) + \sigma\left(\frac{(1+\alpha)\left[\sigma(1+\alpha)-(1-\theta)(1+\alpha\psi)\right]}{\theta(1+\alpha\psi)(\sigma(1+\alpha)-\delta(1+\alpha\psi))}\right)$$
$$= \frac{\delta\left[\sigma(1+\alpha)-(1-\theta)(1+\alpha\psi)\right]}{\theta(\sigma(1+\alpha)-\delta(1+\alpha\psi))} .$$

The coefficients on v_t are

$$-\left(\frac{(1-\psi)\left[\sigma(1+\alpha)-(1-\theta)(1+\alpha\psi)\right]}{\theta(1+\alpha\psi)\left[\sigma(1+\alpha)-\rho(1+\alpha\psi)\right]}\right) - \psi\left(\frac{(1+\alpha)\left[\sigma(1+\alpha)-(1-\theta)(1+\alpha\psi)\right]}{\theta(1+\alpha\psi)(\sigma(1+\alpha)-\delta(1+\alpha\psi))}\right)$$
$$= \frac{-\left[\sigma(1+\alpha)-(1-\theta)(1+\alpha\psi)\right]\left[\sigma(1+\alpha)-(\delta(1-\psi)+\rho\psi(1+\alpha))\right]}{\theta(\sigma(1+\alpha)-\delta(1+\alpha\psi))(\sigma(1+\alpha)-\rho(1+\alpha\psi))} .$$

We have:

$$q_t = \frac{\delta\left[\sigma(1+\alpha)-(1-\theta)(1+\alpha\psi)\right]}{\theta\left(\sigma(1+\alpha)-\delta(1+\alpha\psi)\right)}\left(\pi_t-\pi_t^*\right)-\left(\frac{(1+\alpha)\left[\sigma(1+\alpha)-(1-\theta)(1+\alpha\psi)\right]}{\theta\left(\sigma(1+\alpha)-\delta(1+\alpha\psi)\right)}\right)\left(i_t-i_t^*\right)$$
$$-\left(\frac{\left[\sigma(1+\alpha)-(1-\theta)(1+\alpha\psi)\right]\left[\sigma(1+\alpha)-\left(\delta(1-\psi)+\rho\psi(1+\alpha)\right)\right]}{\theta\left(\sigma(1+\alpha)-\delta(1+\alpha\psi)\right)\left(\sigma(1+\alpha)-\rho(1+\alpha\psi)\right)}\right)v_t \qquad .$$
$$-\left(\frac{\sigma(1+\alpha)-(1-\theta)(1+\alpha\psi)}{\theta\left[\sigma(1+\alpha)-\zeta(1+\alpha\psi)\right]}\right)r_t$$

Now we can use the fact that $s_t-s_{t-1}=q_t-q_{t-1}+\pi_t-\pi_t^*$ and the equation above to write:

(17)

$$s_t-s_{t-1} = \frac{(\theta+\delta)\sigma(1+\alpha)-\delta(1+\alpha\psi)}{\theta\left(\sigma(1+\alpha)-\delta(1+\alpha\psi)\right)}\left(\pi_t-\pi_t^*\right)-\left(\frac{(1+\alpha)\left[\sigma(1+\alpha)-(1-\theta)(1+\alpha\psi)\right]}{\theta\left(\sigma(1+\alpha)-\delta(1+\alpha\psi)\right)}\right)\left(i_t-i_t^*\right)$$
$$-\left(\frac{\left[\sigma(1+\alpha)-(1-\theta)(1+\alpha\psi)\right]\left[\sigma(1+\alpha)-\left(\delta(1-\psi)+\rho\psi(1+\alpha)\right)\right]}{\theta\left(\sigma(1+\alpha)-\delta(1+\alpha\psi)\right)\left(\sigma(1+\alpha)-\rho(1+\alpha\psi)\right)}\right)v_t \qquad .$$
$$-\left(\frac{\sigma(1+\alpha)-(1-\theta)(1+\alpha\psi)}{\theta\left[\sigma(1+\alpha)-\zeta(1+\alpha\psi)\right]}\right)r_t-q_{t-1}$$

But
$$\begin{aligned}\pi_t-\pi_t^* &= s_t-s_{t-1}-\left(q_t-q_{t-1}\right)=E_{t-1}s_t-s_{t-1}-\left(E_{t-1}q_t-q_{t-1}\right)\\ &= i_{t-1}-i_{t-1}^*+\eta_{t-1}+r_{t-1}+\theta q_{t-1}\end{aligned}.$$

Also, we have $v_t=\eta_t-\alpha\left(i_t-i_t^*\right)$. Substituting these into (17), we get

(18)

$$s_t-s_{t-1} = \frac{(\theta+\delta)\sigma(1+\alpha)-\delta(1+\alpha\psi)}{\theta\left(\sigma(1+\alpha)-\delta(1+\alpha\psi)\right)}\left(i_{t-1}-i_{t-1}^*+\eta_{t-1}+r_{t-1}+\theta q_{t-1}\right)$$
$$-\left(\frac{(1+\alpha)\left[\sigma(1+\alpha)-(1-\theta)(1+\alpha\psi)\right]}{\theta\left(\sigma(1+\alpha)-\delta(1+\alpha\psi)\right)}\right)\left(i_t-i_t^*\right)$$
$$-\left(\frac{\left[\sigma(1+\alpha)-(1-\theta)(1+\alpha\psi)\right]\left[\sigma(1+\alpha)-\left(\delta(1-\psi)+\rho\psi(1+\alpha)\right)\right]}{\theta\left(\sigma(1+\alpha)-\delta(1+\alpha\psi)\right)\left(\sigma(1+\alpha)-\rho(1+\alpha\psi)\right)}\right)\left(\eta_t-\alpha\left(i_t-i_t^*\right)\right) .$$
$$-\left(\frac{\sigma(1+\alpha)-(1-\theta)(1+\alpha\psi)}{\theta\left[\sigma(1+\alpha)-\zeta(1+\alpha\psi)\right]}\right)r_t-q_{t-1}$$

Rearrange terms. The coefficient on q_{t-1} is given by:

$$\frac{(\theta+\delta)\sigma(1+\alpha)-\delta(1+\alpha\psi)}{\sigma(1+\alpha)-\delta(1+\alpha\psi)}-1=-\left(\frac{\sigma(1+\alpha)(1-\theta-\delta)}{\sigma(1+\alpha)-\delta(1+\alpha\psi)}\right)$$

The coefficient on $i_t-i_t^*$ is:

$$-\left(\frac{(1+\alpha)\left[\sigma(1+\alpha)-(1-\theta)(1+\alpha\psi)\right]}{\theta\left(\sigma(1+\alpha)-\delta(1+\alpha\psi)\right)}\right)+\alpha\left(\frac{\left[\sigma(1+\alpha)-(1-\theta)(1+\alpha\psi)\right]\left[\sigma(1+\alpha)-\left(\delta(1-\psi)+\rho\psi(1+\alpha)\right)\right]}{\theta\left(\sigma(1+\alpha)-\delta(1+\alpha\psi)\right)\left(\sigma(1+\alpha)-\rho(1+\alpha\psi)\right)}\right)$$
$$=-\left(\frac{\left[\sigma(1+\alpha)-(1-\theta)(1+\alpha\psi)\right]\left[(1+\alpha)(\sigma-\rho)+\alpha\delta(1-\psi)\right]}{\theta\left(\sigma(1+\alpha)-\delta(1+\alpha\psi)\right)\left(\sigma(1+\alpha)-\rho(1+\alpha\psi)\right)}\right)$$

So we can write:

$$\begin{aligned}s_t-s_{t-1}=&-\left(\frac{\sigma(1+\alpha)(1-\theta-\delta)}{\sigma(1+\alpha)-\delta(1+\alpha\psi)}\right)q_{t-1}\\&-\left(\frac{\left[\sigma(1+\alpha)-(1-\theta)(1+\alpha\psi)\right]\left[(1+\alpha)(\sigma-\rho)+\alpha\delta(1-\psi)\right]}{\theta\left(\sigma(1+\alpha)-\delta(1+\alpha\psi)\right)\left(\sigma(1+\alpha)-\rho(1+\alpha\psi)\right)}\right)\left(i_t-i_t^*\right)\\&-\left(\frac{\left[\sigma(1+\alpha)-(1-\theta)(1+\alpha\psi)\right]\left[\sigma(1+\alpha)-\left(\delta(1-\psi)+\rho\psi(1+\alpha)\right)\right]}{\theta\left(\sigma(1+\alpha)-\delta(1+\alpha\psi)\right)\left(\sigma(1+\alpha)-\rho(1+\alpha\psi)\right)}\right)\eta_t\\&+\frac{(\theta+\delta)\sigma(1+\alpha)-\delta(1+\alpha\psi)}{\theta\left(\sigma(1+\alpha)-\delta(1+\alpha\psi)\right)}\left(i_{t-1}-i_{t-1}^*+\eta_{t-1}+r_{t-1}\right)-\left(\frac{\sigma(1+\alpha)-(1-\theta)(1+\alpha\psi)}{\theta\left[\sigma(1+\alpha)-\zeta(1+\alpha\psi)\right]}\right)r_t\end{aligned}$$

Now, we get the equation in the form that is used for estimating, which involves $i_t-i_t^*-\left(i_{t-1}-i_{t-1}^*\right)$ and $\eta_t-\eta_{t-1}$. Also, use the fact that $r_t=\varsigma r_{t-1}+\omega_t$ from equation (9).

$$s_t - s_{t-1} = -\left(\frac{\sigma(1+\alpha)(1-\theta-\delta)}{\sigma(1+\alpha)-\delta(1+\alpha\psi)}\right)q_{t-1}$$
$$-\left(\frac{\left[\sigma(1+\alpha)-(1-\theta)(1+\alpha\psi)\right]\left[(1+\alpha)(\sigma-\rho)+\alpha\delta(1-\psi)\right]}{\theta\left(\sigma(1+\alpha)-\delta(1+\alpha\psi)\right)\left(\sigma(1+\alpha)-\rho(1+\alpha\psi)\right)}\right)\left(i_t - i_t^* - \left(i_{t-1}-i_{t-1}^*\right)\right)$$
$$-\left(\frac{\left[\sigma(1+\alpha)-(1-\theta)(1+\alpha\psi)\right]\left[\sigma(1+\alpha)-\left(\delta(1-\psi)+\rho\psi(1+\alpha)\right)\right]}{\theta\left(\sigma(1+\alpha)-\delta(1+\alpha\psi)\right)\left(\sigma(1+\alpha)-\rho(1+\alpha\psi)\right)}\right)(\eta_t-\eta_{t-1})+$$
$$\left[\begin{array}{l}\frac{(\theta+\delta)\sigma(1+\alpha)-\delta(1+\alpha\psi)}{\theta\left(\sigma(1+\alpha)-\delta(1+\alpha\psi)\right)}- \\ \left(\frac{\left[\sigma(1+\alpha)-(1-\theta)(1+\alpha\psi)\right]\left[(1+\alpha)(\sigma-\rho)+\alpha\delta(1-\rho)\right]}{\theta\left(\sigma(1+\alpha)-\delta(1+\alpha\psi)\right)\left(\sigma(1+\alpha)-\rho(1+\alpha\psi)\right)}\right)\end{array}\right]\left(i_{t-1}-i_{t-1}^*\right)$$
$$+\left[\begin{array}{l}\frac{(\theta+\delta)\sigma(1+\alpha)-\delta(1+\alpha\psi)}{\theta\left(\sigma(1+\alpha)-\delta(1+\alpha\psi)\right)}- \\ \left(\frac{\left[\sigma(1+\alpha)-(1-\theta)(1+\alpha\psi)\right]\left[\sigma(1+\alpha)-\left(\delta(1-\psi)+\rho\psi(1+\alpha)\right)\right]}{\theta\left(\sigma(1+\alpha)-\delta(1+\alpha\psi)\right)\left(\sigma(1+\alpha)-\rho(1+\alpha\psi)\right)}\right)\end{array}\right]\eta_{t-1}$$
$$-\left(\frac{\sigma(1+\alpha)-(1-\theta)(1+\alpha\psi)}{\theta\left[\sigma(1+\alpha)-\zeta(1+\alpha\psi)\right]}\right)\omega_t+\left[\frac{(\theta+\delta)\sigma(1+\alpha)-\delta(1+\alpha\psi)}{\theta\left(\sigma(1+\alpha)-\delta(1+\alpha\psi)\right)}-\frac{\zeta\left[\sigma(1+\alpha)-(1-\theta)(1+\alpha\psi)\right]}{\theta\left[\sigma(1+\alpha)-\zeta(1+\alpha\psi)\right]}\right]r_{t-1}$$

We can rewrite the term on $i_{t-1}-i_{t-1}^*$ as:

$$\frac{(\theta+\delta)\sigma(1+\alpha)-\delta(1+\alpha\psi)}{\theta\left(\sigma(1+\alpha)-\delta(1+\alpha\psi)\right)}-\left(\frac{\left[\sigma(1+\alpha)-(1-\theta)(1+\alpha\psi)\right]\left[(1+\alpha)(\sigma-\rho)+\alpha\delta(1-\psi)\right]}{\theta\left(\sigma(1+\alpha)-\delta(1+\alpha\psi)\right)\left(\sigma(1+\alpha)-\rho(1+\alpha\psi)\right)}\right)$$
$$=\frac{(\theta+\delta-1)\left[\sigma(1+\alpha)-(1+\alpha\psi)\right]\left[\sigma(1+\alpha)-\rho(1+\alpha\psi)\right]+(\rho-\delta)\alpha(1-\psi)\left[\sigma(1+\alpha)-(1-\theta)(1+\alpha\psi)\right]}{\theta\left(\sigma(1+\alpha)-\delta(1+\alpha\psi)\right)\left(\sigma(1+\alpha)-\rho(1+\alpha\psi)\right)}$$

The term on η_{t-1} can be written as:

$$\frac{(\theta+\delta)\sigma(1+\alpha)-\delta(1+\alpha\psi)}{\theta\left(\sigma(1+\alpha)-\delta(1+\alpha\psi)\right)}-\left(\frac{\left[\sigma(1+\alpha)-(1-\theta)(1+\alpha\psi)\right]\left[\sigma(1+\alpha)-\left(\delta(1-\psi)+\rho\psi(1+\alpha)\right)\right]}{\theta\left(\sigma(1+\alpha)-\delta(1+\alpha\psi)\right)\left(\sigma(1+\alpha)-\rho(1+\alpha\psi)\right)}\right)=$$
$$\frac{(\theta+\delta-1)\left[\sigma(1+\alpha)-(1+\alpha\psi)\right]\left[\sigma(1+\alpha)-\rho(1+\alpha\psi)\right]-(\rho-\delta)(1-\psi)\left[\sigma(1+\alpha)-(1-\theta)(1+\alpha\psi)\right]}{\theta\left(\sigma(1+\alpha)-\delta(1+\alpha\psi)\right)\left(\sigma(1+\alpha)-\rho(1+\alpha\psi)\right)}$$

To simplify the term on r_{t-1}, we can write:

$$\frac{(\theta+\delta)\sigma(1+\alpha)-\delta(1+\alpha\psi)}{\theta(\sigma(1+\alpha)-\delta(1+\alpha\psi))}-\frac{\zeta[\sigma(1+\alpha)-(1-\theta)(1+\alpha\psi)]}{\theta[\sigma(1+\alpha)-\zeta(1+\alpha\psi)]}=$$

$$\frac{[\sigma(1+\alpha)-\zeta(1+\alpha\psi)][(\theta+\delta-\zeta)\sigma(1+\alpha)-(1+\alpha\psi)(\delta-\zeta(1-\theta))]+(\delta-\zeta)(1+\alpha\psi)\zeta[\sigma(1+\alpha)-(1-\theta)(1+\alpha\psi))]}{\theta[\sigma(1+\alpha)-\delta(1+\alpha\psi)][\sigma(1+\alpha)-\zeta(1+\alpha\psi)]}$$

With these simplifications, we can arrive at the equation in the text:

(19) $$s_t-s_{t-1}=\beta_1 q_{t-1}+\beta_2(\eta_t-\eta_{t-1})+\beta_3\left(i_t-i_t^*-\left(i_{t-1}-i_{t-1}^*\right)\right)+\beta_4\eta_{t-1}+\beta_5\left(i_{t-1}-i_{t-1}^*\right)+z_{j,t}$$

where

$$\beta_1=-\left(\frac{\sigma(1+\alpha)(1-\theta-\delta)}{\sigma(1+\alpha)-\delta(1+\alpha\psi)}\right),$$

$$\beta_2=-\left(\frac{\left[\sigma(1+\alpha)-(1-\theta)(1+\alpha\psi)\right]\left[\sigma(1+\alpha)-\left(\delta(1-\psi)+\rho\psi(1+\alpha)\right)\right]}{\theta\left(\sigma(1+\alpha)-\delta(1+\alpha\psi)\right)\left(\sigma(1+\alpha)-\rho(1+\alpha\psi)\right)}\right),$$

$$\beta_3=-\left(\frac{\left[\sigma(1+\alpha)-(1-\theta)(1+\alpha\psi)\right]\left[(1+\alpha)(\sigma-\rho)+\alpha\delta(1-\psi)\right]}{\theta\left(\sigma(1+\alpha)-\delta(1+\alpha\psi)\right)\left(\sigma(1+\alpha)-\rho(1+\alpha\psi)\right)}\right)$$

$$\beta_4=\frac{(\theta+\delta-1)\left[\sigma(1+\alpha)-(1+\alpha\psi)\right]\left[\sigma(1+\alpha)-\rho(1+\alpha\psi)\right]-(\rho-\delta)(1-\psi)\left[\sigma(1+\alpha)-(1-\theta)(1+\alpha\psi)\right]}{\theta\left(\sigma(1+\alpha)-\delta(1+\alpha\psi)\right)\left(\sigma(1+\alpha)-\rho(1+\alpha\psi)\right)}$$

$$\beta_5=\frac{(\theta+\delta-1)\left[\sigma(1+\alpha)-(1+\alpha\psi)\right]\left[\sigma(1+\alpha)-\rho(1+\alpha\psi)\right]+(\rho-\delta)\alpha(1-\psi)\left[\sigma(1+\alpha)-(1-\theta)(1+\alpha\psi)\right]}{\theta\left(\sigma(1+\alpha)-\delta(1+\alpha\psi)\right)\left(\sigma(1+\alpha)-\rho(1+\alpha\psi)\right)}$$

and, $z_t=-\left(\dfrac{\sigma(1+\alpha)-(1-\theta)(1+\alpha\psi)}{\theta\left[\sigma(1+\alpha)-\zeta(1+\alpha\psi)\right]}\right)\omega_t+z_1 r_{t-1}$, where

$$z_1=\frac{\left[\sigma(1+\alpha)-\zeta(1+\alpha\psi)\right]\left[(\theta+\delta-\zeta)\sigma(1+\alpha)-(1+\alpha\psi)\left(\delta-\zeta(1-\theta)\right)\right]+(\delta-\zeta)(1+\alpha\psi)\zeta\left[\sigma(1+\alpha)-(1-\theta)(1+\alpha\psi)\right)\right]}{\theta\left[\sigma(1+\alpha)-\delta(1+\alpha\psi)\right]\left[\sigma(1+\alpha)-\zeta(1+\alpha\psi)\right]}$$

Recall the restrictions we have assumed: $0<\theta<1$, $0\leq\rho<1$, $0\leq\delta<1$, $0\leq\varsigma<1$, $\sigma>1$, $\alpha>0$, $\delta<1-\theta$ and $\rho<1-\theta$..

Under these conditions, first one can see that $\beta_1<0$. The denominator of β_1 must be positive since $\sigma>1$. The numerator is positive since $\delta<1-\theta$.

We must have $\beta_2<0$. From $\sigma>1$, we can see that the terms $\sigma(1+\alpha)-(1-\theta)(1+\alpha\psi)$, $\sigma(1+\alpha)-\delta(1+\alpha\psi)$, and $\sigma(1+\alpha)-\rho(1+\alpha\psi)$ are all positive. Also from $\sigma>1$,

$$\sigma(1+\alpha)-\left(\delta(1-\psi)+\rho\psi(1+\alpha)\right)=\sigma-\left(\delta(1-\psi)+\rho\psi\right)+\alpha(\sigma-\rho\psi)>0.$$

It is also immediate that $\beta_3<0$.

The coefficients on $i_{t-1}-i^*_{t-1}$ and η_{t-1} are, under these assumptions, ambiguous in sign. Note also that the coefficients on $i_t-i^*_t-\left(i_{t-1}-i^*_{t-1}\right)$ and $\eta_t-\eta_{t-1}$ would be much larger than the coefficients on $i_{t-1}-i^*_{t-1}$, and η_{t-1} when θ is small. In our baseline regression, as we have emphasized, the coefficients on q_{t-1}, $i_t-i^*_t-\left(i_{t-1}-i^*_{t-1}\right)$ and $\eta_t-\eta_{t-1}$ are all negative, and almost uniformly highly statistically significant. We note here that also almost all of the coefficients on $i_{t-1}-i^*_{t-1}$, and η_{t-1} are estimated to be negative, and they are smaller in magnitude then the coefficients on $i_t-i^*_t-\left(i_{t-1}-i^*_{t-1}\right)$ and $\eta_t-\eta_{t-1}$.

4. The serial correlation of the residual

From equation (19), the regression residual implied by our model is given by

$z_t = z_0\omega_t + z_1 r_{t-1}$,

where, dividing numerator and denominator by $1+\alpha\psi$, and letting $x=\dfrac{1+\alpha}{1+\alpha\psi}$, we have

$$z_0=-\left(\frac{\sigma x-(1-\theta)}{\theta[\sigma x-\zeta]}\right)$$

$$z_1=\frac{[\sigma x-\zeta]\Big[(\theta+\delta-\zeta)\sigma x-\big(\delta-\zeta(1-\theta)\big)\Big]+(\delta-\zeta)\zeta\big[\sigma x-(1-\theta)\big]}{\theta[\sigma x-\delta][\sigma x-\zeta]}$$

The serial correlation of this error term is given by $\dfrac{\operatorname{cov}\left(z_0\omega_t+z_1r_{t-1},z_0\omega_{t+1}+z_1r_t\right)}{\operatorname{var}\left(z_0\omega_t+br_{t-1}\right)}$.

For the numerator of this expression, we have:

$$\begin{aligned}\operatorname{cov}\left(z_0\omega_t+z_1r_{t-1},z_0\omega_{t+1}+z_1r_t\right)&=\operatorname{cov}\left(z_0\omega_t+z_1r_{t-1},z_1r_t\right)\\&=\operatorname{cov}\left(z_0\omega_t+z_1r_{t-1},z_1\left(\varsigma r_{t-1}+\omega_t\right)\right)\\&=z_0z_1\operatorname{var}\left(\omega_t\right)+\left(z_1\right)^2\varsigma\operatorname{var}\left(r_{t-1}\right)\\&=\left(z_0z_1+\frac{\left(z_1\right)^2\varsigma}{1-\varsigma^2}\right)\operatorname{var}\left(\omega_t\right)\end{aligned}$$

Then, $\operatorname{var}\left(z_0\omega_t+z_1r_{t-1}\right)=\left(\left(z_0\right)^2+\dfrac{\left(z_1\right)^2}{1-\varsigma^2}\right)\operatorname{var}\left(\omega_t\right)$. So,

$$\frac{\operatorname{cov}\left(z_0\omega_t+z_1r_{t-1},z_0\omega_{t+1}+z_1r_t\right)}{\operatorname{var}\left(z_0\omega_t+z_1r_{t-1}\right)}=\frac{z_0z_1\left(1-\varsigma^2\right)+\left(z_1\right)^2\varsigma}{\left(z_0\right)^2\left(1-\varsigma^2\right)+\left(z_1\right)^2}.$$

We can calibrate this expression for the serial correlation of the error term as follows: Engel (2019) measures the monthly serial correlation of the real exchange rate for the six non-U.S. countries in the G7 relative to the U.S., equal on average to 0.98. In our model, the serial correlation of the real exchange rate is given by $1-\theta$, so we set $\theta=0.98$. Engel (2019) also estimates simple Taylor rules for these countries and finds the monthly serial correlation of the error term to be

0.96, so we set $\delta = 0.96$. The serial correlation of the ex ante risk premium is more problematic to calibrate because we need a measure of the serial correlation of the expected excess return on the market (LIBOR) investments. A natural measure is to equilibrate this serial correlation to the serial correlation of the nominal interest rate differential, which is also equal to 0.96 for the same set of countries, because the literature has generally found that the excess return is correlated with the interest rate differential and little else.

Note that the serial correlation of the residual does not depend on ρ, and it only depends on α as it influences σx. Our stability condition is $\sigma x > 1$. With that restriction in place, the serial correlation of the residual is practically independent of the value of σx as this table shows.

Appendix Table					
σx	θ	ς	δ		Serial Correlation of Residual
1	0.02	0.96	0.96		-0.020
2	0.02	0.96	0.96		-0.015
4	0.02	0.96	0.96		-0.015
100	0.02	0.96	0.96		-0.015
2	0.02	0.90	0.96		-0.044
2	0.02	0.95	0.96		-0.024
2	0.02	0.98	0.96		0.027
4	0.02	0.90	0.96		-0.050
4	0.02	0.95	0.96		-0.022
4	0.02	0.98	0.96		0.007
2	0.01	0.96	0.96		-0.009
2	0.03	0.96	0.96		-0.019
2	0.04	0.96	0.96		-0.020
2	0.05	0.96	0.96		-0.019
2	0.06	0.96	0.96		-0.016

5. Less Restrictive Formulations and "Internally Consistent" Regressions

Consider our panel regression for currency *i*. A typical equation for the exchange rate relative to currency *j*, $j = 1, 2, \ldots, 10$, $j \neq i$, is

$$(1) \quad \begin{aligned} s_{ij,t} - s_{ij,t-1} &= \beta_{ij,0} + \beta_{i1} q_{ij,t-1} + \beta_{i2}\left(\eta_{ij,t} - \eta_{ij,t-1}\right) + \beta_{i3}\left(i_{i,t} - i_{j,t} - \left(i_{i,t-1} - i_{j,t-1}\right)\right) \\ &\quad + \beta_{i4}\eta_{ij,t-1} + \beta_{i5}\left(i_{i,t-1} - i_{j,t-1}\right) + z_{ij,t} \end{aligned}$$

In some specifications we replace $\eta_{ij,t}$ with $\eta_{ij,t} = \gamma_{i,t} - \gamma_{j,t}$.

This formulation places three different types of restrictions on a more general panel specification:

1. There are cross-equation restrictions. That is, more generally, the coefficients in the panel could be different for each bilateral exchange rate of currency *i*. We could have, for example, a different coefficient on each real exchange rate, so we have $\beta_{ij,1}$, $j = 1, 2, \ldots, 10$, $j \neq i$, but we have imposed $\beta_{ij,1} = \beta_{ik,1}$ for all $j = 1, 2, \ldots, 10$, $j \neq i \neq k$
2. There are exclusion restrictions. The explanatory variables for $s_{ij,t} - s_{ij,t-1}$ only include country *i* and *j* variables.
3. The explanatory variables in the baseline regression are all expressed in terms of country *i* relative to country *j*. In some cases, that is the only way it is possible to express the variables (such as with $q_{ij,t}$, or when we use the $\tilde{\eta}_t$ measure for η_t). In other cases, we can separate out country *i* and country *j* variables, and not impose that the coefficient on one be equal and of opposite sign to the coefficient on the other (such as with $\hat{\eta}_{ij,t} = IRS_{it} - IRS_{j,t} + i_{j,t} - i_{i,t}$, which can be separated into $IRS_{i,t} - i_{i,t}$ and $IRS_{j,t} - i_{j,t}$, or $i_{i,t} - i_{j,t} - \left(i_{i,t-1} - i_{j,t-1}\right)$ can be separated into $i_{i,t} - i_{i,t-1}$ and $i_{j,t} - i_{j,t-1}$.)

The object of the note is twofold. First, it is to display the form of the more general panel regressions, and to test the restricted panels against the more general panels. Second, is to find whether the model for $s_{ij,t} - s_{ij,t-1}$ is "internally consistent" – that is the model for $s_{ij,t} - s_{ij,t-1}$ is consistent with the model we would get by taking the equation of $s_{ik,t} - s_{ik,t-1}$ and subtracting off the equation for $s_{kj,t} - s_{kj,t-1}$, for $i \neq j \neq k$. In checking for internal consistency, we will ask if the model is "internally consistent if the restrictions are true". The most unrestricted model is internally consistent, as we will show.

All models we consider have fixed effects – that is, exchange-rate specific intercepts.

Relative Variables only

First take the case where all variables are expressed in terms of country *i* relative to country *j*. In this section, assume that this is not a restriction – that the data do not allow for country-specific terms, only relative terms, so that the "unrestricted" Model C can be understood to be unrestricted when the data are only in relative form. It is clearer to consider this case first, before allowing country-specific variables.

Model A

The most restricted case is the baseline model in equation (1). Our findings for this model are reported in Table 2A for the $\tilde{\eta}_t$ measure, and in Table 2F for the $\hat{\eta}_t$ measure. If the restrictions are true, the model is internally consistent. To see this, we can write the model for $s_{ik,t} - s_{ik,t-1}$

$$(2) \qquad \begin{aligned} s_{ik,t} - s_{ik,t-1} = {} & \beta_{ik,0} + \beta_{i1} q_{ik,t-1} + \beta_{i2}\left(\eta_{ik,t} - \eta_{ik,t-1}\right) + \beta_{i3}\left(i_{i,t} - i_{k,t} - \left(i_{i,t-1} - i_{k,t-1}\right)\right) \\ & + \beta_{i4}\eta_{ik,t-1} + \beta_{i5}\left(i_{i,t-1} - i_{k,t-1}\right) + z_{ik,t} \end{aligned}$$

Then, if both (1) and (2) are true, subtracting the former from the latter, we get a model for $s_{jk,t} - s_{jk,t-1}$, where we use the fact that $q_{jk,t} = q_{ik,t-1} - q_{ij,t-1}$, $\eta_{jk,t} = \eta_{ik,t} - \eta_{ij,t}$, and $i_{j,t} - i_{k,t} = i_{i,t} - i_{k,t} - \left(i_{i,t} - i_{j,t}\right)$:

$$
\text{(3)} \quad \begin{aligned} s_{jk,t} - s_{jk,t-1} = \beta_{jk,0} + \beta_{i1} q_{jk,t-1} + \beta_{i2}\left(\eta_{jk,t} - \eta_{jk,t-1}\right) + \beta_{i3}\left(i_{j,t} - i_{k,t} - \left(i_{j,t-1} - i_{k,t-1}\right)\right) \\ + \beta_{i4}\eta_{jk,t-1} + \beta_{i5}\left(i_{j,t-1} - i_{k,t-1}\right) + z_{jk,t} \end{aligned}
$$

where $\beta_{jk,0} = \beta_{ik,0} - \beta_{ij,0}$, and $z_{jk,t} = z_{ik,t} - z_{ij,t}$. Clearly this equation is of the same form as (1) and (2). The exchange rate for *jk* depends only on relative *jk* variables.

In fact, we can see that the slope coefficients, β_{i1}, β_{i2}, β_{i3}, β_{i4}, and β_{i5}, are the same as in equations (1) and (2). Since equation (3) is for currency *j*, not currency *i*, but the slope coefficients are the same, we can drop the *i* subscript on them. We can call them β_1, β_2, β_3, β_4, and β_5.

That is, if the cross-equation restrictions for the $s_{ij,t} - s_{ij,t-1}$ and $s_{ik,t} - s_{ik,t-1}$ equations are true, then the model is internally consistent. And, if we estimated the model as a panel for currency *j* instead of for currency *i*, we would get the same slope coefficients.

Concretely, if currency *i* is the AUD, currency *j* is CAD, and currency *k* is EUR, then we can estimate β_1, β_2, β_3, β_4, and β_5 for the panel in which AUD is the base currency. But if CAD or EUR were the base currency, we would find the same parameters β_1, β_2, β_3, β_4, and β_5.

We clearly do not find that to be true in the data, because we report different values for these slope parameters for the panels with each currency as the base. However, the fact that the estimated β_1, β_2, β_3, β_4, and β_5 are not the same across the different panel estimates does not invalidate the hypothesis that the cross-equation restrictions are valid, because there is estimation error in finite samples. Below we test the restriction (Model A vs. Model B.)

Model A is internally consistent if the restrictions are true.

There are 14 parameters to estimate: five slope parameters (β_1, β_2, β_3, β_4, and β_5), and nine intercept parameters in each panel. Even if the restrictions are true, we will find numerically different estimates for the slope parameters in each panel (and $\beta_{jk,0} = \beta_{ik,0} - \beta_{ij,0}$ will not be true also), because of finite samples.

Model B

Now we modify equations (1) and (2) so we do not impose the cross-equation restrictions (but still impose the exclusion restrictions.)

$$
\begin{aligned}
s_{ij,t} - s_{ij,t-1} = {} & \beta_{ij,0} + \beta_{ij,1} q_{ij,t-1} + \beta_{ij,2}\left(\eta_{ij,t} - \eta_{ij,t-1}\right) + \beta_{ij,3}\left(i_{i,t} - i_{j,t} - \left(i_{i,t-1} - i_{j,t-1}\right)\right) \\
& + \beta_{ij,4}\eta_{ij,t-1} + \beta_{ij,5}\left(i_{i,t-1} - i_{j,t-1}\right) + z_{ij,t}
\end{aligned} \tag{4}
$$

$$
\begin{aligned}
s_{ik,t} - s_{ik,t-1} = {} & \beta_{ik,0} + \beta_{ik,1} q_{ik,t-1} + \beta_{ik,2}\left(\eta_{ik,t} - \eta_{ik,t-1}\right) + \beta_{ik,3}\left(i_{i,t} - i_{k,t} - \left(i_{i,t-1} - i_{k,t-1}\right)\right) \\
& + \beta_{ik,4}\eta_{ik,t-1} + \beta_{ik,5}\left(i_{i,t-1} - i_{k,t-1}\right) + z_{ik,t}
\end{aligned} \tag{5}
$$

This model is not internally consistent. If we take the model for $s_{jk,t} - s_{jk,t-1}$ by subtracting (4) from (5) – so that the model for $s_{jk,t} - s_{jk,t-1}$ is equal to the model for $s_{ik,t} - s_{ik,t-1}$ minus that for $s_{ik,t} - s_{ik,t-1}$ – we do not get a model that depends only on *jk* variables. The exclusion restrictions would not hold for $s_{jk,t} - s_{jk,t-1}$.

If, for example, we estimate the model with AUD as a base, and s_{ij} is the AUD/CAD exchange rate and s_{ik} is the AUD/EUR exchange rate, we can infer a model for s_{jk}, the CAD/EUR exchange rate by subtracting (4) from (5). But that model for the CAD/EUR exchange rate would depend separately on the AUD/CAD real exchange rate and the AUD/EUR real exchange rate, not just the CAD/EUR exchange rate. But if we estimated a panel with CAD as a base, and only used *jk* variables in the *jk* regression, the CAD/EUR exchange rate would depend only on the CAD/EUR real exchange rate (and other CAD/EUR variables.)

The panel regression for currency i as represented in equations (4) from (5) has 54 parameters to estimate – an intercept and five slope coefficients for each *ij* exchange rate, and there are 9 exchange rates, so $9\times 6=54$. Each panel should give us 54 different parameter estimates.

Since there are no cross-equation restrictions, this model is essentially identical to the equation-by-equation estimates reported in Table 5B.

<u>Model C</u>

In this model, we have no exclusion restrictions. The *ij* exchange rate depends on all variables, including all *ik* variables:

(6)
$$\begin{aligned} s_{ij,t}-s_{ij,t-1} &= \beta_{ij,0}+\sum_{\substack{k=1\\k\neq i}}^{N}\beta_{ij,k,1}q_{ik,t-1}+\sum_{\substack{k=1\\k\neq i}}^{N}\beta_{ij,k,2}\left(\eta_{ik,t}-\eta_{ik,t-1}\right)+\sum_{\substack{k=1\\k\neq i}}^{N}\beta_{ij,k,3}\left(i_{i,t}-i_{k,t}-\left(i_{i,t-1}-i_{k,t-1}\right)\right) \\ &\sum_{\substack{k=1\\k\neq i}}^{N}\beta_{ij,k,4}\eta_{ik,t-1}+\sum_{\substack{k=1\\k\neq i}}^{N}\beta_{ij,k,5}\left(\left(i_{i,t-1}-i_{k,t-1}\right)\right)+z_{ij,t} \end{aligned}$$

In this equation, there are 45 explanatory variables, plus an intercept variable, for the exchange rate $s_{ij,t}-s_{ij,t-1}$.

For exchange rate $s_{im,t}-s_{im,t-1}$, we have:

(7)
$$\begin{aligned} s_{im,t}-s_{im,t-1} &= \beta_{im,0}+\sum_{\substack{k=1\\k\neq i}}^{N}\beta_{im,k,1}q_{ik,t-1}+\sum_{\substack{k=1\\k\neq i}}^{N}\beta_{im,k,2}\left(\eta_{ik,t}-\eta_{ik,t-1}\right)+\sum_{\substack{k=1\\k\neq i}}^{N}\beta_{im,k,3}\left(i_{i,t}-i_{k,t}-\left(i_{i,t-1}-i_{k,t-1}\right)\right) \\ &\sum_{\substack{k=1\\k\neq i}}^{N}\beta_{im,k,4}\eta_{ik,t-1}+\sum_{\substack{k=1\\k\neq i}}^{N}\beta_{im,k,5}\left(\left(i_{i,t-1}-i_{k,t-1}\right)\right)+z_{im,t} \end{aligned}$$

This equation has another 46 parameters. The entire panel for currency *i* has $9 \times 46 = 414$ parameters.

This formulation is internally consistent. We can take the equation for $s_{jm,t} - s_{jm,t-1}$ from this panel by subtracting (6) from (7), or we could estimate an equation for $s_{jm,t} - s_{jm,t-1}$ from a panel for currency *j*, and they would both involve the same 45 explanatory variables with no cross-equation restrictions.

<u>Country-Specific Variables</u>

We can allow country-specific, rather than relative variables, to replace $\hat{\eta}_{ij,t} = IRS_{it} - IRS_{j,t} + i_{j,t} - i_{i,t}$ with $IRS_{i,t} - i_{i,t}$ and $IRS_{j,t} - i_{j,t}$, or $i_{i,t} - i_{j,t} - \left(i_{i,t-1} - i_{j,t-1}\right)$ with $i_{i,t} - i_{i,t-1}$ and $i_{j,t} - i_{j,t-1}$. We are most interested in whether the individual convenience yields matter, rather than their relative values, as we have already allowed in some specifications. To keep the analysis a bit simpler, we will only consider $i_{i,t} - i_{j,t} - \left(i_{i,t-1} - i_{j,t-1}\right)$ in relative form, instead of splitting it into $i_{i,t} - i_{i,t-1}$ and $i_{j,t} - i_{j,t-1}$. Define $\gamma_{i,t} \equiv IRS_{i,t} - i_{i,t}$

<u>Model D</u>

This is the most restricted form of this class of models. We report estimates from this model in Table 5A. We only include variables for country *i* and country *j* in the regression for $s_{ij,t} - s_{ij,t-1}$, and for the panel for currency *i*, we impose cross-equation restrictions on the parameters. We have:

$$(8) \quad \begin{aligned} s_{ij,t} - s_{ij,t-1} = {} & \beta_{ij,0} + \beta_{i1} q_{ij,t-1} + \beta_{i2}\left(\gamma_{i,t} - \gamma_{i,t-1}\right) + \beta_{i3}\left(\gamma_{j,t} - \gamma_{j,t-1}\right) + \beta_{i4}\left(i_{i,t} - i_{j,t} - \left(i_{i,t-1} - i_{j,t-1}\right)\right) \\ & + \beta_{i5}\gamma_{i,t-1} + \beta_{i6}\gamma_{j,t-1} + \beta_{i7}\left(i_{i,t-1} - i_{j,t-1}\right) + z_{ij,t} \end{aligned}$$

The equation for $s_{ik,t} - s_{ik,t-1}$ is

(9) $$\begin{aligned} s_{ik,t}-s_{ik,t-1} &= \beta_{ik,0}+\beta_{i1}q_{ik,t-1}+\beta_{i2}\left(\gamma_{i,t}-\gamma_{i,t-1}\right)+\beta_{i3}\left(\gamma_{k,t}-\gamma_{k,t-1}\right)+\beta_{i4}\left(i_{i,t}-i_{k,t}-\left(i_{i,t-1}-i_{k,t-1}\right)\right) \\ &+\beta_{i5}\gamma_{i,t-1}+\beta_{i6}\gamma_{k,t-1}+\beta_{i7}\left(i_{i,t-1}-i_{k,t-1}\right)+z_{ik,t} \end{aligned}$$

Unlike the simplest case (Model A) when only relative variables are present, this model is not internally consistent. If we subtract equation (8) from equation (9) to get a model for $s_{jk,t}-s_{jk,t-1}$, the equation would become:

$$\begin{aligned} s_{ik,t}-s_{ik,t-1} &= \beta_{jk,0}+\beta_{i1}q_{jk,t-1}+\beta_{i3}\left[\left(\gamma_{k,t}-\gamma_{k,t-1}\right)-\left(\gamma_{j,t}-\gamma_{j,t-1}\right)\right]+\beta_{i4}\left(i_{ji,t}-i_{k,t}-\left(i_{j,t-1}-i_{k,t-1}\right)\right) \\ &+\beta_{i6}\left(\gamma_{k,t-1}-\gamma_{i,t-1}\right)+\beta_{i7}\left(i_{i,t-1}-i_{k,t-1}\right)+z_{ik,t} \end{aligned},$$

but the internally consistent equation, which we would get from a panel in which *j* is the base currency, is:

$$\begin{aligned} s_{jk,t}-s_{jk,t-1} &= \beta_{jk,0}+\beta_{j1}q_{jk,t-1}+\beta_{j2}\left(\gamma_{j,t}-\gamma_{j,t-1}\right)+\beta_{j3}\left(\gamma_{k,t}-\gamma_{k,t-1}\right)+\beta_{j4}\left(i_{j,t}-i_{k,t}-\left(i_{j,t-1}-i_{k,t-1}\right)\right) \\ &+\beta_{j5}\gamma_{j,t-1}+\beta_{j6}\gamma_{k,t-1}+\beta_{j7}\left(i_{j,t-1}-i_{k,t-1}\right)+z_{ik,t} \end{aligned}$$

The structures of these last two equations are different, so Model D is not internally consistent. For each currency used as the base currency, the panel involves estimating 7 slope parameters, and 9 intercepts, for a total of 16 parameters.

<u>Model E</u>

This model imposes cross-equation restrictions on the parameters of the relative variables, but not on the country-specific variables for country *j* in the regression for the *ij* exchange rate. It continues to assume the zero restrictions that only variables for country *i* and country *j* in the regression for $s_{ij,t}-s_{ij,t-1}$. It is internally consistent, if the restrictions are true.

(10) $$\begin{aligned} s_{ij,t}-s_{ij,t-1} &= \beta_{ij,0}+\beta_{i1}q_{ij,t-1}+\beta_{i2}\left(\gamma_{i,t}-\gamma_{i,t-1}\right)+\beta_{j3}\left(\gamma_{j,t}-\gamma_{j,t-1}\right)+\beta_{i4}\left(i_{i,t}-i_{j,t}-\left(i_{i,t-1}-i_{j,t-1}\right)\right) \\ &+\beta_{i5}\gamma_{i,t-1}+\beta_{j6}\gamma_{j,t-1}+\beta_{i7}\left(i_{i,t-1}-i_{j,t-1}\right)+z_{ij,t} \end{aligned}$$

Then for $s_{ik,t}-s_{ik,t-1}$, we have:

(11)
$$s_{ik,t} - s_{ik,t-1} = \beta_{ik,0} + \beta_{i1} q_{ik,t-1} + \beta_{i2}\left(\gamma_{i,t} - \gamma_{i,t-1}\right) + \beta_{k3}\left(\gamma_{k,t} - \gamma_{k,t-1}\right) + \beta_{i4}\left(i_{i,t} - i_{k,t} - \left(i_{i,t-1} - i_{k,t-1}\right)\right)$$
$$+\beta_{i5}\gamma_{i,t-1} + \beta_{k6}\gamma_{k,t-1} + \beta_{i7}\left(i_{i,t-1} - i_{k,t-1}\right) + z_{ik,t}$$

If we subtract equation (10) from equation (11) to get a model for $s_{jk,t} - s_{jk,t-1}$, the equation would become:

(12)
$$s_{jk,t} - s_{jk,t-1} = \tilde{\beta}_{jk,0} + \tilde{\beta}_{j1} q_{jk,t-1} + \tilde{\beta}_{j2}\left(\gamma_{j,t} - \gamma_{j,t-1}\right) + \tilde{\beta}_{k3}\left(\gamma_{k,t} - \gamma_{k,t-1}\right) + \tilde{\beta}_{j4}\left(i_{j,t} - i_{k,t} - \left(i_{j,t-1} - i_{k,t-1}\right)\right)$$
$$+\tilde{\beta}_{j5}\gamma_{j,t-1} + \tilde{\beta}_{k6}\gamma_{k,t-1} + \tilde{\beta}_{j7}\left(i_{j,t-1} - i_{k,t-1}\right) + z_{jk,t}$$

where $\tilde{\beta}_{jk,0} = \beta_{ik,0} - \beta_{ij,0}$, $\tilde{\beta}_{j1} = \beta_{i1}$. $\tilde{\beta}_{j2} = -\beta_{j3}$, $\tilde{\beta}_{k3} = \beta_{k3}$, $\tilde{\beta}_{j4} = \beta_{i4}$, $\tilde{\beta}_{j5} = -\beta_{j6}$, $\tilde{\beta}_{k6} = \beta_{k6}$, and $\tilde{\beta}_{j7} = \beta_{i7}$.

If the restricted Model E was true, then if equation (12) were estimated from a panel with currency *j* as the base currency, the estimated parameters would satisfy the parameter relationships from the panel with *i* as a base currency in an infinitely large sample (but not in a finite sample.)

That is, Model E is internally consistent if the restrictions are true. For each panel, there are 32 parameters to estimate. There are 9 intercept terms, 3 coefficients on the relative variables ($q_{ij,t-1}$, $i_{i,t} - i_{j,t} - \left(i_{i,t-1} - i_{j,t-1}\right)$, and $i_{i,t-1} - i_{j,t-1}$, 10 coefficients on the $\gamma_{j,t} - \gamma_{j,t-1}$, and 10 coefficients on the $\gamma_{j,t-1}$ variables.

<u>Model F</u>

This model puts on no cross-equation restrictions, but it imposes the zero restrictions (that only variables for country *i* and country *j* in the regression for $s_{ij,t} - s_{ij,t-1}$). It is not internally consistent, for the same reasons that Model B is not:

$$s_{ij,t} - s_{ij,t-1} = \beta_{ij,0} + \beta_{ij,1} q_{ij,t-1} + \beta_{ij,2}\left(\gamma_{i,t} - \gamma_{i,t-1}\right) + \beta_{ij,3}\left(\gamma_{j,t} - \gamma_{j,t-1}\right) + \beta_{ij,4}\left(i_{i,t} - i_{j,t} - \left(i_{i,t-1} - i_{j,t-1}\right)\right)$$
$$+\beta_{ij,5}\gamma_{i,t-1} + \beta_{ij,6}\gamma_{j,t-1} + \beta_{ij,7}\left(i_{i,t-1} - i_{j,t-1}\right) + z_{ij,t}$$

This equation has 8 parameters to estimate (1 intercept and 7 slope coefficients.) The panel has 9 exchange rates, so the panel entails estimation of $9 \times 8 = 72$ parameters.

Model G

Model G has no cross-equation constraints, and no zero constraints, and is therefore internally consistent:

$$s_{ij,t} - s_{ij,t-1} = \beta_{ij,0} + \sum_{\substack{k=1 \\ k \neq i}}^{N} \beta_{ij,k,1} q_{ik,t-1} + \sum_{k=1}^{N} \beta_{ij,k,2} \left(\gamma_{k,t} - \gamma_{k,t-1} \right) + \sum_{\substack{k=1 \\ k \neq i}}^{N} \beta_{ij,k,3} \left(i_{i,t} - i_{k,t} - \left(i_{i,t-1} - i_{k,t-1} \right) \right)$$
$$\sum_{k=1}^{N} \beta_{ij,k,4} \gamma_{k,t-1} + \sum_{\substack{k=1 \\ k \neq i}}^{N} \beta_{ij,k,5} \left(\left(i_{i,t-1} - i_{k,t-1} \right) \right) + z_{ij,t}$$

This equation has 1 intercept, 9 coefficients on each of the three relative variables ($q_{ik,t-1}$, $i_{i,t} - i_{k,t} - \left(i_{i,t-1} - i_{k,t-1} \right)$, and $i_{i,t-1} - i_{k,t-1}$), and 10 coefficients each on $\gamma_{k,t} - \gamma_{k,t-1}$ and $\gamma_{k,t-1}$, for a total of 48. Since there are 9 exchange rates in each panel, there are $9 \times 48 = 432$ parameters.

The possible nested tests (with number of parameters in each model in parentheses) are:

Model A (14) is nested in Models B (54), C (414), D (16), E (32), F (72), G (432)

Model B (54) is nested in Models C (414), F (72) and G (432).

Model C (414) is nested in Model G (432).

Model D (16) is nested in Models E (32), F (72). G (432)

Model E (32) is nested in Models F (72), G (432)

Model F (72) is nested in Model G (432).

So there are 16 possible F-tests, with each of the ten currencies serving as a base currency.

These are the p-values for those tests:

P value of the F tests

Test	constraints	AUD	CAD	EUR	JPY	NZD	NOK	SEK	CHF	GBP	USD
A vs B	40	0.000	0.004	0.000	0.000	0.071	0.138	0.000	0.018	0.139	0.059
A vs C	400	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
A vs D	2	0.014	0.156	0.006	0.045	0.000	0.000	0.169	0.122	0.100	0.000
A vs E	18	0.003	0.006	0.005	0.011	0.000	0.001	0.022	0.011	0.017	0.000
A vs F	58	0.000	0.014	0.000	0.000	0.000	0.005	0.000	0.008	0.108	0.004
A vs G	418	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
B vs C	360	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
B vs F	18	0.027	0.526	0.069	0.562	0.000	0.003	0.173	0.102	0.238	0.007
B vs G	378	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
C vs G	18	0.039	0.001	0.003	0.720	0.075	0.067	0.029	0.000	0.834	0.103
D vs E	16	0.121	0.008	0.023	0.017	0.260	0.058	0.032	0.039	0.046	0.011
D vs F	56	0.000	0.017	0.000	0.000	0.136	0.066	0.000	0.020	0.186	0.229
D vs G	416	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
E vs F	40	0.000	0.177	0.000	0.001	0.167	0.206	0.001	0.088	0.526	0.809
E vs G	400	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
F vs G	360	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

We generally reject the more restrictive models in favor of the less restrictive models. In the text, we have reported estimation results only for models A (Tables 2A and 2F), B (Table 5B), and D (Table 5A). There is a tradeoff. Our baseline model is more parsimonious; however, it is not internally consistent. There is always a tradeoff between the econometric gains in power by having a more parsimonious model, versus the distortions that arise when imposing restrictions that are not true. When we consider that we know we do not really have the “true” model (for example, the *ij* exchange rate may not depend just on *i* and *j* variables, or they may be other left-out variables), than the consistency criterion might not be a good one in practice.

As the following table shows, the relative liquidity yields remain highly significant in the more highly parameterized models, B, E and F, even though there are many more parameters estimated in these models. (We did not test for individual significance of coefficients for Models C and G, which have 414 and 432 parameters in each panel.)

Liquidity measure ($\Delta\hat{\eta}_{j,t}$) is significant at (cumulative):	Model B	Model E		Model F
	Total pair: 45	Home: 9	Foreign: 90	Total pair: 90
10%	35	8	62	56
5%	30	8	59	50
1%	25	7	49	43

Bibliography

Adrian, T., Etula, E., and Shin, H. S. (2010). Risk appetite and exchange rates. *FRB of New York Staff Report*, (361).

Aghion, P., Bacchetta, P., and Banerjee, A. (2001). Currency crises and monetary policy in an economy with credit constraints. *European economic review*, 45(7):1121–1150.

Aguiar, M. and Amador, M. (2013). Take the short route: How to repay and restructure sovereign debt with multiple maturities. Technical report, National Bureau of Economic Research.

Aguiar, M., Chatterjee, S., Cole, H., and Stangebye, Z. (2016). Quantitative models of sovereign debt crises. In *Handbook of Macroeconomics*, volume 2, pages 1697–1755. Elsevier.

Aguiar, M. and Gopinath, G. (2006). Defaultable debt, interest rates and the current account. *Journal of international Economics*, 69(1):64–83.

Akinci, O. and Queralto, A. (2018). Exchange rate dynamics and monetary spillovers with imperfect financial markets. *FRB of New York Staff Report*, (849).

Alfaro, L., Asis, G., Chari, A., and Panizza, U. (2019). Corporate debt, firm size and financial fragility in emerging markets. *Journal of International Economics*, 118:1–19.

Alter, A. and Elekdag, S. (2017). *Emerging market corporate leverage and global financial conditions*. International Monetary Fund.

Aoki, K., Benigno, G., and Kiyotaki, N. (2016). Monetary and financial policies in emerging markets. *Unpublished paper, London School of Economics.[652].*

Arce, F., Bengui, J., and Bianchi, J. (2019). A macroprudential theory of foreign reserve accumulation. Technical report, National Bureau of Economic Research.

Arellano, C. (2008). Default risk and income fluctuations in emerging economies. *American Economic Review*, 98(3):690–712.

Arellano, C., Bai, Y., and Bocola, L. (2017). Sovereign default risk and firm heterogeneity. Technical report, National Bureau of Economic Research.

Arellano, C., Bai, Y., and Mihalache, G. (2018). Inflation targeting with sovereign default risk.

Arellano, C. and Ramanarayanan, A. (2012). Default and the maturity structure in sovereign bonds. *Journal of Political Economy*, 120(2):187–232.

Arslanalp, M. S. and Tsuda, M. T. (2014). *Tracking global demand for emerging market sovereign debt*. Number 14-39. International Monetary Fund.

Asonuma, T. (2016). *Sovereign defaults, external debt, and real exchange rate dynamics*. International Monetary Fund.

Avdjiev, S., Du, W., Koch, C., and Shin, H. S. (2019). The dollar, bank leverage, and deviations from covered interest parity. *American Economic Review: Insights*, 1(2):193–208.

Baba, N. and Packer, F. (2009). Interpreting deviations from covered interest parity during the financial market turmoil of 2007–08. *Journal of Banking & Finance*, 33(11):1953–1962.

Baba, N., Packer, F., and Nagano, T. (2008). The spillover of money market turbulence to fx swap and cross-currency swap markets. *BIS Quarterly Review, March*.

Backus, D. K. and Kehoe, P. J. (1989). On the denomination of government debt: a critique of the portfolio balance approach. *Journal of Monetary Economics*, 23(3):359–376.

Bai, Y. and Zhang, J. (2012). Financial integration and international risk sharing. *Journal of International Economics*, 86(1):17–32.

Banerjee, R., Devereux, M. B., and Lombardo, G. (2016). Self-oriented monetary policy, global financial markets and excess volatility of international capital flows. *Journal of International Money and Finance*, 68:275–297.

Banerjee, R. N., Hofmann, B., and Mehrotra, A. (2020). Corporate investment and the exchange rate: The financial channel. *BIS working papers No 839*.

Banti, C., Phylaktis, K., and Sarno, L. (2012). Global liquidity risk in the foreign exchange market. *Journal of International Money and Finance*, 31(2):267–291.

Benigno, G. (2004). Real exchange rate persistence and monetary policy rules. *Journal of Monetary Economics*, 51(3):473–502.

Bernanke, B. S., Gertler, M., and Gilchrist, S. (1999). The financial accelerator in a quantitative business cycle framework. *Handbook of macroeconomics*, 1:1341–1393.

Beveridge, S. and Nelson, C. R. (1981). A new approach to decomposition of economic time series into permanent and transitory components with particular attention to measurement of the âbusiness cycleâ. *Journal of Monetary economics*, 7(2):151–174.

Bevilaqua, J., Hale, G., and Tallman, E. (2019). *Corporate Spreads, Sovereign Spreads, and Crises*. Elsevier, Journal of International Economics.

Bianchi, J. (2011). Overborrowing and systemic externalities in the business cycle. *American Economic Review*, 101(7):3400–3426.

Bianchi, J., Hatchondo, J. C., and Martinez, L. (2018). International reserves and rollover risk. *American Economic Review*, 108(9):2629–70.

BIS (2019). Monetary policy frameworks in emes: inflation targeting, the exchange rate and financial stability. *Annual Economic Report, Chapter 2*.

Bocola, L. (2016). The pass-through of sovereign risk. *Journal of Political Economy*, 124(4):879–926.

Borri, N. and Verdelhan, A. (2011). Sovereign risk premia. In *Working paper della American Finance Association annual meeting*.

Bräuning, F. and Ivashina, V. (2019). Us monetary policy and emerging market credit cycles. *Journal of Monetary Economics*.

Broner, F. A., Lorenzoni, G., and Schmukler, S. L. (2013). Why do emerging economies borrow short term? *Journal of the European Economic Association*, 11(suppl_1):67–100.

Brunnermeier, M. K. and Pedersen, L. H. (2009). Market liquidity and funding liquidity. *The review of financial studies*, 22(6):2201–2238.

Bruno, V. and Shin, H. S. (2014). Cross-border banking and global liquidity*. *The Review of Economic Studies*, page rdu042.

Bruno, V. and Shin, H. S. (2015). Capital flows and the risk-taking channel of monetary policy. *Journal of Monetary Economics*, 71:119–132.

Bruno, V. and Shin, H. S. (2017). Global dollar credit and carry trades: a firm-level analysis. *The Review of Financial Studies*, 30(3):703–749.

Bruno, V. and Shin, H. S. (2019). Dollar exchange rate as a credit supply factor–evidence from firm-level exports.

Burger, J. D., Warnock, F. E., and Warnock, V. C. (2012). Emerging local currency bond markets. *Financial Analysts Journal*, 68(4):73–93.

Burnside, C., Eichenbaum, M., Kleshchelski, I., and Rebelo, S. (2011). Do peso problems explain the returns to the carry trade? *The Review of Financial Studies*, 24(3):853–891.

Caballero, R. J., Farhi, E., and Gourinchas, P.-O. (2008). An equilibrium model of" global imbalances" and low interest rates. *American economic review*, 98(1):358–93.

Caballero, R. J., Farhi, E., and Gourinchas, P.-O. (2016). Global imbalances and currency wars at the zlb. Technical report, National Bureau of Economic Research.

Caballero, R. J., Farhi, E., and Gourinchas, P.-O. (2017). The safe assets shortage conundrum. *Journal of Economic Perspectives*, 31(3):29–46.

Calvo, G. A. (1983). Staggered prices in a utility-maximizing framework. *Journal of Monetary Economics*, 12(3):383–398.

Calvo, G. A. and Reinhart, C. M. (2000). Fear of floating. Technical report, National Bureau of Economic Research.

Campbell, J. Y. and Clarida, R. H. (1987). The dollar and real interest rates. In *Carnegie-Rochester Conference Series on Public Policy*, volume 27, pages 103–139. Elsevier.

Carstens, A. and Shin, H. S. (2019). Emerging markets aren't out of the woods yet. *Foreign Affairs Magazine*, March.

Cavallino, P. (2019). Capital flows and foreign exchange intervention. *American Economic Journal: Macroeconomics*, 11(2):127–70.

Cavallino, P. and Patel, N. (2019). Fx intervention: goals, strategies and tactics. *BIS Paper*, (104b).

Cerutti, E. M., Obstfeld, M., and Zhou, H. (2019). Covered interest parity deviations: Macrofinancial determinants. Technical report, National Bureau of Economic Research.

Céspedes, L. F., Chang, R., and Velasco, A. (2004). Balance sheets and exchange rate policy. *American Economic Review*, 94(4):1183–1193.

Chang, R. (2018). Foreign exchange intervention redux. Technical report, National Bureau of Economic Research.

Chang, R., Fernández, A., and Gulan, A. (2017). Bond finance, bank credit, and aggregate fluctuations in an open economy. *Journal of Monetary Economics*, 85:90–109.

Chang, R. and Velasco, A. (2017). Financial frictions and unconventional monetary policy in emerging economies. *IMF Economic Review*, 65(1):154–191.

Chui, M. K., Kuruc, E., and Turner, P. (2016). A new dimension to currency mismatches in the emerging markets-non-financial companies.

Clark, T. E. and West, K. D. (2006). Using out-of-sample mean squared prediction errors to test the martingale difference hypothesis. *Journal of econometrics*, 135(1-2):155–186.

Cook, D. (2004). Monetary policy in emerging markets: Can liability dollarization explain contractionary devaluations? *Journal of Monetary Economics*, 51(6):1155–1181.

Degryse, H., De Jonghe, O., Jakovljević, S., Mulier, K., and Schepens, G. (2019). Identifying credit supply shocks with bank-firm data: Methods and applications. *Journal of Financial Intermediation*.

Del Negro, M., Giannone, D., Giannoni, M. P., and Tambalotti, A. (2019). Global trends in interest rates. *Journal of International Economics*, 118:248–262.

Della Corte, P., Sarno, L., Schmeling, M., and Wagner, C. (2018). Exchange rates and sovereign risk. *Available at SSRN 2354935*.

Devereux, M. B. and Engel, C. (2002). Exchange rate pass-through, exchange rate volatility, and exchange rate disconnect. *Journal of Monetary economics*, 49(5):913–940.

Devereux, M. B. and Yetman, J. (2014). Globalisation, pass-through and the optimal policy response to exchange rates. *Journal of International Money and Finance*, 49:104–128.

Diamond, D. W., Hu, Y., and Rajan, R. G. (2020). The spillovers from easy liquidity and the implications for multilateralism. *IMF Economic Review*, 68(1):4–34.

Diebold, F. and Mariano, R. (1995). Comparing predictive accuracy. *Journal of Business & Economic Statistics*, 13(3):253–63.

Dooley, M. P. and Isard, P. (1985). The appreciation of the dollar: An analysis of the safe haven phenomenon. Technical report, International Monetary Fund Working paper.

Dornbusch, R. (1976). Expectations and exchange rate dynamics. *Journal of political Economy*, 84(6):1161–1176.

Dornbusch, R. (1986). Flexible exchange rates and excess capital mobility. *Brookings Papers on Economic Activity*, 1986(1):209–226.

Driscoll, J. C. and Kraay, A. C. (1998). Consistent covariance matrix estimation with spatially dependent panel data. *Review of economics and statistics*, 80(4):549–560.

Du, W., Im, J., and Schreger, J. (2018a). The us treasury premium. *Journal of International Economics*, 112:167–181.

Du, W., Pflueger, C. E., and Schreger, J. (2016). Sovereign debt portfolios, bond risks, and the credibility of monetary policy. Technical report, National Bureau of Economic Research.

Du, W. and Schreger, J. (2017). Sovereign risk, currency risk, and corporate balance sheets.

Du, W., Tepper, A., and Verdelhan, A. (2018b). Deviations from covered interest rate parity. *The Journal of Finance*, 73(3):915–957.

Eaton, J. and Gersovitz, M. (1981). Debt with potential repudiation: Theoretical and empirical analysis. *The Review of Economic Studies*, 48(2):289–309.

Eichenbaum, M., Johannsen, B. K., and Rebelo, S. (2017). Monetary policy and the predictability of nominal exchange rates. Technical report, National Bureau of Economic Research.

Eichengreen, B. and Hausmann, R. (1999). Exchange rates and financial fragility. Technical report, National bureau of economic research.

Eichengreen, B., Hausmann, R., and Panizza, U. (2005). The pain of original sin. *Other people's money: Debt denomination and financial instability in emerging market economies*, pages 13–47.

Eichengreen, B. J., Hausmann, R., and Panizza, U. (2002). Original sin: the pain, the mystery, and the road to redemption. Technical report, [sn].

Engel, C. (1992). The risk premium and the liquidity premium in foreign exchange markets. *International Economic Review*, pages 871–879.

Engel, C. (2014). Exchange rates and interest parity. In *Handbook of international economics*, volume 4, pages 453–522. Elsevier.

Engel, C. (2016). Exchange rates, interest rates, and the risk premium. *American Economic Review*, 106(2):436–74.

Engel, C. (2019). Real exchange rate convergence: The roles of price stickiness and monetary policy. *Journal of Monetary Economics*, 103:21–32.

Engel, C. and Park, J. (2018). Debauchery and original sin: The currency composition of sovereign debt. *NBER Working Paper*, (w24671).

Engel, C. and Wu, S. P. Y. (2018). Liquidity and exchange rates: An empirical investigation. Working Paper 25397, National Bureau of Economic Research.

Farhi, E. and Gabaix, X. (2016). Rare disasters and exchange rates. *The Quarterly Journal of Economics*, 131(1):1–52.

Farhi, E. and Maggiori, M. (2018). A model of the international monetary system. *The Quarterly Journal of Economics*, 133(1):295–355.

Fatum, R. and Yamamoto, Y. (2016). Intra-safe haven currency behavior during the global financial crisis. *Journal of International Money and Finance*, 66:49–64.

Forbes, K. (2012). The "big c": identifying and mitigating contagion. In *Proceedings-Economic Policy Symposium-Jackson Hole*, pages 23–87. Federal Reserve Bank of Kansas City.

Frenkel, J. A. (1976). A monetary approach to the exchange rate: doctrinal aspects and empirical evidence. *The scandinavian Journal of economics*, pages 200–224.

Gabaix, X. and Maggiori, M. (2015). International liquidity and exchange rate dynamics. *The Quarterly Journal of Economics*, 130(3):1369–1420.

Gertler, M. and Karadi, P. (2011). A model of unconventional monetary policy. *Journal of monetary Economics*, 58(1):17–34.

Gertler, M. and Karadi, P. (2015). Monetary policy surprises, credit costs, and economic activity. *American Economic Journal: Macroeconomics*, 7(1):44–76.

Gertler, M., Kiyotaki, N., et al. (2010). Financial intermediation and credit policy in business cycle analysis. *Handbook of monetary economics*, 3(3):547–599.

Gordon, G. and Guerron-Quintana, P. A. (2018). Dynamics of investment, debt, and default. *Review of Economic Dynamics*, 28:71–95.

Gorton, G. (2017). The history and economics of safe assets. *Annual Review of Economics*, 9:547–586.

Gourinchas, P.-O. (2012). Global imbalances and global liquidity.

Gourinchas, P.-O. (2018). Monetary policy transmission in emerging markets: An application to chile. *Series on Central Banking Analysis and Economic Policies no. 25*.

Gourinchas, P.-O. and Jeanne, O. (2012). Global safe assets.

Grilli, V. and Roubini, N. (1992). Liquidity and exchange rates. *Journal of International Economics*, 32(3-4):339–352.

Hale, G. B., Jones, P. C., and Spiegel, M. M. (2020). Home currency issuance in international bond markets. *Journal of International Economics*, 122:103256.

Hardy, B. and Saffie, F. (2019). From carry trades to trade credit: Financial intermediation by nonfinancial corporations.

Hassan, T. A. (2013). Country size, currency unions, and international asset returns. *The Journal of Finance*, 68(6):2269–2308.

Hébert, B. and Schreger, J. (2017). The costs of sovereign default: Evidence from argentina. *American Economic Review*, 107(10):3119–45.

Hofmann, B., Shim, I., and Shin, H. S. (2017). Sovereign yields and the risk-taking channel of currency appreciation. *BIS Quarterly Review*.

Hofmann, B., Shim, I., and Shin, H. S. (2019a). Bond risk premia and the exchange rate. *BIS Working Papers No 775*.

Hofmann, B., Shin, H. S., and Villamizar-Villegas, M. (2019b). Fx intervention and domestic credit: Evidence from high-frequency micro data. *BIS Papers No 774*.

Isard, P. and Stekler, L. (1985). Us international capital flows and the dollar. *Brookings Papers on Economic Activity*, 1985(1):219–236.

Itskhoki, O. and Mukhin, D. (2017). Exchange rate disconnect in general equilibrium. Technical report, National Bureau of Economic Research.

Ivashina, V., Scharfstein, D. S., and Stein, J. C. (2015). Dollar funding and the lending behavior of global banks. *The Quarterly Journal of Economics*, 130(3):1241–1281.

Jeanne, O. and Rose, A. K. (2002). Noise trading and exchange rate regimes. *The Quarterly Journal of Economics*, 117(2):537–569.

Jiang, Z., Krishnamurthy, A., and Lustig, H. (2018). Foreign safe asset demand and the dollar exchange rate. Technical report, National Bureau of Economic Research.

Jiménez, G., Ongena, S., Peydró, J.-L., and Saurina, J. (2012). Credit supply and monetary policy: Identifying the bank balance-sheet channel with loan applications. *American Economic Review*, 102(5):2301–26.

Jordà, Ò. (2005). Estimation and inference of impulse responses by local projections. *American economic review*, 95(1):161–182.

Kaas, L., Mellert, J., and Scholl, A. (2016). Sovereign and private default risks over the business cycle.

Kearns, J. and Patel, N. (2016). Does the financial channel of exchange rates offset the trade channel? *BIS Quarterly Review*.

Khwaja, A. I. and Mian, A. (2008). Tracing the impact of bank liquidity shocks: Evidence from an emerging market. *American Economic Review*, 98(4):1413–42.

Kim, Y. J., Tesar, L. L., and Zhang, J. (2015). The impact of foreign liabilities on small firms: Firm-level evidence from the korean crisis. *Journal of International Economics*, 97(2):209–230.

Kim, Y. J. and Zhang, J. (2012). Decentralized borrowing and centralized default. *Journal of International Economics*, 88(1):121–133.

Kollmann, R. (2001). The exchange rate in a dynamic-optimizing business cycle model with nominal rigidities: a quantitative investigation. *Journal of International Economics*, 55(2):243–262.

Kollmann, R. (2002). Monetary policy rules in the open economy: effects on welfare and business cycles. *Journal of Monetary Economics*, 49(5):989–1015.

Korinek, A. (2010). Excessive dollar borrowing in emerging markets: Balance sheet effects and macroeconomic externalities. *Available at SSRN 967524*.

Krishnamurthy, A. and Vissing-Jorgensen, A. (2012). The aggregate demand for treasury debt. *Journal of Political Economy*, 120(2):233–267.

Kuttner, K. N. (2001). Monetary policy surprises and interest rates: Evidence from the fed funds futures market. *Journal of monetary economics*, 47(3):523–544.

Linnemann, L. and Schabert, A. (2015). Liquidity premia and interest rate parity. *Journal of International Economics*, 97(1):178–192.

Lizarazo, S. V. (2013). Default risk and risk averse international investors. *Journal of International Economics*, 89(2):317–330.

Longstaff, F. A., Pan, J., Pedersen, L. H., and Singleton, K. J. (2011). How sovereign is sovereign credit risk? *American Economic Journal: Macroeconomics*, 3(2):75–103.

Lustig, H., Roussanov, N., and Verdelhan, A. (2014). Countercyclical currency risk premia. *Journal of Financial Economics*, 111(3):527–553.

Maggiori, M. (2013). The us dollar safety premium. In *2013 Meeting Papers*, number 75. Society for Economic Dynamics.

Maggiori, M. (2017). Financial intermediation, international risk sharing, and reserve currencies. *American Economic Review*, 107(10):3038–71.

Mancini, L., Ranaldo, A., and Wrampelmeyer, J. (2013). Liquidity in the foreign exchange market: Measurement, commonality, and risk premiums. *The Journal of Finance*, 68(5):1805–1841.

Mancini-Griffoli, T. and Ranaldo, A. (2011). Limits to arbitrage during the crisis: funding liquidity constraints and covered interest parity. *Available at SSRN 1569504*.

Manzo, G. and Veronesi, P. (2016). Sovereign credit risk. *Handbook of Fixed-Income Securities*, pages 561–586.

Mark, N. C. (1995). Exchange rates and fundamentals: Evidence on long-horizon predictability. *The American Economic Review*, pages 201–218.

McCauley, R. N., McGuire, P., and Sushko, V. (2015). Global dollar credit: links to us monetary policy and leverage. *Economic Policy*, 30(82):187–229.

McFadden, D. (1973). Conditional logit analysis of qualitative choice behavior. *Frontiers of Econometrics*.

Meese, R. A. and Rogoff, K. (1983). Empirical exchange rate models of the seventies: Do they fit out of sample? *Journal of international economics*, 14(1-2):3–24.

Melvin, M. and Taylor, M. P. (2009). The crisis in the foreign exchange market. *Journal of International Money and finance*, 28(8):1317–1330.

Mendoza, E. G., Quadrini, V., and Rios-Rull, J.-V. (2009). Financial integration, financial development, and global imbalances. *Journal of Political economy*, 117(3):371–416.

Morelli, J. M., Ottonello, P., and Perez, D. J. (2019). Global banks and systemic debt crisesâ. *New York University and University of Michigan*.

Morris, S., Shim, I., and Shin, H. S. (2017). Redemption risk and cash hoarding by asset managers. *Journal of Monetary Economics*, 89:71–87.

Na, S., Schmitt-Grohé, S., Uribe, M., and Yue, V. (2018). The twin ds: Optimal default and devaluation. *American Economic Review*, 108(7):1773–1819.

Nagel, S. (2016). The liquidity premium of near-money assets. *The Quarterly Journal of Economics*, 131(4):1927–1971.

Nickolas, S. (2018). What investments are considered liquid assets? *Investopedia*.

Obstfeld, M. and Rogoff, K. (2000). The six major puzzles in international macroeconomics: is there a common cause? *NBER macroeconomics annual*, 15:339–390.

Obstfeld, M. and Rogoff, K. (2003). Risk and exchange rates. In *In Economic Policy in the International Economy: Essays in Honor of Assaf Razin, E. Helpman and*. Citeseer.

Ottonello, P. and Perez, D. (2018). The currency composition of sovereign debt. *American Economic Journal: Macroeconomics*.

Pan, J. and Singleton, K. J. (2008). Default and recovery implicit in the term structure of sovereign cds spreads. *The Journal of Finance*, 63(5):2345–2384.

Paravisini, D. (2008). Local bank financial constraints and firm access to external finance. *The Journal of Finance*, 63(5):2161–2193.

Paravisini, D., Rappoport, V., Schnabl, P., and Wolfenzon, D. (2015). Dissecting the effect of credit supply on trade: Evidence from matched credit-export data. *The Review of Economic Studies*, 82(1):333–359.

Park, J. (2017). Sovereign default and capital accumulation. *Journal of International Economics*, 106:119–133.

Pavlova, A. and Rigobon, R. (2008). The role of portfolio constraints in the international propagation of shocks. *The Review of Economic Studies*, 75(4):1215–1256.

Perez, D. (2015). Sovereign debt, domestic banks and the provision of public liquidity. *Manuscript, New York University*, 3:14.

Ranaldo, A. and Söderlind, P. (2010). Safe haven currencies. *Review of finance*, 14(3):385–407.

Remolona, E. M., Scatigna, M., and Wu, E. (2008). The dynamic pricing of sovereign risk in emerging markets: Fundamentals and risk aversion. *Journal of Fixed Income, Vol. Spring*.

Rey, H. (2013). Dilemma not trilemma: The global financial cycle and monetary policy independence. In *Jackson Hole Economic Symposium*.

Rey, H. (2015). Dilemma not trilemma: The global financial cycle and monetary policy independence. Working Paper 21162, National Bureau of Economic Research.

Salomao, J. and Varela, L. (2018). Exchange Rate Exposure and Firm Dynamics. CEPR Discussion Papers 12654, C.E.P.R. Discussion Papers.

Sosa-Padilla, C. (2018). Sovereign defaults and banking crises. *Journal of Monetary Economics*, 99:88–105.

Tomz, M. and Wright, M. L. (2007). Do countries default in bad times? *Journal of the European Economic association*, 5(2-3):352–360.

Tourre, F. (2017). A macro-finance approach to sovereign debt spreads and returns. *manuscript, University of Chicago*.

Valchev, R. (2020). Bond convenience yields and exchange rate dynamics. *American Economic Journal: Macroeconomics*, 12(2):124–66.

West, K. D. (1996). Asymptotic inference about predictive ability. *Econometrica: Journal of the Econometric Society*, pages 1067–1084.

Wright, M. L. (2006). Private capital flows, capital controls, and default risk. *Journal of International Economics*, 69(1):120–149.