IMPACT OF CLIMATE, FINANCIAL, AND TRADE SHOCKS ON FIRMS AND HOUSEHOLDS

By

Nouhoum Traore

A dissertation submitted in partial fulfillment of
the requirements for the degree of

Doctor of Philosophy
(Agricultural and Applied Economics)

at the
UNIVERSITY OF WISCONSIN-MADISON
2018

Date of final oral examination: 05/08/2018

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

Jeremy D. Foltz, Professor, Agricultural and Applied Economics
Enghin Atalay, Assistant Professor, Economics
Ian Coxhead, Professor, Agricultural and Applied Economics
Akiko Suwa-Eisenmann, Professor, Economic

Dedication

This dissertation is dedicated to my late father, Sallah Traore, and late uncle and friend, Oumar Coulibaly – Despite they are no longer with us, they continue to inspire my life.

Acknowledgements

I would like to earnestly thank my advisor, Jeremy Foltz, for his patience, great research mentorship, and moral support. He has been a true mentor and friend throughout this lonely journey. I will forever be indebted to him and to all my other Dissertation Committee members –Enghin Atalay, Ian Coxhead, and Akiko Suwa-Eisenmann–for their invaluable advice, mentorship, and feedback. A special thank goes to Akiko Suwa-Eisenmann for being my coach and friend while at Paris School of Economics.

Words are not enough to express my gratitude to Jonathan Conning, Dean Karlan, and Aissatou Ouedraogo for always supporting my decision to pursue a doctoral degree. I am grateful to my family and friends for their constant support and encouragement throughout this journey.

I am thankful to Institute National de la Statistique de Côte d'Ivoire (INS), Institute National de la Statistique du Mali (INSTA), and Francois Bourguignon for providing me with the necessary data for my research. I am also grateful to the department of Agricultural and Applied Economics at Wisconsin-Madison and Policy Design and Evaluation Research in Developing Countries (PODER) for generous funding.

This dissertation benefited a lot from the insight and comments of many professors and seminar participants at Wisconsin-Madison and Paris school of economics. Many thanks to Jean-Paul Chavas, Denis Cogneau, Sylvie Lambert, Francois Libois, Karen Macours, David Margolis, Laura Schechter, Emilia Tjernstrom, and Kenneth D West for their comments.

Last but not least, my highest gratitude to Allah for blessing my live with lovely and exceptional people, not all mentioned here, whose exceptional mentoring, encouragement, love, and affection shaped my life and made this journey possible.

Table of Content

Executive Summary

The level of globalization the world has experienced over recent decades is unprecedented in modern history. More than ever, the world is integrated economically, socially, politically, and culturally as a result of technological innovations in the areas of transportation and communication. This has opened a potential for higher and sustained growth and presents an unparalleled opportunity to reduce extreme poverty in developing countries. This increased globalization has, however also led to a rise in risks to that prosperity coming from trade and financial shocks. In addition the changing climate adds to the risks these newly globalized economies face.

While the African continent is not secluded from the consequences of globalization, it attracted relatively less study on the implications of the distributional effects of trade shocks or the effects of financial or temperatures shocks on the competitiveness of its firms in an integrated world market. This dissertation fills the gap in the aforementioned literature by attempting to explain the impacts of climate, trade, and financial shocks on firms and household in Sub-Saharan Africa.

In the first essay of the dissertation, I examine the relationship between temperatures and firm performance by using detailed production data from manufacturing, service, and agricultural firms in Côte d'Ivoire. To guide the empirical work, I introduce climate mitigation technology choice into a model of trade with heterogeneous firms. An empirical test of the model shows that increased temperatures leads to lower firm revenues, profits, and survival rate. In addition, my empirical results suggest a negative relationship between daily temperatures and measures of firm performance: total factor

productivity, labor and capital productivity. Finally, I find a lower effect of temperatures on firms that can invest in climate mitigation technology. These findings show that higher temperatures in developing countries decrease competitiveness, thus providing the first quantitative estimates of this cost of climate change.

In the second essay, I analyze the effect of a drastic cut in Malian livestock export following the 2002 political crisis in Côte d'Ivoire on the consumption and poverty status of livestock farm households in Mali. Using household data before (2001) and after the crisis (2006), I propose a difference in differences strategy to estimate the causal impact of the shock on six household outcomes of consumptions and poverty measures. My results suggest that the trade shock had a negative impact on the consumption of livestock households and worsened their poverty status. The effect was stronger on the consumption of food purchased; suggesting that as a coping mechanism, households cut down their consumption of luxury goods. I find no evidence that households located in livestock export shed were more affected, suggesting some level of livestock market integration in the country.

In the third essay, I study the determinant of firm's performance in Côte d'Ivoire during and after a financial crisis following the 2011 post-electoral conflict. Using a panel of firm data from 2010-2013, I find that better pre-financial conditions were not key defining factors of firm performance during the crisis. Amid the crunch of external financing opportunities, firms relied more on trade credit from suppliers and clients to post more sales and decrease their odd of exiting the market. Firm pre-crisis conditions were not important in getting trade credit, therefore, I argue that business network rather than financial soundness plays a major role in firm's access to trade credits.

Essay 1.

Temperatures, Productivity, and Firm Competitiveness in Developing Countries: Evidence from Africa

1. Introduction

As global temperatures rise, it becomes more important to understand the influence of temperature on economic productivity. A growing body of literature has established strong negative relationship between historical fluctuations in levels of temperature and aggregate economic performance (Dell et al., 2012; Burke et al., 2015). However, most of these studies are based on aggregate data and use a cross-country approach. Such an approach does not provide insights on the mechanism behind the observed effects of temperature on economic activity. Further, while these studies suggest that temperatures affect output in sectors other than agriculture, they have been limited in explaining the consequences of the observed effects on firm performance. This paper uses firm-level data across multiple sectors of the economy to analyze the relationship between temperature changes and firm performance. These firm-level effects have important implications for the competitiveness of the economy in the international market.

We answer this question using data from Côte d'Ivoire. Africa is especially vulnerable to rising temperatures due to its low levels of development, making study of the effects of climate change in Africa all the more important. First, we adapt a trade model with heterogeneous firms à la Melitz (2003) to analyze the impact of increased temperatures on firm revenues, profits, and exit productivity cutoff. Second, using a unique, detailed firm-level data set from Côte d'Ivoire coupled with climate data, we estimate total factor productivity (TFP) non-parametrically, using the most recent techniques in the field of industrial organization. Third, we empirically investigate whether and how temperatures affect firm productivity. Finally, we test the key prediction from our model that increased temperatures decreases firm's revenues, profits, and market survival rate.

We augment the typical trade model by allowing firms to invest in technologies that mitigate the effects of high temperatures. The seminal work of Melitz (2003) on heterogeneous firms and trade liberalization has stimulated a large empirical literature investigating the links between firm productivity and competitiveness in the global market. Recent studies extend this literature to investigate which types of domestic firms take advantage of trade openness and what factors influence their survival in the export market (Manova, 2013; Minetti and Zhu, 2011). This paper adds a new dimension to current trade theory by examining the effects of temperatures on firm's productivity and market survival. As is standard in the literature, our model predicts that the least productive firms exit the market, the medium productive firms continue producing, but do not invest in climate mitigation technology, and the most productive firms continue producing and invest in climate mitigation technology. Our additional insight is that higher temperatures increase the exit productivity cutoff, because they increase firms' production costs. As a result, some firms make negative profits and stop producing.

In the empirical application we start by using the non-parametric methods developed by Gandhi et al. (2011) to estimate total factor productivity (TFP) across the manufacturing, agriculture, and service sectors. Next, to identify the effects of temperatures on firms' revenues, profits, and TFP, we exploit year-to-year variation in firms' exposure to a daily distribution of temperatures, constructed in a series of temperature bins. We find a strong and statistically significant negative effect between temperatures and firms' revenues, profits, and TFP. In our preferred baseline specification, a one-standard-deviation rise in days with high average temperatures decreases firm's revenues, profits, and TFP, respectively, by 14.83%, 21.71%, and 3.61% relative to the impact of a day with moderate average temperatures. For firms that can invest in climate mitigation technology, the effects of high temperatures on revenues are significantly reduced. To assess the potential mechanisms behind the observed effects of temperatures on TFP, we estimate the effects of temperatures on labor and capital productivity. In various specifications, we find no evidence that the observed effect of temperatures on TFP is solely explained by labor productivity, which suggests high temperatures affect capital productivity as well. The model also predicts that increased temperatures reduces firm market survival rate as a result of higher production costs. To examine the impact of higher temperatures on a firm's exit, we estimate the change in the probability that a firm exits as a function of temperatures. We found that a one-standard-deviation rise in days with high average temperatures increases firm exit rate by 0.044 percentage points. This result demonstrates the negative effect of climate change on firms' competitiveness.

The unique and comprehensive data used in this paper helps overcome many of the endogeneity and identification issues in the previous literature. Our data spans a range of manufacturing, agriculture, and service sectors with different levels of mechanization, ability to control for temperatures, and different level of exposure to temperatures. Moreover, by having information about the exact address of the plant, we can identify temperatures at the smallest administrative division where the firm is located. This unique feature of the data enables us to exploit exogenous variation in temperatures at different firms' locations and across time to estimate the impact of increased temperatures on firms. In addition, the richness of our data enables us to perform several robustness checks including different identification strategies, using alternative sub-samples of the data and temperature measures, and controlling for major events in the country. These robustness checks allow us to address potential threats to identification that might come from the concentration of the majority of firms in few localities in the country, sample selection issues due to entry and exit of firm and data requirement to estimate non-parametric firm's productivity. In all specifications, we find strong support for our main results that high temperatures affect firms' revenues, profits, productivity, and market exit rate.

This paper contributes to a number of different strands of the literature on climate, firms, and African development. First, by adding insights from the trade literature on productivity with the climate and productivity literature we make important advances to the climate literature. The trade theory framework we use pays close attention to how temperatures affect competitiveness in contrast to most climate-productivity analyses, which only focus on the effects of temperatures on firm's output.

Secondly, we are the first paper to analyze the effects of temperatures using firm level data in Africa. While this literature has not yet focused on Africa, there are good reasons to believe that African firms are most vulnerable to climate change due to missing market of credit and a high vulnerability of their agriculture sector. Moreover, if non-agricultural sectors are expected to attenuate the effect of climate change by absorbing affected workers in the African agricultural sector, it is important for adequate climate adaptation policies to understand how temperatures might also affect non-agricultural sectors.

Finally, this work also makes important contributions to the broad literature trying to understand factors affecting the competitiveness of African firms. To design a sound industrialization policy, which is often suggested as the path for sustainable growth and poverty reduction in the continent, it is important to understand all the contributing factors that constrain African firms. Our results bolster current evidence on the contributing factors to poor performance of African's firms and in doing so add a new dimension to the analysis of the impact of climate change on economic activities in developing countries.

The reminder of the paper proceeds as follow: in section 2 we review the literature and discuss the mechanisms through which temperature might affect firm productivity. In section 3 we introduce a theoretical model of firm behavior under climate variability. In section 4 we provide the empirical framework and the data. In section 5 we offer the empirical analysis. In the last section we conclude and provide policy implications.

2. Literature Review

While globalization has fostered the expansion of higher productivity sectors in most of East Asia, it seems to have induced an undesirable structural labor movement in Sub-Saharan Africa from the most productive to less productive sectors (McMillan and Rodrik, 2011). Despite a multitude of studies that have looked into potential factors (e.g. weak institutions, political instability, inadequate infrastructures) trailing behind African firms, there are none on the effect of climate on the manufacturing sector in the continent. It is possible that low productivity in African firms is related to climate.

The relationship between temperatures and economic activities has been well established at the aggregate output level. Using historical fluctuations in temperatures within countries and GDP information for about 120 countries, Dell et al. (2012) found that high temperatures reduce agricultural output, manufacturing output, and political stability in poor countries. In a similar exercise, using a non-linear estimation methodology, Burke et al. (2015) showed that increased temperatures affect economic activities not only in developing countries but in developed countries as well. While these studies have resuscitated the debate on the impact of climate on broader economic activities, they are limited in explaining the micro-mechanism behind the observed effects.

Previous studies that used micro-level data have been mainly focused on understanding the influence of temperatures on agricultural yield (Auffhammer et al., 2006; Deschenes and Greenstone, 2007; Schlenker and Robert, 2009; Lobell et al., 2011). However, despite the economic importance of agriculture in most developing countries, it cannot alone explain GDP losses due to temperature fluctuations observed in macro studies. Few recent studies have investigated the impacts of climate change on labor productivity and absenteeism (Cachon et al., 2012; Zivin and Neidell, 2014; Sudarshan et al., 2015; Park, 2016). Using county level payroll and weather data from 1986 to 2012, Park (2016) estimated the impact of heat days on local labor productivity in the US. He found that an additional day above 32C caused a 0.048% decline in payroll per capita that year, and that the coldest counties suffered more, suggesting that the hottest counties had already invested in long-term adaptation. Using daily worker productivity and attendance from Indian manufacturing firms, Sudarshan et al. (2015) found that intrinsic labor productivity decreases by between 4% - 9% per degree on days above 27C. This is one of the few studies to use firm level data to directly measure the impact of temperatures on firms' productivity. They show that an additional day of high temperature is associated with a 1% - 2% increase in absenteeism of contracted workers. However, they observe no impact on daily (non-contracted) workers for whom the cost of absenteeism is high. In assessing the economic implication of their results, they found that firm output decreases in years of high temperature a little over 3% per degree-day.

While such pioneering micro studies on the impact of extreme weather on firms' productivity (Cachon et al., 2012; Sudarshan et al., 2015) create a basis for firm level evidence of temperatures' effects, they are likely to suffer from external validity issues since the scope of their analysis is usually restricted to specific industries within the manufacturing sector. Moreover, the features of the data (e.g. cross sectional, the lack of information on firm's exact location) used in previous papers raised potential identification concerns about their findings.

2.1. How Does Temperature Affect Economic Activity?

At first glance, the relationship between temperature shocks and secondary or tertiary economic sectors is not obvious. However, there are several ways in which extreme temperatures can affect the production process of firms. One of the primary mechanisms identified in the literature is that higher temperatures cause intrinsic labor productivity loss and a reduction in labor supply (Park, 2016; Sudarshan et al., 2015; Zivin and Neidell, 2014; Cachon et al., 2012; Hsiang, 2010). Hsiang (2010) found that the effect of temperature on economic output in the Caribbean is structurally similar to the effect of intrinsic labor productivity. With the exception of (Zhang et al., 2017), which document the relationship between temperatures and firm output, TFP, labor and capital productivity, most of the previous micro studies have been solely focused on labor productivity channel. Zhang et al. (2017) found that while the effect of temperatures on labor and capital are limited, temperatures affect both labor and capital productivity. Although there are good reasons to believe that temperatures can affect the proper function of machines or divert investment from productive capital, the impact of temperatures on capital productivity has been mostly neglected in the climate-firm literature.

In many developing countries, temperatures can induce higher industrial production cost. In warmer seasons, while there is higher energy demand for cooling purposes from both households and firms, increased temperatures decrease the stream flow of water, which poses potential operating and efficiency problems for hydroelectric plants- the primary source of electricity for many countries in SSA. High demand of energy and downward pressure on electricity and water supply due to hotter seasons lead to poor water supply and intensive power outages, which poses tremendous handicap to firm production. According to (Kaplinsky and Morris 2008), Kenyan firms facing frequent power interruptions lost significant part of their production despite investing in generators. Most probably because of the strict data requirement, there is no study that has investigated energy interruption as a potential mechanism through which temperatures can affect firm productivity in Africa.

Finally, increases in input prices could also lead to higher production costs for firms. Given the established evidence of the negative impact of temperatures on the efficiency of agricultural production, especially in the tropics, one would expect that higher temperatures would affect both the supply and price of agricultural output. This is particularly of concern for food manufacturing firms or firms that use agricultural output as intermediate inputs.

As shown by Melitz (2003), exposure to globalization induces the most productive firms to enter the export market and the least competitive firms to exit. Hence, if we assume that firms in tropical regions are relatively more exposed to climate change than firms elsewhere, they will be less competitive in the global market if climate change affects firm productivity, ceteris paribus. In other words, in a globalized market where firms in small countries are price takers, climate change can exogenously increases the survival productivity threshold for firms in climate vulnerable countries.

3. Theoretical Model

This section develops a simple model to study the effects of temperatures on the competitiveness of heterogeneous firms by introducing climate mitigation technology choice in Melitz style trade model. This add-on to Melitz model enables us to consider the impact of temperatures on the behavior of firms; an implication of climate on economic activity in developing countries that has been missed in previous studies. To a certain extent, the insights in our model are close to that of Bustos (2011) and Manova (2013). However, while Bustos (2011) and Manova (2013) focuses respectively on the impact of increased trade on firm technology upgrading and the implication of credit constraints for heterogeneous firms in international trade, our model analyses the impact of temperature shocks on firm sorting and exit.

3.1. ***Set up of the Model***

We incorporate climate costs and climate mitigation technology choice into a static, partial equilibrium model à la Melitz (2003). Each of J, countries is endowed with L units of labor used by heterogeneous firms to produce differentiated products in a single monopolistically competitive industry. Assuming that firms face exogenous constant elasticity of substitution (CES) demand schedule, the demand function for each variety (ω), in country j is determined by $q_j(\omega) = E_j P_j^{\sigma-1}\left[p_j(\omega)\right]^{-\sigma}$, where $p_j(\omega)$ is the price of the variety, $\sigma = 1/(1-\rho)$ is the elasticity of substitution between any two goods, $P_j = \left[\int_0^M p_j(\omega)^{1-\sigma} d\omega\right]^{\frac{1}{1-\sigma}}$ is aggregate price index, M is the number of varieties, and E_j is the aggregate level of spending in the economy. The assumption of symmetry in production technology ensures that wages, the numeraire, and aggregate variables are the same across countries.

Firm entry. - Each economy is populated with a continuum of monopolistically competitive firms, each producing a differentiated product under increasing return to scale technology. Within the industry, firms are heterogeneous in their productivity φ, and they face fixed entry costs of f_e units of labor. Productivity φ, unknown to firms before starting production, is drawn from a known cumulative Pareto distributive function $G(\varphi) = 1 - \varphi^{-k}\ with\ k > 1$. After observing their productivity, firms decide whether to produce or exit the market.

Temperature Cost. - We assume that temperatures differently affect production technology in different countries, that is, to manufacture 1 unit of a good in country j, firms need to employ $\gamma_j(\theta) > 1$ units of labor that could otherwise be produced with 1 unit of labor in the scenario of no temperature effect $\left(\gamma_j(\theta = \theta^*) = 1\right)$, where $\theta \; and \; \theta^*$ are respectively the level of current and optimal temperatures. $\gamma_j(\theta)$, which increases in temperature, captures differences in the effects of temperatures on production factors in different countries. Thus the production of each variety involves a fixed cost (f) and a marginal cost $\left(\frac{\gamma_j(\theta)}{\varphi}\right)$, both expressed in terms of units of labor.

A simple interpretation of the climate variable cost would be the decrease in labor productivity due to weather condition. As demonstrated in previous studies (Hsiang, 2010; Sudarshan et al., 2015; Park, 2016), high temperatures reduce intrinsic labor productivity through fatigue or discomfort. To a certain extent, temperatures can affect capital productivity as well (Zhang et al., 2017). Alternatively, climate costs can also be interpreted analogously to environmental regulation requirements. In order to comply with the carbon emission regulation in most countries, firms need to make specific investments in production technology, which might not necessarily increase their productivity.

Henceforth, we will focus on the domestic market, so we will drop the sector j subscript to reduce the intensity of notation.

Production Technology. - Upon staying active, firms produce goods using a technology that features a marginal cost $(\gamma(\theta)/\varphi)$ and a fixed cost (f), both expressed in units of labor. Firms can choose to improve their production technology by reducing their marginal cost of production through an investment in climate mitigation technology at a fixed cost. This can be expressed as the choice between two technologies, low (l), and high (h), where technology h features a higher fixed cost (ηf) and a lower marginal cost

$(\gamma(\theta)/\lambda(\theta)\varphi)$, where $\lambda(\theta) > 1$ is increasing in temperatures with $[\lambda(\theta = \theta^* = 1)]$, and $\eta > 1$. The total cost functions under each technology are:

$$TC^l(q,\varphi) = l^l = f + \frac{q\gamma(\theta)}{\varphi}$$

$$TC^h(q,\varphi) = l^h = \eta f + \frac{q\gamma(\theta)}{\lambda(\theta)\varphi}$$

where l^l *and* l^h are, respectively, labor for firm using low and high technology.

3.2. *Firm behavior*

Profit Maximization

Under CES preferences, the static problem for a monopolistic competitive firm, with productivity φ, is to maximize the following profit function:

$$(1)\ max_{l,q}\,\pi(e,\varphi,\theta) = pq - \frac{q\gamma(\theta)}{\varphi} - f + e\left[\left(1 - \frac{1}{\lambda(\theta)}\right)\frac{q\gamma(\theta)}{\varphi} - f(\eta - 1)\right]$$

s.t.

$$(1.1)\ q(\varphi,\theta) = EP^{\sigma-1}[p(\varphi,\theta)]^{-\sigma},$$

$$(1.2)\ A(\varphi,\theta) \equiv \left(1 - \frac{1}{\lambda(\theta)}\right)\frac{q(\varphi,\theta)}{\varphi}\gamma(\theta) - f(\eta - 1) \geq 0.$$

Where $e = (0,1)$ is an indicator for firm investment status in climate mitigation technology. In the absence of climate mitigation technology choice, the equilibrium production quantities, price of variety, revenues, and profits are the same as in Melitz (2003) scaled by a climate cost shifter $\gamma(\theta)$:

$$(2)\ \ p(\varphi,\theta) = \frac{\gamma(\theta)}{\rho\varphi}, q(\varphi,\theta) = EP^{\sigma-1}\left[\frac{\gamma(\theta)}{\rho\varphi}\right]^{-\sigma},$$

$$r^l(\varphi) = \left[\frac{\gamma(\theta)}{\rho P \varphi}\right]^{1-\sigma} E, \qquad \pi^l(\varphi,\theta) = \gamma(\theta)^{1-\sigma}\frac{1}{\sigma}E(P\rho)^{\sigma-1}\varphi^{\sigma-1} - f.$$

Climate Mitigation Technology. – Since the benefits of investing in climate mitigation technology increase with productivity and temperature, the investment constraint (1.2) for firms with productivity level above a certain cut-off is not binding. Substituting $A(\varphi,\theta) = 0$ into (1), the equilibrium revenues and profits for firms using *high* technology are the following:

(3) $$r^h(\varphi,\theta) = \left[\frac{\gamma(\theta)}{\rho P \lambda(\theta)\varphi}\right]^{1-\sigma} E,$$

$$\pi^h(\varphi,\theta) = \gamma(\theta)^{1-\sigma}\frac{1}{\sigma}E(P\rho)^{\sigma-1}\varphi^{\sigma-1}\lambda(\theta)^{\sigma-1} - \eta f.$$

Firms make the decision of whether to invest in climate mitigation technology by comparing the profits in (2) and (3). The decisions to stay active and technology choice are represented in Figure 1, where the two possible profits are depicted as a function of firm productivity. The equilibrium in Figure 1 is obtained when $\varphi^* < \varphi^h$ where φ^* is the productivity cutoff for staying in market and φ^h is the level of productivity above which a firm using *low* technology finds it profitable to invest in climate mitigation technology $[\pi^l(\varphi^h)] = [\pi^h(\varphi^h)]$. This equilibrium results in the sorting of firms into three different groups: the least productive firms $\varphi < \varphi^*$ exit, the low productive firms $(\varphi^* < \varphi < \varphi^h)$ produce with low technology, and the most productive firms $(\varphi^h < \varphi)$ produce with *high* technology by investing in climate mitigation technology.

Proposition 1: *An increase in temperatures reduces firm revenues and profits* $\left(\frac{\partial \mathrm{r}(\varphi,\theta)}{\partial \theta} < 0, \frac{\partial \pi(\varphi,\theta)}{\partial \theta} < 0\right)$.

Proof. *See Online Appendix A.*

Proposition 2: *The effect of temperatures on revenues and profits is lower for firms that invest in climate mitigation technology*

$$\left(\left|\frac{\partial \mathrm{r}^h(\varphi,\theta)}{\partial \theta}\right| < \left|\frac{\partial \mathrm{r}^l(\varphi,\theta)}{\partial \theta}\right|, \left|\frac{\partial \pi^h(\varphi,\theta)}{\partial \theta}\right| < \left|\frac{\partial \pi^l(\varphi,\theta)}{\partial \theta}\right|\right).$$

Proof. *See Online Appendix A.*

Intuitively, when there is temperature increases labor productivity reduces and as a result firms produce less and experience higher costs given the same level of production factors. Firm can mitigate the cost of high temperatures by investing in climate mitigation technology (e.g. AC), which will lessen the effects of temperatures on their productivity.

Exit from Market. –The least productive firms maximize profit by using *low* technology. As a result, the exit cutoff productivity φ^*, is defined as:

$$(4)\ \ \pi^l(\varphi^*) = 0 \iff \varphi^* = \left(\frac{\sigma f}{E}\right)^{\frac{1}{\sigma-1}} \frac{\gamma(\theta)}{P\rho}$$

It is important to note that in a standard Melitz model, a firm's decision to exit is based on its long run profit and, consequently, expectations over future temperatures should be taken into account. However, to make modeling simple and given our context, a developing country with credit constraints, short term cash flow can be critical to firm survival. For this reason, we will assume that short-term profits motivate a firm's decision to exit.

Proposition 3 *(Exit Cut-off) An increase in temperatures reduces firm survival rate* $\left(\frac{\partial\varphi^*}{\partial\theta} > 0\right)$

Proof. *See Online Appendix A.*

Technology Choice. - The marginal firm using *high* technology is indifferent in using the *low* technology, that is, $\pi^h(\varphi^h) = \pi^l(\varphi^h)$. Therefore, the cutoff productivity level requires to invest in climate mitigation technology is defined by:

$$\pi^h(\varphi^h) = \pi^l(\varphi^h) = 0 \Leftrightarrow (\lambda(\theta)^{\sigma-1} - 1)\gamma(\theta)^{1-\sigma}\frac{1}{\sigma}E(P\rho)^{\sigma-1}{\varphi_h}^{\sigma-1} = (\eta - 1)f$$

combining this condition with equation (4), we can express φ^h as a function of the exit cutoff productivity:

$$(5)\ \varphi^h = \varphi^*\left(\frac{\eta - 1}{\lambda(\theta)^{\sigma-1} - 1}\right)^{\frac{1}{\sigma-1}}$$

Note that $\varphi^h > \varphi^*$ as long as $\left(\frac{\eta-1}{\lambda(\theta)^{\sigma-1}-1}\right)^{\frac{1}{\sigma-1}} > 1$. This implies that only the most productive firms invest in climate mitigation technology. Because demand is elastic $(\sigma > 1)$, adopting *high* technology will result in higher revenues for firms. Given that the benefit of investing in climate mitigation technology is increasing in productivity and costs are the same for all firms, after certain level of productivity, the dominant strategy for all firms is to adopt *high* technology. From (5), it is also worth mentioning that no firm will invest in climate mitigation technology when there is no temperature effect $[\lambda(\theta = \theta^* = 1]$, and an increase in the cost of climate mitigation technology results in a lower share of firms adopting the technology $h\left[\left({\varphi^h}/{\varphi^*}\right)^{-k}\right]$. This implies that firms' decision to invest in adaption technology is motived by both, weather conditions and the cost of technology. For example, if weather conditions have no impact on technology costs, an increase in temperatures will lead to more adoption. On the other hand, if the cost of technology is affected by weather, than the effect of increased temperatures on adoption will depend on the net benefit of investing in the technology.

Discussion. - The model outlined above generates testable implications of the effect of temperatures on economic activity that we will evaluate in the empirical section. The key results to our model are that an increase in temperatures decreases firm revenues, profits, and survival rate (Proposition 1 and 3). The model also suggests that firms investing in climate mitigation technology are less affected by temperatures (Proposition 2). Finally, the model predicts that higher temperatures have an ambiguous impact on climate adoption cutoff productivity.

4. Data and Empirical Framework

4.1. *Empirical Framework*

There are two basic but important differences between the assumptions in our model and the empirical analysis. First, for simplicity reasons we spare our modeling from introducing the tested assumption that temperatures affect economic production non-linearly (Burke et al., 2015). However, in the empirical estimation, we use the bin approach, which captures the non-linear relationship between temperatures and economic production. Second, productivity is exogenously determined in our model, while in the climate literature, there is evidence that temperatures affect firm productivity (Sudarshan et al., 2015; Zhang et al. 2017; Zivin and Neidell, 2014; etc.). Thus we will start our empirical investigation by first testing whether temperatures affect firm productivity, and then we will explore the mechanism behind such effects (if any).

To test the impact of temperatures on firm productivity, we estimate TFP using Gandhi et al. (2011) and Ackerberg et al. (2006) method and use wage per capita and the unit cost of capital as proxies for labor and capital productivity, respectively. We are conscious about the possibility that rents and other factors might cause the returns to labor and capital at firm level to diverge from a market benchmark rate. However, given that our goal is not to estimate the impact of temperatures on returns to capital but rather to test whether temperatures affect labor and capital productivity, we believe that market benchmark rate is a valid measure. Finally, we will test the prediction of the model that: (1) an increase in temperatures reduces firm revenues, profits, and market survival and (2) temperatures have a lower effect on firms that can invest in climate mitigation technology.

Our empirical strategy for studying the impact of temperatures on firms' performance is to regress the variable of interest (TFP, firm revenues, profits, and exit, and labor, capital productivity) on the temperature variables constructed using the bin approach and other control variables following equation (6). According to the model, firms that invest in climate mitigation technology will be affected differently than those that do not. To capture the differential effects of temperatures on firms using different technology, we include a dummy variable (Z_i), indicating whether a firm invested in climate mitigation technology or did not. Our key regression is thus specified as:

(6) $Y_{it} = \alpha_i + D_d + \beta_1' temp_{rt} + \beta_2' \, temp_{rt} * Z_i + rain_{rt} + X_{it} + \varepsilon_{it}$

where Y_{it} is the firm level outcome of interest. Our first outcomes of interest are TFP, labor productivity, and capital productivity. As mentioned above, we will test the assumption in the literature that temperatures affect firm productivity. Our second outcomes of interest are firm revenues and profits. Our last outcome of interest is firm exit. In estimating the effect of temperatures on firm exit we replace weather variables in equation (6) by lag values. Firm fixed-effect and district fixed-effect are respectively represented by α_i and D_d. While firm fixed-effect controls for firm specific time invariant characteristics, district fixed-effect controls for shock inherent to each district, such as climate trends, the quality of institution, and policy shocks within the geographical district. The key explanatory variable, $temp_{rt}$, measures temperature in region's r in year t. To capture the non-linear effect of temperatures on economic activities, $temp_{rt}$ is constructed in series of temperature bins $[b_{rt1}, b_{rt2}, \ldots, b_{rtn}]$, in which bin_{rtn} represents the number of days falling into the nth temperature bin for region r in year t. To test whether firms with a specific feature (e.g. investing in climate mitigation technology, labor intensive, outdoor) are differently affected by temperature, we augment equation (6) with terms that interact the temperature bins and Z_i, a dummy variable for the feature of the firm. $rain_{rt}$ represents precipitations in region r in year t. Other control variables: production factors, firm's characteristics, and time trends are included in vector X_{it}. Finally ε_{it} is the error term clustered at region-year level, which will allow us to control for spatial correlation across firms within each region.

4.2. *Data and Construction of Variables*

We use two sources of data to analyze the impact of temperatures on firms' outcomes. Firm-level data, covering the universe of registered firms in Côte d'Ivoire from 1998-

2013, are collected by the *Registre des Entreprises*, a department of the National Institute of Statistics (INS). Since almost all the establishments have only one branch, we will refer to each establishment as “firm" instead of “plant". The data contains information on sales (domestic, and exported), inputs, employment, ownership status, and operating costs of all formal agricultural, manufacturing, service, and trade establishments in the country. The records distinguish between public enterprises, private domestic firms, and foreign firms.

Given the focus of our analysis, we exclude associations, public administrations, and firms in health, sport, education, and personal beauty industries from the sample. We also exclude firms with zero or missing values of key variables as well as firms with values outside the range of 1 to 99 percentile. Because of permanent firms’ exits and possibly the temporary lapses of some firms in filing their balance sheet information, the structure of the data is unbalanced panel.

All monetary variables used in the analysis are converted in real terms using the country GDP deflator from the World Bank. This helps to mitigate the input-quality or markup differences across time that are incorporated in prices. Using firm location information, we merge firm level data with temperature and precipitation data from Surface Meteorology and Solar Energy developed by the Atmospheric Sciences Data Center at the Langley Research of the US National Aeronautics and Space Administration (NASA). The climate dataset contains daily average temperature and precipitation information at a 0.5X0.5 grid degree resolution.

The Capital (K) is measured by the total value of fixed assets in the book values. Labor is represented by the total number of internal permanent and seasonal employees and the total wage bill of all internal workers. Investment (I) is the sum of the value of new investment in machinery and vehicles. Intermediate inputs (M) are defined as the sum of expenditure on raw materials, other goods, and services. While a firm's entry year is directly observed in the data[1], we estimated the firm's exit status. Using the firm's unique account number as an identifier, we are able to distinguish a permanent exit from a temporary lapse in reporting or change in the name of the firm. The ability to detect true exit and entry provide a significant advantage for our data compared to similar data from other countries (Klapper, 2015). Finally, firm revenue (Y) is the value of total sales of all finished goods.

4.3. ***Productivity Estimation***

Our measure of productivity is based on the production function estimated by the method of Gandhi, Navarro, and Rivers (Gandhi et al. (2011), GNR henceforth). The Ackerberg-Cave-Frazer (Ackerberg et al. (2006), ACF henceforth) approach is used for robustness check. One of the critical issues in identifying firms' production functions is the possibility that there are factors influencing production that are observed by the firm but not by the econometrician. In such a case, estimating the production function using the ordinary least square method leads to biased and inconsistent estimates of productivity parameters.

Concerned by the potential simultaneity issues, recent empirical studies have used production function estimation based on the "proxy variable" approach (Olley and Pakes, 1996; Levinsohn and Petrin, 2003; Ackerberg et al., 2006). The objective of these

[1]The dataset is a census of all formal firms in the country therefore, entry of new firms is observed on a yearly basis.

[2] This is estimated by multiplying the coefficient on days above 27°C in column 2 of Table 2 (-

methods is to get around the identification issue by inferring the productivity from the observed firm's input choice. However, it has been pointed out by ACF that the early "proxy variable" approaches as well suffer from identification issues. Therefore, they propose an estimation method built on Olley and Pakes (1996) and Levinsohn and Petrin (2003) that does not suffer from the timing and dynamic implications of input choices (Parrotta et al., 2014).

Gandhi et. al (2011) is the first paper to show non-parametric identification of the production function with flexible and quasi-fixed inputs. They argue that the production function is non-parametrically non-identified within the structural model of production in Olley-Pakes, Levinsohn-Petrin, and Ackerberg-Cave-Frazer since there is no exogenous source of variation for a flexible input that comes from outside the production function. GNR provides an improvement over previous “proxy variable” techniques by solving the non-identification issue. They did so, by transforming the firm's first order condition in a gross output specification (see Appendix C for more details on GNR method).

5. Empirical Analysis

5.1. *Descriptive Statistics*

Table 1 provides an overview of the merged firm level and weather data. Information on firms with missing variables, panel length and sub-sector length are reported in appendix Table A5, Table A6, and Table A7. The clean full sample includes 8, 979 unique firms or 34,670 firm-year observations. The skewed distribution of key variables in the sample, as common to firm data from most developing countries, suggests that our economy is mainly composed of small firms and few very large firms. From 1998 to 2013, the median and average value of firm's revenue are and $259, 800 and $1.861 million respectively and the median and average firm size are 9 and 40 employees respectively. Firm entry and exit rate over the 16 years period are respectively 18.6% and 9.9%.

Despite the presence of firms in most of the regions, as is the case in many developing countries, a large proportion of firms are concentrated in the capital. Figure 1 depicts the average number of firms in each region during the period of 1998-2013. Generally, there is a large presence of firms in coastal regions, Abidjan and San-Pedro in the north and in the west (respectively about 88% and 2% of the sample). The figure suggests that there is no formal economic activity in the center of the country.

Weather records for 1998-2013 are extrapolated from Surface Meteorology and Solar Energy developed by the Atmospheric Sciences Data Center at the Langley Research of the US National Aeronautics and Space Administration (NASA). This dataset has been extensively validated by ground level measurements. However, larger errors were found in surface temperatures where the site data did not represent the entire grid box, which is likely to be the case in our study country (Whitlock et al., 1995). An alternative source for weather data would be ground level data from local weather stations. However, given a poor spatial and temporal coverage of weather stations that report ground level temperature and rainfall readings, it is less likely that such data would be of higher quality than reanalysis data. Reanalysis data solve the potential bias concerns about ground level data in developing countries due to the lack of coverage and the variation in data quality from different location by combining data from ground stations and satellites using climate models. This type of data has been widely used by economist in both developed and developing countries to analyze the impact of climate on economic activities (Dell et al. 2012; Sudarshan et al., 2015; Burke et al. 2015; Zhang et al., 2017).

Temperature and precipitation are calculated using daily observations. While temperature measure is constructed using daily mean, precipitation is estimated as annual cumulative value using daily observations. To facilitate the comparison of our results with previous works (Hsiang, 2010; Sudarshan et al., 2015), we define our high temperature variable to be the number of days with average temperatures above 27°C. Also this number seems to be a good breakpoint in our case study since the historical average daily temperature for the period 1990-2013 in Côte d'Ivoire is 25.85°C with a standard deviation of roughly 0.65. As such, our temperature shock breakpoint, 27°C, is 1.77 standard deviation above the historical daily average temperatures. Figure 3a and 3b represent respectively the distribution of daily temperatures over years and regions. The regional heterogeneity in the number of hot days is depicted in Figure 4. Hot days are observed in both in the north and the south of the country. For a robustness check to our baseline results we use a different breakpoint. In the sample, the average number of days in that fall into the 3 temperature bins - below 25°C, between 25°C and 27°C, and above 27°C - are respectively 90 days, 226 days, and 49 days.

5.2 *Results*

The empirical analysis proceeds in two steps. The first step tests the hypothesis in the literature that temperatures affect firm productivity and if so, investigates the mechanism behind such effect. The second step then tests the predictions of the model that (1) increased temperatures reduces firms' revenues, profits, and market survival rate, and (2) high temperatures less affect the revenues of firms that invest in climate mitigation technology.

Effects of Temperatures on TFP

We start by showing that temperatures indeed affect firm total factor productivity as suggested in the climate and economic activity literature. To this end, we regress (log) TFP on temperature, constructed using the bin approach, following the regression specified in equation (7). The specification includes precipitation, labor, capital, firm age, export status, time trend, district fixed effects, as well as firm fixed effects. Standard errors are clustered at region-year pair to control for spatial correlation between firms within each region. To avoid multicollinearity, we omit the bin with number of days between 25°C and 27°C. Consequently, the coefficients for other bins indicate the effect of temperature relative to the reference bin.

As reported in Table 2, we find economically meaningful and statistically significant negative effects of high temperatures (days with average temperatures above 27°C) on TFP. In the first columns (1) and (3) no other variable except rainfall are controlled for. The second columns (2) and (4) represent the baseline results. They differ from the first in that key firms characteristics including labor, capital, age, and export status are controlled for. Throughout columns (1)-(4), temperatures bins are constructed using daily mean temperature. In columns (1) and (2), the independent variable is TFP estimated using Gandhi-Navarro-Rivers method and in columns (3) and (4), we use TFP estimated using Ackerberg-Caves-Frazer estimator as a robustness check.

The main results confirm the hypothesis in the literature that temperature affects economic activity. Our preferred specification indicates that a one-standard-deviation rise in days with average temperatures above 27°C reduces firm TFP by 3.62%[2] relative to the impact of days with average temperature between 25°C and 27°C[3]. At a first glance this effect of temperatures on TFP seems a bit small. However, one should take into account the fact it is biased downward (as we will later see) since the sample contains firms that use climate mitigation technology. On the other hand, we generally find that days with temperatures below 25°C have no significant effect on economic activity. In general, controlling for firm key characteristics produces different estimates, suggesting that the effect of high temperatures on firms is heterogeneous. The main findings are robust whether we use a different measure of TFP, a different temperature breakpoint, or control for lagged temperatures. Furthermore, the null hypothesis that the effects of all the temperature bins are jointly equal to zero, are rejected in all the specifications.

5.2.2 *Mechanisms of Transmission of the Observed Effects*

Given the importance of the established negative effects of high temperatures on firm TFP, our next focus is to understand the mechanisms through which such effects took place. Unlike previous studies, which have been mainly focused on labor productivity as the mechanism though which temperatures affect economic activities (Sudarshan et al., 2015; Zivin and Neidell, 2014) we also decided to test if capital productivity is a viable channel through which temperatures affect firm activity. Moreover, we also test whether labor intensive and out-door firms are more affected by temperatures.

[2] This is estimated by multiplying the coefficient on days above 27°C in column 2 of Table 2 (-0.07) by the standard deviation of days above 27°C in Table 1 (51.68 days). Please note that the dependent variable is already by 100 to reduce the number of decimal points in the coefficients.
[3]One standard deviation in days with average temperature above 27°C is 51.7 days.

Effects on labor and capital productivity

Since TFP can be thought of as a weighted average of labor and capital productivity, then it is important to know if the observed effects of temperatures on TFP were through labor, capital productivity, or both. Because of our inability to estimate labor and capital productivity separately in a Cobb-Douglas production function, we use wage per capita and the price of capital - imputed from total value added minus total wage bill, divided by net value of fixed assets as a proxy for labor and capital productivity, respectively. Payroll has been previously used in the literature to estimate the effects of temperature shocks on labor productivity (Park, 2016). This choice is motivated by the fact that changes in wage per capita closely reflect changes in marginal labor product. However, the drawback is that it might also include changes in labor supply.

We could also directly test if the observed effect of temperatures on TFP solely originates from labor productivity by including an interaction of labor-intensive variable (firms with higher labor per sales) and temperature bins in equation (7). However, there are a number of potential issues that can result from such estimation. First, both labor and sales might change because of temperatures. If temperature shock decreases firm value added, then for the same number of employees (e.g. same number of workers, produce less), what is the impact on sales? If price does not change, sales decrease too, and labor intensity will increase. If price moves up due to excess demand, effect on labor intensity is ambiguous. Second, there might be more variability to labor supply of more weather dependent firms or possibly a difference in labor supply between firms that can adjust labor and others that will keep them idle, at the expense of the level of wage. For the above reasons, our preferred estimation approach is to directly test the effect of temperatures on labor and capital productivity using proxy.

Table 3 represents the effect of temperature on labor and capital productivity. Regression models are estimated using equation (7). Results in column (1) and (2) suggest that a one-standard-deviation rise in days with higher temperatures reduces labor and capital productivity by 6.25% and 22.74% respectively. Using average labor and capital elasticity from our GNR and ACF productivity estimation[4], the weighted sum of the affect of temperatures on labor and capital productivity suggest that a one-standard-deviation rise in days with high temperatures reduces firm productivity by 5.97% and 2.16% respectively. These effects are in the range of what we found in our main results as the effects of high temperatures on TFP. These results provide strong support that capital productivity is as well affected by temperatures; a channel that has not been so far well explored in the literature.

Effects of Temperatures on Labor Intensive and Out-door Firms

To test whether labor intensive firms or firms that operate outdoor are differentially affected by temperatures, we regress (log) TFP on temperature bins and their interactions with a dummy for labor intensive firms and out-door firms, respectively. We classify firms in the agriculture and construction sectors as out-door firms since most of the activities of those firms are implemented outdoor. Given that labor supply might be endogenous to temperatures, we define labor intensity in the initial year, as a number of employees over total sales. However, we are conscious this definition prevents labor

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[4]The average elasticity for labor and capital using GNR method are 0.3 and 0.14, respectively. Using ACF method, the average elasticity for labor and capital are respectively 0.2 and 0.04.

intensity status to change of overtime, which is likely to create other bias if firm labor change overtime for reasons that are not related to weather.

In columns (1) and (2) of Table 4, labor intensity is defined as either below or above the mean of raw labor intensity. As such, labor-intensive firms are classified as firms with the ratio of initial labor over initial sales above the mean value. Similarly in columns (3) and (4) labor intensity is defined using the median value of the ratio (initial labor/ initial sales), and consequently firms with value above the median as classified as labor intensive. Using both, our preferred TFP measures (GNR) and ACF, we found statistically significant negative coefficients on the interaction terms in column (1) and (2) suggesting that labor-intensive firms are more affected by non labor-intensive firms. However, when labor-intensive firms using the median raw labor intensity, the results are no more significant. This result provides an additional support to the claim that labor productivity is a viable channel through which temperature affects economic activity. On the other hand, using our baseline TFP measures (GNR) we found no evidence that firms operating mostly outside are more affected by temperatures (Table 5). Although using TFP measures by ACF we find a significant coefficient on the interaction term, we conclude that temperatures do not differently affect the TFP of outside firms.

5.2.3 *Testing the Predictions of the Model*

Effects of Temperature on Firm Revenues and Profits

We next test the hypothesis 1, 2, and 3 from the model, according to which extreme temperatures reduce firm revenues, profits, and survival rate. To do so, we follow the regression specified in equation (7) by regressing (log) revenues and (log) profits on temperature[5]. As the outcome measures for revenues and profits, we use total sales and profits reported by the firms. We also use our own estimated firm profit as a robustness check to firm reported profits. To assess the impact of temperatures on firm survival rate, we regress exit on lagged temperature bins. The choice of lagged temperatures over current temperatures in the case of firm exit is motivated by three factors. First, firm exit is not reported in the data; therefore, we classified a firm to be exiting when it does not appear in the last two rounds of the panel. Although this definition of exit is a bit more conservative, we believe it is appropriate since it is common in long panels for firms to disappear in one round and reappear in the next round. Second, since output measures are annual instead of monthly, it is possible that a firm starts the process of exiting in a prior year, therefore, current temperatures is less likely to have an impact on the observe exit. Finally, it is very likely that temperatures in previous years have an impact on current output (Dell et al., 2012; Deryugina and Hsiang, 2014). For example, extreme temperatures in a prior year may slow down capital accumulation and reduce short-term cash flows. This outcome may affect firm competitiveness and increase its probability of exiting the market. In all the specifications, we control for precipitation, labor, capital, firm age, export status, time trend, district fixed effects, as well as firm fixed effects. In the regression of firm exit, we also control for firm productivity. Standard errors are clustered at region-year pair to control for spatial correlation between firms within each region.

Table 6 provides a strong empirical support for hypothesis 1, 2, and 3. There is a strong negative and statistically significant relationship between temperatures and the

[5]To avoid multicollinearity, we omit the bin with number of days between 25°C and 27°C. Consequently, the coefficients for other bins indicate the effect of temperature relative to the reference bin.

three outcomes of interest: firm revenues, profits, and market survival rate. This result is robust whether we use a different temperature bin's breakpoint, a different measure of profits, or control for lagged temperatures. Also, the null hypothesis that the effects of all the temperature bins are jointly equal to zero, are rejected in all the specifications. Column (1) contains the result of the effect of temperatures on firm revenues, Columns (2) and (3) represent the effect on profits, and columns (4) and (5) report the effect of lagged temperatures on firm exit. The second columns (5) differ from the first column (4) because of the addition of temperature bins lagged by two-year.

A one-standard-deviation rise in days with average high temperatures (above 27°C) respectively reduces firm revenues and profits by 14.83% and 21.71% relative to days with moderate average temperatures (below between 25°C and 27°C)[6]. The estimated impact of one-standard-deviation rise using own estimated profits is somewhat smaller, although the two profit measures are strongly correlated. By contrast, while the effects of days with average temperatures below 25°C is not significant using our estimated profits, it has a very large and significant coefficients on firm reported profits. This result suggests that not only high temperatures but also cooler than average temperatures might negatively affect firm profits. On the other hand, a one-standard-deviation rise in one-year lagged days with average high temperatures (above 27°C) increases exit rate by 0.044 percentage points[7]. This is a 35% increase in average firm exit rate of 12.62%. The

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[6] 14.83% and 21.71% are obtained by multiplying the coefficients on days above 27°C in column (1) and (2) of Table 6 by the standard deviation of days above 27°C (51.68 days). Please note that the dependent variable is already by 100 to reduce the number of decimal points in the coefficients.

[7] 0.044 is obtained by multiplying the coefficients on days above 27°C in column (4) of Table 6 by the standard deviation of days above 27°C (51.68 days). Please note that the dependent variable is already by 100 to reduce the number of decimal points in the coefficients.

effect of temperatures on firm survival is an important implication of climate change that has not yet been analyzed in the literature.

From the above results, it is clear that the economic consequence of the extreme temperatures is considerable in developing countries. For example, using the average aggregate revenues in the sample ($4.12 billion), a one-standard-deviation rise in the number of days with average high temperatures reduces total average firm revenues by around $611 million compared to the impact of days with moderate average temperatures. When we extrapolate this estimate using the share of manufacturing (33% of 2016 GDP)[8], we find the cost to the national economy is around $1.8 billion, or about 5% of the GDP. While appropriate climate adaptation mechanisms can help firms to mitigate the impact of temperatures, widespread use of such mechanisms is likely to be undermined in most developing countries due to firm limited access to credits.

Effects of Temperature on Firms Investing in Technology

To test hypothesis 3 from the model that temperature has a lesser affect on the revenues of firms that invest in climate mitigation, we regress (log) revenues on temperature bins and their interactions with a dummy indicating whether the firms invest in climate technology or not. Except the dummy variable and its interactions with temperature bins, the specification is similar to the one described in the previous section.

This specification requires the use of an empirical proxy to indicate firms that invest in climate mitigation technology. In the absence of direct observation of firm investment choice in climate mitigation technology, we exploit firm level of fixed and financial

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[8] The GDP of Côte d'Ivoire in 2016 was $36.16 billion. We estimate the country wide cost ($1.8 billion) by multiplying the share of manufacturing in GDP (33%*36.16) by the effect of temperatures on revenues (14.83%).

assets. This choice is motivated by the presumption that firms with more asset, less financially constrained, are more likely to invest in technology that improve the performance of their workers. Consequently, we classify firms that invest in climate technology as those with total fixed and financial asset above the mean or median values. Column (1) and (2) in Table 7 represent the effects where adoption choice is defined as using mean and median total asset values, respectively. In both regressions, we have very strong evidence that firms investing in climate mitigation technology are less affected compared to those that do not. For instance, the effect of one-standard-deviation rise in days with high temperature on revenues is reduced by 8.73.% (more than half of the total effects) for firms investing in climate mitigation technology compared to those that do not. In other word, this result suggests that while temperatures affect economic activity, it has affected economic entities heterogeneously. This is a very important finding and could have important policy implication. In the next section, we discuss potential treats to our results and provide some robustness checks.

5.3 *Robustness Checks*

It is important to assess whether the strong relationship between economic activity and weather established in baseline regressions is causal. Our identification is from plausibly exogenous variations in temperature within firms over time after controlling for firm specific characteristics and shocks common to districts where firms are located. There are, however, a couple of potential issues that can affect our results. First, the concentration of firms in few locations creates potential problems for our identification of the effects. As in many other developing countries, most of the formal economic activity in Côte d'Ivoire is concentrated in the capital, Abidjan. As such, while the level of temperatures changes overtime, the majority of the firms in our sample experience more or less the same level of temperature for a given period. Second, there could be a legitimate concern that our baseline results include effects other than the effects of high temperatures such as time or different political crisis effects on firm revenue and productivity. Third, because of the requirement of productivity estimation, missing data issues, and entry and exit of firms over time, our main specification is estimated using an unbalanced sample of firms. As a result, selection issues could threaten the validity of our baseline findings. Finally, it could be argued that our measure of temperature shock is a not a good enough proxy for the true temperature shocks observed by firms. One could also think that it is not only the level of temperature that affects economic activity but also the variability of temperature, which increases with climate change. We perform several robustness checks, reported in the appendix, to address all the above issues.

Table A1 shows how robust our baseline results are to increasing variation in temperature measures. To introduce more variation in the location of firms, and consequently in our temperature data, we divide Abidjan into two sub-regions North and South. We gather new temperature measures for each sub-region and match them with our firm data. To test whether there is any variation between new temperature measures, South-Abidjan and the former temperature measure of the region of Abidjan, we estimate the correlation between the two measures. As it can be seen in Table A1.2, there are some variations left in the temperatures of South-Abidjan that are not explained by the previous temperature measures of Abidjan. Thus, dividing Abidjan into two sub-regions slightly increases the variability in our temperatures measures for a given period in time. The results when Abidjan is divided in two zones are similar, with slightly larger coefficients, to baseline results. The result of Table 4, 5, and 7 provide an alternative identification strategy by relying on firm vulnerability to temperatures. The effect of temperature on revenue and TFP might differ across firm's types because of the difference in climate exposures, resistance to temperatures, or simply the use of climate adaptation technology such as air conditioning. Given our lack of information on individual firm vulnerability or adaptation strategy to temperature shocks, we assume that labor intensive firms or firms that perform most of their activity outdoor, agriculture and construction, are more vulnerable to temperatures. The results are qualitatively similar to our main results. When the interaction between temperature bins and dummy for labor intensive firms, firms that invest in climate mitigation technology, or firms that perform outdoor activity are including in the regressions, the main coefficients are still significant and the coefficient on the interaction terms have the right sign and significant in most cases.

In the last section of Table A, we control for conflict years. Côte d'Ivoire experienced two major crises over the past 15 years. In September of 2002 a military mutiny led to a rebellion that ended up splitting the north and the south of the country from 2002 to 2007. While the conflict was not intense throughout the whole period of 2002-2007 that many people refer to as "no peace no war period" it has an impact on firm productivity as suggested by Klapper et al. (2015). Also, in 2011 the country experienced a brief post-election crisis. Although the second crisis was very short, it might also have affected economic activity. After controlling for conflict years, we still find similar estimates of the effect of temperatures although the magnitude is somehow smaller than the ones found in the baseline.

Based on results in Table A1, we conclude that our baseline results are robust to alternative identification strategy. Furthermore, the fact that we are able to find statistically significant effects in our baseline results despite the heavy concentration of firms in Abidjan suggests our result would have been even stronger if firms were evenly distributed throughout the country.

Table A2 presents the results from several robustness checks on alternative sub-sample of the data. First, we replace the clean sample of firms from the baseline specification by a larger sample of firms by only dropping firms with missing sales. Since we cannot estimate productivity measures used in the main specification using this sub-sample[9], we proxied TFP by value added per capita, estimated for firms, which reported positive value added. In both estimations, we find similar qualitative results on firm revenues and productivity, with the effects on value added per capita somewhat larger in magnitude than the effects on our TFP measures in baseline regressions. Finally, we dropped firms with gaps appearance in the panel to test the sensitivity of the baseline results the structure of the panel data. As shown by the results, the effect of high temperature on firms' revenues and productivity is similar to the findings in the main regressions. Results in Table A2 provide strong evidence that our baseline results are not driven by the structure of the data. In all the specifications with different sub-samples, we the effect of high temperatures on firms' revenues and productivity remains negative, large, and statistically significant.

In Table A3 we run our baseline specification using alternative measures of temperatures shocks. First, instead of 27°C, we define our extreme temperatures as days

[9]The estimation of TFP using either GNR or ACF method requires non-missing values for not only firm revenue but also capital, labor, and intermediate inputs. That is the reason why the sample used in the baseline specifications is a smaller sub-sample of the data.

with temperatures below and above bottom 10% and top 10% of temperature distribution. Even using the new temperature bins, the estimates of the effect of high temperatures on firms are nearly identical to our baseline results when we re-define a different breakpoint for temperature shock. Table A3 also presents results using alternative measures of temperatures. As mentioned above, it could be the case that our measures do not well capture the effect of temperatures on economic activity. To compare our baseline estimates to estimates using other measures of temperature, we re-estimate equation (7) by replacing temperature bins by average temperatures and the coefficient of variation (CV) of daily temperatures respectively. While results of robustness checks using average temperature, qualitatively suggest that an increase in average temperatures negatively affect economic activity, the magnitude of the estimates is way too big and not statistically significant. This could be explained by the fact that yearly average temperature is a very poor indicator of temperatures. Results using the variability in daily average temperatures, CV, also suggest that they poorly capture the effect of temperatures on economic activity when compared to temperature bins used in our main specification. While regression estimates suggest that high coefficient of variation of daily temperatures is negatively corrected with economic activities, the estimates of the effect are often very large and not statistically significant. The weak and inconsistent estimate of the effect of CV suggests that temperature variability is not a major driver of the effects of temperatures on economic activity.

To conclude the results of this section, our baseline results are consistent and robust to different identification strategy, controlling for conflict years, using alternative sub-samples of the data, and different temperature bins and measures. In most cases, we find strong support for our main results that high temperatures affect firm activities.

6. Conclusion

The implementation of optimal climate policy requires better understanding of the mechanisms behind the established negative relationship between temperatures and aggregate outputs. This study provides an inclusive treatment of the relationship between temperatures and key firm competitiveness measures. To this end, we develop a model by introducing climate mitigation technology choice in a standard trade model with cross-country differences in climate costs. Applying our model to a large panel of manufacturing, service, and agricultural firms in Côte d'Ivoire from 1998 to 2013, we found that temperature affects firm productivity as argued in the literature. Consequently, high temperatures reduce firms' revenues, profits, and survival rate. The effect of temperatures on revenues is reduced for firms likely to invest in climate mitigation technology.

We also explore the mechanisms through which temperatures affect firm outcomes and which type of firms are most likely to suffer from the established effects. Our results suggest the effect of temperatures on total factor productivity is through its effect on both labor and capital productivity. While the labor productivity channel has been investigated in the previous literature, there are fewer evidences on capital productivity as a channel through which temperatures affect economic activity. Moreover, while our results provide supportive evidence that labor-intensive firms suffer from high temperatures, we could not find strong evidence that outdoor firms, agriculture and construction firms, are more affected by high temperatures.

The findings in this paper have two important implications. First, regarding the current analysis of the impact of weather on economic activity, our results suggest that we should take into account the role of climate mitigation technology and pay close attention to how temperatures affect the competitiveness of firms. Neglecting these two factors will result in inaccurate measures of the impact of temperatures on economic activity. Second, while temperature affects all firms, labor-intensive and small firms with less capital are the most vulnerable to increased temperatures. Consequently, it is critical for optimal climate policy in developing countries to facilitate the use of adaption technology by paying particular attention to labor-intensive and small firms.

Future research should pay particular attention to the role of technology choice in mitigating the impact of weather conditions on firms' outcomes. While we try to respond this question using a rough proxy for firms' technology choice, we believe that with a more detailed data on firms' technology use, one can provide a better analysis of the role of technology in mitigating the effect of climate on firms. Moreover, it will be important to know which types of firms are likely to adopt climate mitigation technology.

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Figures:

Figure 1: Producing and Technology Choices

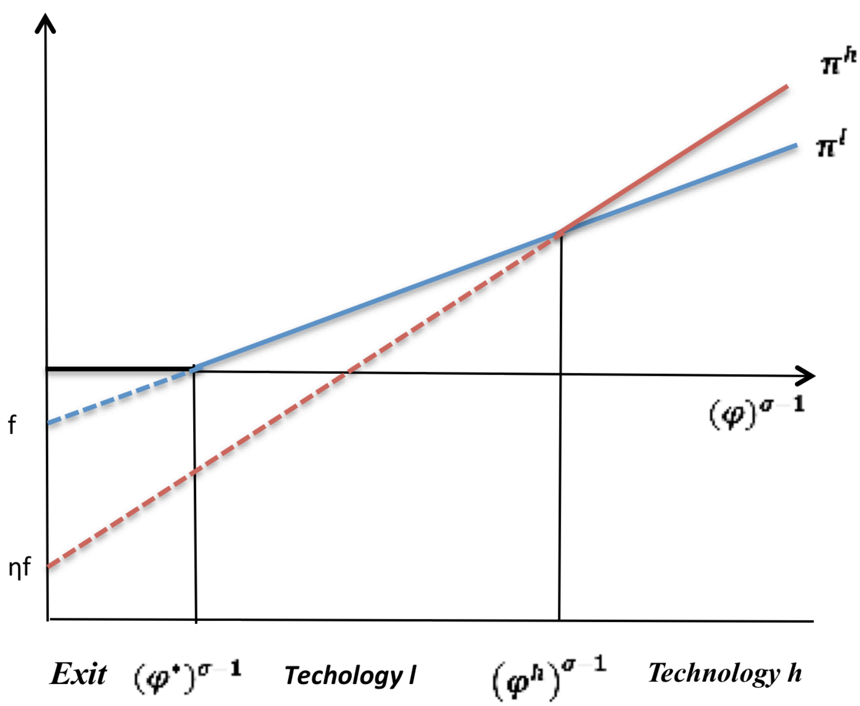
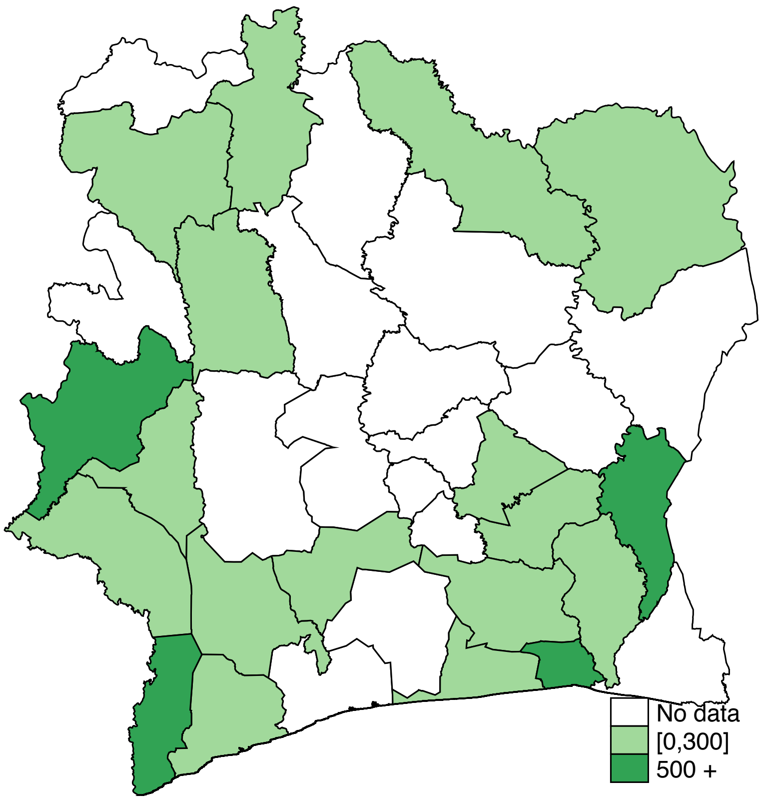
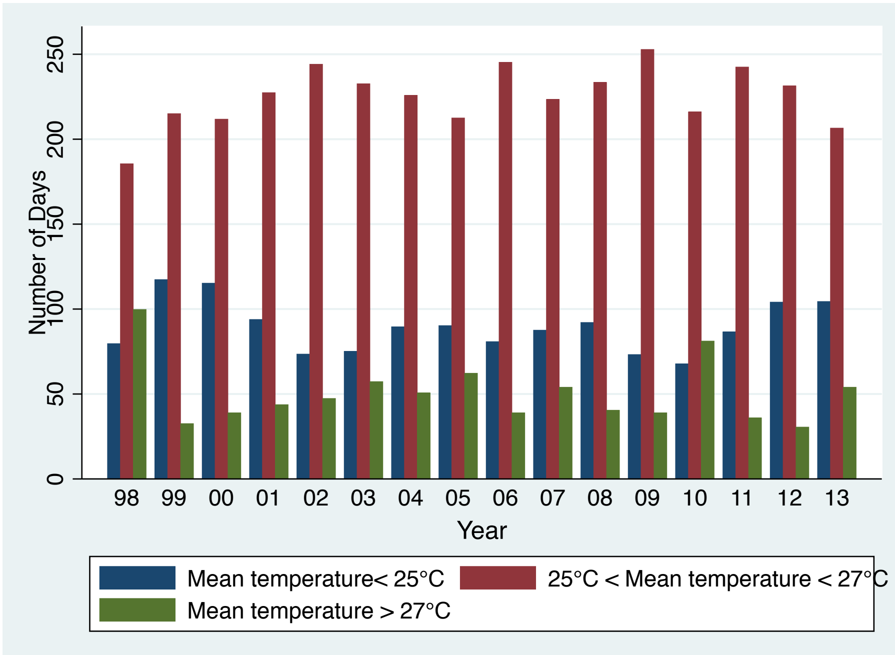


Figure 2: Geographic Distribution of the Number of Firms



Notes: this figure reports the average number of firms for each region during the period of 1998-2013

Graph 3a: Distribution of Daily Temperatures over Years



Graph 3b: Distribution of Daily Temperatures over Regions

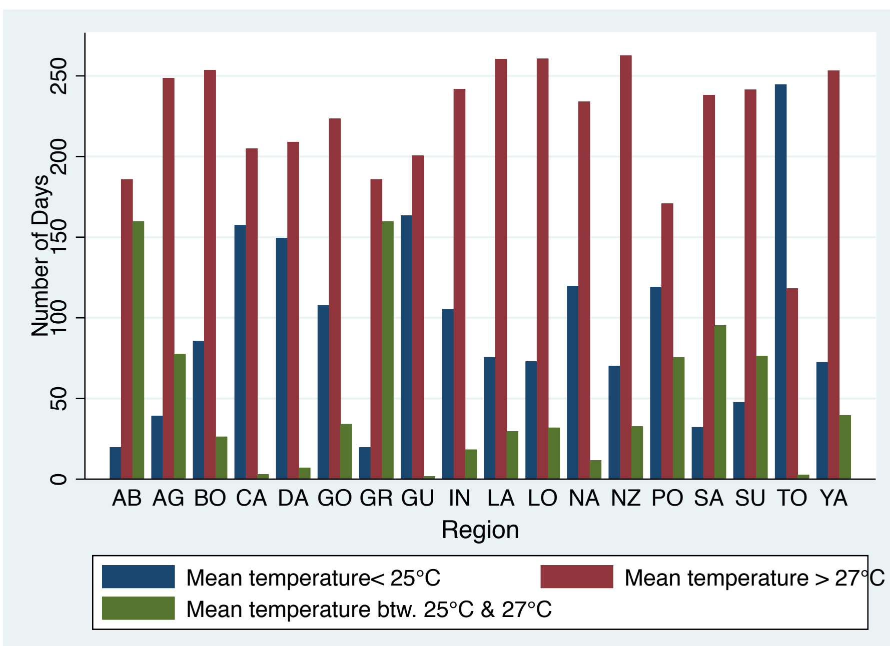
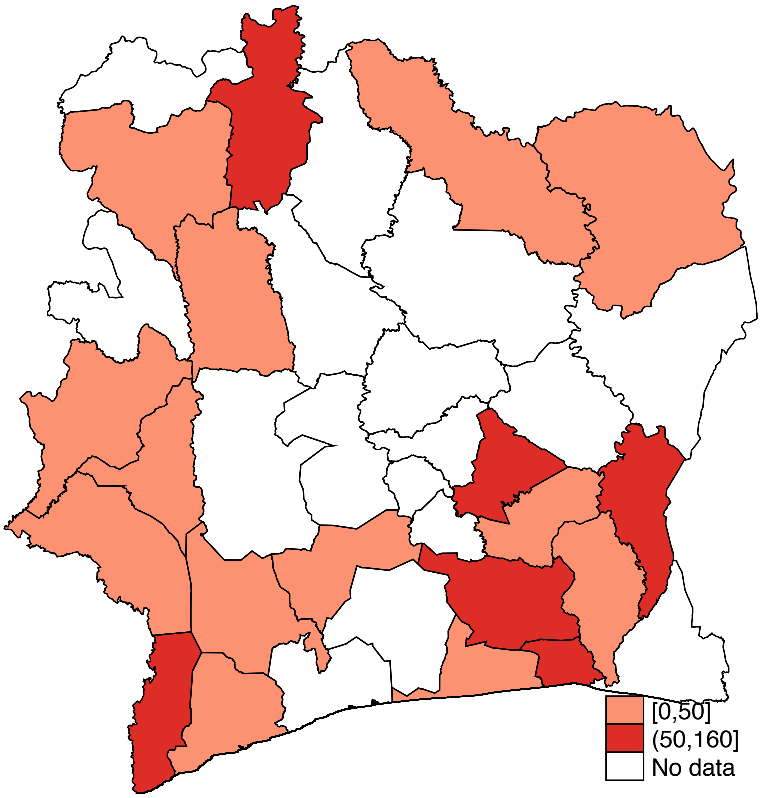


Figure 3: Geographic Distribution of the number of days above 27°C



Notes: this figure represents the average number of days with temperature above 27°C for each region during the period of 1998-2013

Tables:

Table 1: Summary Statistics of Firm and Weather Data

Variables	Obs	Median	Mean	SD	Min	Max
Firm - Year Data						
Revenue (000 USD)	34,670	259.8	1,861	5,754	0.746	77,187
Profit (000 USD)	34,670	4.854	53.38	1,530	-26,716	256,726
Value Added (000 USD)	25,142	78.61	391.6	988.9	0.00346	20,424
Log TFP (GNR)	34,667	8.123	8.209	1.073	4.06	12.95
Log TFP (ACF)	34,667	2.585	2.402	1.016	-6	10.81
Labor (person)	34,670	9	40.07	124.5	1	3,210
Payroll (000 USD)	34,627	30.96	191.5	478	0.348	4,889
Total Asset (000 USD)	34,670	55.37	708.3	2,647	0.254	53,837
Capital (000 USD)	34,670	48.26	638.4	2,411	0.254	40,833
Firm Age (year)	34,670	9	11.65	9.95	1	96
Firm Exit	27,188	-	0.126	-	-	-
Number of Firms	8,979	8,979	8,979	8,979	8,979	8,979
Weather-Year Data						
Temperature (C)	304	25.73	25.76	0.537	24.17	27.02
Days below 25C	304	85	89.99	51.97	4	274
Days above 27C	304	26	48.82	51.68	0	197
Precipitation (mm)	304	2,212	2,203	402.8	1,100	3,305

Notes: the data covers all registered firms in Cote d'Ivoire. Labor is measured by employment and all monetary units are deflated in 1998 CFA and converted in thousand of USD. Precipitation is annual cumulative values in mm. Temperature variables are estimated using daily average temperatures.

Table 2: Effects of Temperature on TFP

	TFP (GNR)		TFP (ACF)	
	(1)	(2)	(3)	(4)
Days below 25C	-0.084*	-0.054	0.047	0.013
	(0.046)	(0.038)	(0.032)	(0.035)
Days above 27C	-0.078***	-0.070***	-0.107***	-0.102***
	(0.026)	(0.024)	(0.033)	(0.030)
Observations	34,644	34,644	34,644	34,644
Control	NO	YES	NO	YES
Firm FE	YES	YES	YES	YES
District FE	YES	YES	YES	YES
Time Trend	YES	YES	YES	YES
F-test (All bins=0)	6.825	6.397	5.301	5.840
Prob>F	0.00126	0.00190	0.00546	0.00325

Notes: the dependent variables are logarithms of TFP (multiplied by 100 to reduce the number of decimal point in the coefficients). In columns (1)- (2) and (3)-(4) TFP is measured respectively by Grandhi-Navarro-Rivers estimator and Ackerberg-Caves-Frazer estimator. Bins are constructed using daily average temperature. The comparison bin is the number of days with average temperature between 25°C and 27°C. Control variables include rain, rain square, (log) capital, (log) labor, and dummies for export status, and age above firm median age. Standard errors are clustered at region-year level. *** p<0.01, ** p<0.05, * p<0.1

Table 3: Effect of Temperature on Labor and Capital Productivity

	Labor Productivity	Capital Productivity
	(1)	(2)
Days below 25C	0.046	-0.978**
	(0.064)	(0.455)
Days above 27C	-0.121***	-0.439**
	(0.029)	(0.213)
Observations	20,693	20,693
Control	YES	YES
Firm FE	YES	YES
District FE	YES	YES
Time Trend	YES	YES
F-test (All bins=0)	8.463	4.196
Prob>F	0.000	0.016

Notes: the dependent variables are logarithms of labor and capital productivity multiplied by 100 to reduce the number of decimal point in the coefficients). Labor productivity is proxied by wage per capita andcapital productivity by value added ninus payroll divided by total fixed assets. All observation with missing value added have been dropped. The comparison bin is the number of days with average temperature between 25°C and 27°C. Rain, rain square, dummy for export status, age above medium are controlled for in all the regressions. (log) asset and (log) labor are respectively controlled in column (1) and (2). Standard errors are clustered at region-year level. *** p<0.01, ** p<0.05, * p<0.1

Table 4: Effect of Temperature on Labor Intensive Firms

	TFP (GNR)	TFP (ACF)	TFP (GNR)	TFP (ACF)
	(1)	(2)	(1)	(2)
	Labor Intensity (above mean)		Labor Intensity (above median)	
Days below 25C	-0.057*	-0.006	-0.067**	-0.036
	(0.034)	(0.029)	(0.032)	(0.027)
Days above 27C	-0.061**	-0.058*	-0.064***	-0.044
	(0.024)	(0.032)	(0.022)	(0.043)
25C X Above Mean	0.049	0.279**		
	(0.048)	(0.133)		
27C X Above Mean	-0.066*	-0.321*		
	(0.035)	(0.177)		
25C X Above Med			0.044	0.172**
			(0.029)	(0.072)
27C X Above Med			-0.016	-0.142
			(0.014)	(0.091)
Observations	34,644	34,644	34,644	34,644
Control	YES	YES	YES	YES
Firm FE	YES	YES	YES	YES
District FE	YES	YES	YES	YES
Time Trend	YES	YES	YES	YES
F-test (Interactions=0)	3.189	5.181	2.743	5.749
Prob>F	0.0426	0.00613	0.0660	0.00355

Notes: the dependent variables are logarithms of TFP (multiplied by 100 to reduce the number of decimal point in the coefficients). Raw labor intensity is defined as the ratio of employees to sale. In columns (1) and (2), labor intensive firms are classified as those with raw labor intensity above the mean. Similarly, in columns (3) and (4) labor intensive firms are those with raw labor intensity above the median. The comparison bin is the number of days with average temperature between 25°C and 27°C. Rain, rain square, (log) capital, dummy for export status, age above medium are controlled for in all the regressions. Standard errors are clustered at region-year level. *** p<0.01, ** p<0.05, * p<0.1

Table 5: Effect of Temperature on Outdoor Firms

	TFP (GNR)	TFP (ACF)
	(1)	(2)
Days below 25C	-0.049	0.017
	(0.036)	(0.031)
Days above 27C	-0.070***	-0.088***
	(0.023)	(0.027)
25C X Outdoor Firm	-0.044	-0.032
	(0.048)	(0.106)
27C X Outdoor Firm	-0.002	-0.117**
	(0.047)	(0.052)
Observations	34,644	34,644
Control	YES	YES
Firm FE	YES	YES
District FE	YES	YES
Time Trend	YES	YES
F-test (All interactions=0)	0.463	2.818
Prob>F	0.630	0.0613

Notes: the dependent variables are logarithms of revenues and TFP (multiplied by 100 to reduce the number of decimal point in the coefficients). Outdoor firms are construction and agriculture firms. The comparaison bin is the number of days with average temperature between 25°C and 27°C. Rain, rain square, (log) capital, (log) labor, dummy for export status, age above medium are controlled for in all the regressions. Standard errors are clustered at region-year level. *** p<0.01, ** p<0.05, * p<0.1

Table 6: Effect of Temperature on Firm Revenues, Profits, and Exit Rate

	Revenue	Profit (reported)	Profit (estimated)	Exit	Exit
	(1)	(2)	(3)	(4)	(5)
Days below 25C	-0.148	-0.654***	-0.050		
	(0.001)	(0.237)	(0.167)		
Days above 27C	-0.287***	-0.422***	-0.203**		
	(0.001)	(0.113)	(0.088)		
Lag1 days below 25C				-0.009	0.014
				(0.049)	(0.043)
Lag1 days above 27C				0.086**	0.090***
				(0.036)	(0.030)
Lag2 days below 25C					0.036
					(0.039)
Lag2 days above 27C					0.115**
					(0.048)
Observations	34,647	23,156	21,048	27,177	27,177
Control	YES	YES	YES	YES	YES
Firm FE	YES	YES	YES	YES	YES
District FE	YES	YES	YES	YES	YES
Time Trend	YES	YES	YES	YES	YES
F-test (All bins=0)	6.397	10.67	2.653	3.796	2.904
Prob>F	0.001	0.000	0.072	0.023	0.022

Notes: the dependent variables are dummy for exit and the logarithms of revenues and profits (multiplied by 100 to reduce the number of decimal point in the coefficients). While reported profits are the profits reported by the firm, estimated profits are the profits we estimated using firm production information. We assume the cost of capital to be 10% of total capital (depreciation rate). The comparison bin is the number of days with average temperature between 25°C and 27°C. Rain, rain square, (log) capital, (log) labor, dummy for export status, age above medium are controlled for in all the regressions. Standard errors are clustered at region-year level. *** p<0.01, ** p<0.05, * p<0.1

Table 7: Effect of Temperature on the Revenue of Firms Investing in Climate Mitigation Technology

	Revenue	
	(1)	(2)
Days below 25C	0.017	0.000
	(0.106)	(0.115)
Days above 27C	-0.292***	-0.330***
	(0.083)	(0.090)
25C X Technology (Mean)	-0.123**	
	(0.049)	
27C X Technology (Mean)	0.169***	
	(0.054)	
25C X Technology (Median)		-0.040
		(0.047)
27C X Technology (Median)		0.126***
		(0.038)
Observations	34,647	34,647
Control	YES	YES
Firm FE	YES	YES
District FE	YES	YES
Time Trend	YES	YES
F-test (Interactions=0)	11.95	10.15
Prob>F	0.000	0.000

Notes: the dependent variable is(log) TFP (multiplied by 100 to reduce the number of decimal point in the coefficients). Technology adaption is proxied by firm total asset. Firm with total assets above either the average or the median total assets in the sample are defined as those likely to invest in climate mitigation technology. The comparison bin is the number of days with average temperature between 25°C and 27°C. Rain, rain square, (log) capital, (log) labor, dummy for export status, age above medium are controlled for in all the regressions. Standard errors are clustered at region-year level. *** p<0.01, ** p<0.05, * p<0.1

Online Appendix A

A. Theoretical Model, Comparative Statics

$A.1.1.\ \dfrac{\partial\pi(\varphi,\theta)}{\partial\theta} < 0$

$$\pi^l(\varphi,\theta) = \gamma(\theta)^{1-\sigma}\frac{1}{\sigma}E(P\rho)^{\sigma-1}\varphi^{\sigma-1} - f$$

Differentiating the above equation w.r.t. θ

$$\frac{\partial\pi^l(\varphi,\theta)}{\partial\theta} = \frac{(1-\sigma)}{\sigma\gamma(\theta)^{\sigma}}E(P\rho)^{\sigma-1}\varphi^{\sigma-1}\left(\frac{\partial\gamma(\theta)}{\partial\theta}\right) < 0\ because\ \sigma > 1\ and\ \frac{\partial\gamma(\theta)}{\partial\theta} > 0$$

$A.1.2.\ \dfrac{\partial r(\varphi,\theta)}{\partial\theta}$

The sign of $\frac{\partial r(\varphi,\theta)}{\partial\theta}$ is the same as the sign of $\frac{\partial\pi(\varphi,\theta)}{\partial\theta}$ in (A.1.1), therefore $\frac{\partial r(\varphi,\theta)}{\partial\theta} < 0$.

$A.2.1.\ \left|\dfrac{\partial\pi^h(\varphi,\theta)}{\partial\theta}\right| < \left|\dfrac{\partial\pi^l(\varphi,\theta)}{\partial\theta}\right|$

$$\pi^h(\varphi,\theta) = \gamma(\theta)^{1-\sigma}\frac{1}{\sigma}E(P\rho)^{\sigma-1}\varphi^{\sigma-1}\lambda(\theta)^{\sigma-1} - \eta f$$

Differentiating the above equations w.r.t. θ

$$\frac{\partial\pi^h(\varphi,\theta)}{\partial\theta} = (1-\sigma)\frac{(\rho P\varphi)^{\sigma-1}}{\gamma(\theta)^{\sigma}}\frac{E}{\sigma}\lambda(\theta)^{\sigma}\left[\frac{\frac{\partial\gamma(\theta)\lambda(\theta)}{\partial\theta} - \frac{\partial\lambda(\theta)\gamma(\theta)}{\partial\theta}}{\lambda(\theta)^2}\right]$$

Using the derivation in (A.1.1), $\left|\frac{\partial\pi^h(\varphi,\theta)}{\partial\theta}\right| < \left|\frac{\partial\pi^l(\varphi,\theta)}{\partial\theta}\right|$ implies that:

$$\frac{\partial\gamma(\theta)}{\partial\theta} > \lambda(\theta)^{\sigma}\left[\frac{\frac{\partial\gamma(\theta)\lambda(\theta)}{\partial\theta} - \frac{\partial\lambda(\theta)\gamma(\theta)}{\partial\theta}}{\lambda(\theta)^2}\right]$$

From the investment constraint in technology, equation (1.1), firms will only invest in climate mitigation technology if its benefits are positive; therefore, the above inequality has to hold.

$$A.2.2\ \left|\frac{\partial r^{h}(\varphi,\theta)}{\partial\theta}\right| < \left|\frac{\partial r^{l}(\varphi,\theta)}{\partial\theta}\right|$$

The condition for this inequality to hold is the same as in (A.2.1), therefore, $\left|\frac{\partial r^{h}(\varphi,\theta)}{\partial\theta}\right| < \left|\frac{\partial r^{l}(\varphi,\theta)}{\partial\theta}\right|$.

$$A.3\ \frac{\partial\varphi^*}{\partial\theta} > 0$$

$$\varphi^* = \left(\frac{\sigma f}{E}\right)^{\frac{1}{\sigma-1}}\frac{\gamma(\theta)}{P\rho}$$

Differentiating the above equation w.r.t. θ

$$\frac{\partial\varphi^*}{\partial\theta} = \frac{1}{P\rho}\left(\frac{\sigma f}{E}\right)^{\frac{1}{\sigma-1}}\left(\frac{\partial\gamma(\theta)}{\partial\theta}\right) > 0\ because\ \frac{\partial\gamma(\theta)}{\partial\theta} > 0$$

Online Appendix B

B. Definition of key variables

Revenue: is measured as the annual total sales, domestic and foreign sales, of the firm.

TFP (GNR): is firm total factor productivity measured using Ghandi-Navarro-Rivers productivity estimator.

TFP (ACF): is firm total factor productivity measured using Ackerberg-Caves-Frazer estimator productivity estimator.

Labor and Wage: labor is the total number of internal permanent and seasonal employees and the total wage bill of all internal works. When there was no internal employee declared, we replace labor by the total number of external worker.

Capital and Asset: capital is measured by the total value of fixed asset in the book values and asset is proxied by the total value of fixed and financial asset in the book values.

Intermediates: are defined as the sum of expenditure on raw materials, other goods, and services.

Firm exit: exiting firms are defined as firms that are not observed in the sample during the last two years of the panel, 2012 and 2013.

Online Appendix C

C. TFP Estimation

C.1 Gandhi, Navarro, and Rivers (GNR) Techniques

The relationship between output and inputs of firm *j* and time *t* are of the form:

$$Y_{jt} = F_t(L_{jt}, K_{jt}, M_{jt})e^{\nu}_{jt}$$

where *L*, *K*, *and M* are labor, capital, and intermediate inputs, respectively. Let $\nu_{jt} = \omega_{jt} + \varepsilon_{jt}$ be the hicks-neutral productivity shock with two elements: persistence productivity shock (ω_{jt}) and ex-post shock (ε_{jt}). The persistent shock ω_{jt} evolves exogenously following a Markovian process, which implies that the firm's expectation of future productivity depends only on past productivity. Therefore, it can be expressed as: $\omega_{jt} = h(\omega_{jt-1}) + \eta_{jt}$ where η_{jt} is the "innovation" in period *t* and satisfies $E(\eta_{jt}|\,\omega_{jt-1}) = 0$. Further, $E(\varepsilon_{jt}) = 0$. Let's denote $(e^{\varepsilon_{jt}}) = \varepsilon$. Labor and capital are dynamic and their values in period *t* are determined at or prior to period *t*-1. On the other hand, the intermediate input is flexibly determined at period *t*. This implies that:

$$E\left(\eta_{jt} + \varepsilon_{jt}\middle|L_{jt}, K_{jt}, L_{jt-1}, K_{jt-1}, M_{jt-1}, \dots, L_1, K_1, M_1\right) = 0 \qquad (1)$$

Assuming that intermediate inputs can be written as $M_{jt} = Z_t(L_{jt}, K_{jt}, \omega_{jt})$, where Z_t is a strictly monotone function in ω_{jt}. This implies that we can invert Z_t to obtain $\omega_{jt} = Z_t^{-1}(L_{jt}, K_{jt}, M_{jt})$. Let ρ_t be intermediate inputs price and P_t be the output. The first order condition with respect to intermediate inputs:

$$P_t F_{M,t}\left(L_{jt}, K_{jt}, M_{jt}\right)e^{\omega_{jt}} = \rho_t \qquad (2)$$

where $F_{M,t}$ is the partial derivative of the production function with respect to M. The logs of this first order condition and the production function form a system of equations.

$$log\rho_t = logP_t + logF_{M,t}\left(L_{jt}, K_{jt}, M_{jt}\right) + \omega_{jt}$$

$$logY_{tj} = logF_{M,t}\left(L_{jt}, K_{jt}, M_{jt}\right) + \omega_{jt} + \varepsilon_{jt}$$

Taking the difference of these two equations to remove the productivity shock, adding M_{jt} to both sides, and re-arranging results in the following equation:

$$s_{jt} = logG_t\left(L_{jt}, K_{jt}, M_{jt}\right) - \varepsilon_{jt} \qquad (3)$$

where $G_t\left(L_{jt}, K_{jt}, M_{jt}\right) = \frac{F_{M,t}\left(L_{jt},K_{jt},M_{jt}\right)M_{jt}}{F_t\left(L_{jt},K_{jt},M_{jt}\right)}$ is the elasticity of the production function with respect to the intermediate input, and $s_{jt} = \log\left(\rho_t M_{jt}\right)/\left(P_t Y_{jt}\right)$ is the log of the share of intermediate inputs to outputs. A non-parametric regression estimation of equation 3 using observable s_{jt} and data on $\left(L_{jt}, K_{jt}, M_{jt}\right)$ will identify the ex-post shock and the elasticity. If we divide both sides of the elasticity function by M_{jt}, we will get $\frac{G_t\left(L_{jt},K_{jt},M_{jt}\right)}{M_{jt}} = \frac{\partial F_t\left(L_{jt},K_{jt},M_{jt}\right)}{\partial M_{jt}}$. By the fundamental theorem of calculus:

$$\int \frac{G_t\left(L_{jt}, K_{jt}, M_{jt}\right)}{M_{jt}} dM_{jt} = logF_t\left(L_{jt}, K_{jt}, M_{jt}\right) + Q_t\left(L_{jt}, K_{jt}\right) \qquad (4)$$

which implies that the share regression in equation (3) can help us non-parametrically identify the production function up to a constant $Q_t\left(L_{jt}, K_{jt}\right)$.

If we subtract equation 4 from the production function, we will get the following:

$$logY_{jt} - \int \frac{G_t\left(L_{jt},K_{jt},M_{jt}\right)}{M_{jt}} dM_{jt} - \varepsilon_{jt} = -Q_t\left(L_{jt}, K_{jt}\right) + \omega_{jt} \qquad (5)$$

the left hand side of equation 5 is observable/identifiable from the data. Denoting this LHS expression by $\mathcal{R}_{jt}$, we have then,

$$\omega_{jt} = \mathcal{R}_{jt} + Q_t\left(L_{jt}, K_{jt}\right)$$

We have earlier assumed that $\omega_{jt} = h(\omega_{jt-1}) + \eta_{jt}$.

Thus, we can express equation 5 as:

$$\mathcal{R}_{jt} + Q_t\left(L_{jt}, K_{jt}\right) = h\left(\mathcal{R}_{jt-1} + Q_t\left(L_{jt-1}, K_{jt-1}\right)\right) + \eta_{jt} \qquad (6)$$

the moment restriction we have stated in equation (1) can then help to non-parametrically identify the following regression:

$$\mathcal{R}_{jt} = -Q_t(L_{jt}, K_{jt}) + \tilde{h}(\mathcal{R}_{jt-1}, L_{jt-1}, K_{jt-1}) + \eta_{jt} \quad (7)$$

From the above regression, we can recover $Q_t(L_{jt}, K_{jt})$, which implies that we can recover the production function using equation 4 and also the productivity shock.

C.2 Ackerberg, Cave, and Frazer Estimation Techniques

The ACF estimation procedure draws on aspects of both OP and LP, with the main difference that no coefficient is estimated in the first stage of estimation. However, the first stage is critical to get rid of the transmission bias. To fix ideas, consider the following value added production function,

$$y_{it} = \beta_L l_{it} + \beta_K k_{it} + \varphi_{it} + \varepsilon_{it}$$

where φ_{it} *and* ε_{it} represent respectively productivity and the error term. Labor is chosen by firms at time $t - b$ $(0 < b < 1)$. Then capital is chosen at or before $t - 1$. Finally material input is chosen at time *t*, after both labor and capital. Suppose that φ_{it} evolves according to a first order Markov process between these sub-periods, $t - 1,\ t - b, and\ t$. In other word:

$$p(\varphi_{it}|I_{it-b}) = p(\varphi_{it}|\varphi_{it-b})$$

and

$$p(\varphi_{it-b}|I_{it-1}) = p(\varphi_{it-b}|\varphi_{it-1})$$

Given the timing assumption (selecting labor, capital, and material input), a firm's material input demand at time *t* is a function of productivity, capital, and labor, that is:

$$m_{\square t} = f_t(l_{it}, k_{it}, \varphi_{it})$$

Inverting material input demand function for φ_{it} and replacing it in the production function results in the following first stage equation:

$$y_{it} = \beta_L l_{it} + \beta_K k_{it} + f_t^{-1}(l_{it}, k_{it}, m_{it}) + \varepsilon_{it}$$

While we cannot identify the coefficients in the first stage, we can exclude the portion of output determined by either the unanticipated shocks at time *t* or measurement error, that is, $\widehat{\Phi}_{it}$ of the composite term,

$$\widehat{\Phi}_{it} = \beta_L l_{it} + \beta_K k_{it} + f_t{}^{-1}(l_{it}, k_{it}, m_{it})$$

Using this equation we cannot still accurately identify the coefficient on labor and capital since the inverse function is also a function of labor and capital. In order to identify those coefficients, we need two independent moment conditions in the second stage. Given the first-order Markov assumption on productivity, we have:

$$\varphi_{it} = E[\varphi_{it}|I_{it-1}] + \xi_{it} = E[\varphi_{it}|\varphi_{it-1}] + \xi_{it}$$

where ξ_{it} is mean independent of all information known at *t-1*. Given the timing assumption, both capital and lagged labor are part of the information set at time *t-1*. This implies:

$$E\left[\xi_{it}.\begin{pmatrix} l_{it-1} \\ k_{it} \end{pmatrix}\right] = 0$$

These are the two moments conditions to identify β_K *and* β_L. We can recover the implied ξ_{it} for any value of the parameters (β_K, β_L) as follows. First, given any candidate estimates of (β_K, β_L), compute the implied productivity using this specification:

$$\varphi_{it}(\beta_K, \beta_L) = \widehat{\Phi}_{it} - \beta_k l_{it}, -\beta_L K_{it})$$

Second, non-parametrically regress $\varphi_{it}(\beta_K, \beta_L)$ on $\varphi_{it-1}(\beta_K, \beta_L)$ and a constant term. Given the implied residuals, one can form the sample analogue to the required moment conditions. Now, coefficients on labor and capital can be estimated by minimizing the sample analogue. Finally, using the unbiased coefficients $\left(\hat{\beta}_K, \hat{\beta}_L\right)$, one can estimate the equation of interest:

$$\hat{\varphi}_{i\square} = y_{it} - \hat{\beta}_k l_{it}, -\hat{\beta}_L k_{it}$$

Online Appendix D

D. Robustness Check Tables

Table D1: Increasing Temperature Variation and Controlling for Conflict Years

	Revenue	Profit	TFP (GNR)
	(1)	(2)	(3)
A. Dividing Abidjan into Two Sub-regions			
Days below 25C	-0.128	-0.666***	-0.053
	(0.162)	(0.002)	(0.040)
Days above 27C	-0.308***	-0.453***	-0.080***
	(0.097)	(0.001)	(0.025)
Observations	34,647	23,156	34,644
Control	YES	YES	YES
Firm FE	YES	YES	YES
District FE	YES	YES	YES
Time Trend	YES	YES	YES
F-test (All bins=0)	5.132	9.529	5.487
Prob>F	0.006	0.000	0.004
B. Controlling for Conflict Year			
Days below 25C	-0.105	-0.599***	-0.042
	(0.124)	(0.187)	(0.033)
Days above 27C	-0.178***	-0.280***	-0.040**
	(0.063)	(0.082)	(0.017)
Conflict year dummy	-15.056***	-20.076***	-4.198***
	(3.481)	(5.042)	(0.985)
Observations	34,647	23,156	34,644
Control	YES	YES	YES
Firm FE	YES	YES	YES
District FE	YES	YES	YES
Time Trend	YES	YES	YES
F-test (All bins=0)	4.871	11.85	4.481
Prob>F	0.00828	1.13e-05	0.0121

Notes: the dependent variables are logarithms of revenues, profits, and TFP (multiplied by 100 to reduce the number of decimal point in the coefficients). Profits are the reported profits and TFP is measured by Grandhi-Navarro-Rivers estimator. In panel A, we add more variation to temperatures by dividing Abidjan into two sub-regions. In Panel B, we control for the period of the past two political crises that the country faced. Bins are constructed using daily average temperature. The comparison bin is the number of days with average temperature between 25°C and 27°C. Control variables include rain, rain square, (log) capital, (log) labor, and dummies for export status, and age above firm median age. Standard errors are clustered at region-year level. *** p<0.01, ** p<0.05, * p<0.1

Table D2: Robustness Checks using Alternative Sub-samples of the Data

	Revenue	Profit	TFP (GNR)	TFP (VA/labor)
	(1)	(2)	(3)	(4)
C. Dropping firms with gap in panels				
Days below 25C	-0.069	-0.524**	-0.027	
	(0.133)	(0.217)	(0.031)	
Days above 27C	-0.270***	-0.380***	-0.059**	
	(0.090)	(0.116)	(0.025)	
Observations	20,641	13,171	20,638	
Control	YES	YES	YES	
Firm FE	YES	YES	YES	
District FE	YES	YES	YES	
Time Trend	YES	YES	YES	
F-test (All bins=0)	4.647	7.413	3.342	
Prob>F	0.010	0.000	0.036	
B. Dropping only firm with missing log VA (N=29,193)				
Days below 25C				-0.143
				(0.167)
Days above 27C				-0.202**
				(0.096)
Observations				25,518
Control				YES
Firm FE				YES
District FE				YES
Time Trend				YES
F-test (All bins=0)				2.588
Prob>F				0.076

Notes: the dependent variables are logarithms of revenues, profits, TFP, and value added per capita (multiplied by 100 to reduce the number of decimal point in the coefficients). Profits are the reported profits and TFP is measured by Grandhi-Navarro-Rivers estimator. In panel A, all firms with gaps in their appearance in the sample are dropped . In panel B, all firms will value-added greater than zero are kept in the sample. Bins are constructed using daily average temperature. The comparison bin is the number of days with average temperature between 25°C and 27°C. Control variables include rain, rain square, (log) capital, (log) labor, and dummies for export status, and age above firm median age. Standard errors are clustered at region-year level. *** p<0.01, ** p<0.05, * p<0.1

Table D3: Robustness Checks using Alternative Temperature Measures

	Revenue	Profit	TFP (GNR)
	(1)	(2)	(3)
A. Bottom and Top 10% as Bin Cut-off			
Days below bottom 10%	0.310*	-0.030	0.058
	(0.162)	(0.230)	(0.045)
Days above top 10%	-0.136*	-0.234**	-0.037*
	(0.080)	(0.117)	(0.022)
F-test (All bins=0)	2.304	2.020	1.709
Prob>F	0.102	0.135	0.183
B. Using Mean Temperature			
Mean Temperature	-704.929**	-381.688	-167.539*
	(313.141)	(443.827)	(85.207)
Mean Temperature square	12.724**	6.599	3.016*
	(5.917)	(8.464)	(1.608)
B. Using Coefficient of Variation			
Coef. of variation	-4,447.619**	-4,335.110	-1,264.384**
	(1,956.493)	(3,662.014)	(559.408)
Coef. of variation square	43,665.035*	22,244.218	12,130.626
	(25,983.837)	47,526.537	(7,355.036)
Observations	34,647	23,156	34,644
Control	YES	YES	YES
Firm FE	YES	YES	YES
District FE	YES	YES	YES
Time Trend	YES	YES	YES

Notes: the dependent variables are logarithms of revenues, profits, and TFP (multiplied by 100 to reduce the number of decimal point in the coefficients). Profits are the reported profits and TFP is measured by Grandhi-Navarro-Rivers estimator. In panel A, we use a new bottom and top 10% of average temperature as temperature bin cut-off . In panel B, replace temperature bins by average temperature and its square and in panel C by the coefficient of variation and its square. Bins are constructed using daily average temperature. Control variables include rain, rain square, (log) capital, (log) labor, and dummies for export status, and age above firm median age. Standard errors are clustered at region-year level. *** p<0.01, ** p<0.05, * p<0.1

Table D4: Panel information

Year	Number of firms with missing: Capital	Labor	Intermediate	Sale	Number of firms with valid values for capital, labor, intermediate input, and sale
1998	560	16	24	130	1945
1999	379	6	6	104	1881
2000	425	12	9	110	1759
2001	440	3	11	114	1743
2002	388	4	3	93	1632
2003	108	5	0	74	2046
2004	149	119	3	109	1920
2005	121	112	7	99	1787
2006	99	91	4	94	1650
2007	110	116	2	80	1608
2008	135	128	4	100	1735
2009	207	152	9	167	2048
2010	349	206	28	278	2713
2011	710	417	66	646	3996
2012	1177	472	85	695	5483
2013	2158	353	40	465	2384
Total	7,515	2,212	301	3,358	36,330

Table D4.1: Number of Firms by Sector

Sector	Number of firms
Agriculture	1073
Commerce	15150
Construction	3287
Extraction	233
Manufacturing	5849
Service	10735

Table D4.2: Panel length

Number of years in data	Number of firms
1	2062
2	3697
3	3905
4	3446
5	1967
6	1564
7	1420
8	1399
9	1261
10	1674
11	1862
12	1797
13	2089
14	2028
15	3291
16	2868

Essay 2.

Trade Disruption and Rural Poverty: Evidence from a Negative Shock to Malian Livestock Exports after the 2002 Political Crisis in Côte d'Ivoire

1. Introduction

Livestock is an important source of revenue for rural households in many developing countries. In Mali, livestock is the main source of income for 30 percent of the population and represents between 9 and 15 percent of the country total exports (Diarra et al., 2013). While opening to trade is generally believed to promote economic growth, it could have an ambiguous effect on poor households (Winters et al. 2004, Goldberg and Pavnick 2007). This ambiguity rises partly because of the complexity of the structure of households and their diverse source of incomes. Farm households in many developing countries are both producers and consumers of livestock. While trade liberalization provides livestock breeders with an opportunity to sell their animal at higher prices, it also increases the cost of domestic meat consumption. As a result, trade liberalization can either hurt or benefit rural households.

This paper analyzes the link between trade and rural poverty in the context of Mali. Our identification strategy relies on the natural experiment provided by the 2002 political crisis in Côte d'Ivoire that led to a significant unexpected drastic cut (55 percent) of Malian total livestock exports. We use national representative household data in Mali collected before and after the crisis, 2001 and 2006, to estimate the effect of the crisis-induced negative trade shocks on Malian livestock household consumption and poverty indices.

While there are established positive impacts of trade on economic growth (Frankel and Romer, 1999; Irwin and Tervio, 2002; Dollar and Kraay, 2004), a trade shock could affect household economic outcomes in several ways. In an elegant paper, Winters (2000) proposes three possible channels - prices, employment, and fiscal - through which trade reforms can affect household welfare. In this study, we focus on the price and quantity channel, which is the most prominent channel in our context. Before the 2002 civil war, Côte d'Ivoire imported a significant share of its livestock from Mali, which was a major source of income for Malian livestock producers. At the peak of the Ivoirian crisis in 2002, Malian annual cattle export dropped by 54 percent and until 2006 the pre-crisis quantities of exports was not reached. Consequently, Malian livestock producers experienced a significant unexpected negative demand shocks between 2002 and 2006.

In one hand, openness to trade can result in the availability of more goods for local consumers, thus, the creation of more markets. On the other hand, it can result in intense competition for local producers and thus push them out of business. For instance, while Jacoby (2013) found that Indian rural households across the entire income distributions gain from higher food prices, Ivanic et al. (2012) found that the 2010 agricultural commodities price booms results in higher poverty in developing countries. In a similar exercise, Levinsohn et al. (1999) found that the poor suffered more than non-poor from the price increases at the result of Indonesian 1997 financial crisis.

Previous empirical studies have attempted to show the link between trade liberalization and poverty in developing countries. However, most of them face major identification challenges. First, the measure of openness broadly used in cross-country literature linking trade and growth ignores important economic effects at the household level. Second, variable representing the channel through which trade affects households (e.g. prices and quantity) maybe endogenous to changes in household economic status (Justino, 2008). Third, opening to trade is usually an endogenous decision, which is highly correlated to other economic and political factors that influences rural poverty, thus, making it difficult to estimate the causal effect of trade liberalization on the economic outcomes of the poor. Our approach allows us to avoid such problems by exploiting unexpected significant reduction of Malian livestock export to Côte d'Ivoire as a negative trade shock. Since the crisis was unanticipated by traders in both country, the resulting measure of changes in trade level is exogenous to changes in household welfare measures.

This study contributes to the literature in many ways. First, it helps to elucidate the effect of negative trade shocks on rural households welfare in exporting countries, an impact not well studied in the trade literature. Second, our estimation strategy allows us to overcome the identification challenge involved with such estimation. The unexpected drastic cut in Malian livestock export induced by the crisis in Côte d’Ivoire provides us with a unique opportunity to identify the causal effect of trade shock on households. Finally, using our rich dataset on household consumptions, we estimated the effect of the trade shock on different categories of household consumptions (e.g. purchased food, grain consumption) and different measures of poverty.

The reminder of the paper proceeds as follow: in section 2 we review the country background, and discuss the data and identification strategy. In section 3 and 4 we offer the empirical analysis and robustness checks. In the last section we conclude and provide policy implications.

2. Background, Data, and Empirical Framework

2.1.Background

Once called the pearl of West Africa, Côte d'Ivoire has flourished from independence until the 80s mainly thanks to cocoa exports, the diversification of agriculture, and political stability. The country experienced some level of political instability in the 90s including a coup in 1999; however, it is the civil war in 2002 that led to a momentary division of the country and paralyzed its economy. From September 2002 to March 2007, commonly refer to as the "no war, no peace" period, the north of the country controlled by rebels was separated from the South. From 2005 and on, the security situation improved significantly thanks to the deployment of UN forces in 2004 and the Pretoria peace treaty signed in 2005. However, it is until 2007 with the appointment of a prime minister from the rebel group that the country was officially reunited. This political unrest severely affected the Malian livestock exports to the country.

Prior to the crisis, Côte d'Ivoire was the main destination of Malian livestock exports, representing more than 50 percent of the country total livestock exports. The onset of the Ivorian political crisis led to an unexpected 55 percent drastic decrease in Malian cattle exports to the country (figure 1). Since Mali did not experience any major events (e.g. droughts) that negatively affected the livestock sector[10] between 2001 and 2006, we can safely assume that the Ivoirian crisis led to an exogenous decrease in Malian livestock export. The exogenous decline in livestock export resulted in a 40 percent decrease in livestock prices in Mali as the quantities of cattle destined for export are added to the local supply. However, the decrease in the price of live animals did not translate into a

[10] Figure 1 actually displays an increase in Malian livestock production during the same period. Also, the country experiences a sustained significant GDP growth between 2001 and 2006.

decrease in local meat prices, thus, Malian livestock producers were negatively affected by the crisis (Afrique Verte, 2003).

The above observed market failure is mainly explained by the many stages of livestock trade and the existence of middlemen who link farmers to traders. Before reaching final markets, livestock go through several markets. First, farmers sell their livestock to small and medium sized financial traders “Collectors” in collection markets. Collectors then sell livestock to large financial market traders “fairground traders” in a secondary market, usually located within a radius of 200 km of collection markets. Finally, fairground traders, who move from fair to fair to buy or sell animal supply the terminal market, where butchers and exporters buy livestock.

The abrupt decrease of trade between the two countries forced Malian livestock exporters to find other destinations to their livestock. However, because of the lack of adequate road and the many checkpoints between Mali and other potential export markets, it took a while for the Malian livestock sector to reach its pre-crisis level of exports. When the level of violence lessen a bit, some exporters resumed exporting livestock to Côte d’Ivoire using a longer road that takes them to Burkina and Ghana before reaching Abidjan. This led to a significant increase in transportation costs and bribes paid at checkpoints, thus, an important decrease in profits made by exporters. It is until 2006 when the downward trend of Malian livestock export reversed as Senegal, another neighboring country, started to fill the void left by the crisis in Cote d’Ivoire.

From 2002, the beginning of the civil war in Cote d’Ivoire, to 2006, when the livestock export start increasing again), we expect a decrease in the incomes of Malian households dependent on livestock farming. Moreover, we expect the negative income shock to affect the level of consumption and other welfare indicators of livestock farm households. In 2001, consumption per capita for livestock and non-livestock households were about the same. While average consumption per capital for all households improved in 2006, thanks to a sustained GDP growth, livestock household performed poorly compared to non-livestock households. The country total livestock export decreases significantly during the same period (figure 2).

As displayed in figure 3, the gap between livestock and non-livestock consumption of food purchased is even larger. From 2001 to 2006, while non-livestock households consumption of food purchased per capita increases by 56 percent, the consumption of food purchased per capita of livestock households increases only by 17 percent. In the context of rural households living from subsistence farming, one can assume purchased food to be a luxury good. As rational agents, when a negative income shock occurs, we should expect farmers to decrease their consumption of luxury goods.

2.2 **Data and Construction of Key Variables**

Our main source of data are the Enquête Malienne de Conjoncture Economique et Sociales (EMCES) 1994**,** the Enquête Malienne sur l'Evaluation de la Pauvreté (EMEP) 2001, and the Enquête Légère Intégrée Auprès des Ménages (ELIM) 2006, all collected by the Malian National Institute of Statistics (INSTA) with the assistance of the World Bank. The surveys cover 9,158 households and 475 primary sampling units (PSU) in 1994, 4,927 households and 225 PSU in 2001, and 4,452 households and 225 PSU in 2006. The data contain detailed information on household consumption, demographic, and activity. Since we are interested in the change of livestock farm household welfare before and after the crisis, we only use household data for 2001 and 2006 in our main regressions. Household data for 1994 is only used to check the parallel trend assumption. Not being able to observe the same household before and after the crisis might results in identification challenges that we later address. Among other techniques, we control for village/region fixed effects to spare our results from phenomena affecting village/region differently but do not change overtime.

The structure of our data allows us to identify households that are more likely to be affected by the negative livestock export shock. While we cannot identify livestock exporting households, we can homogenously identify livestock producing households across surveys through the observation of household's auto-consumption of milk. This proxy is more likely to leave out some of the households that are affected by the negative trade shock. It could be possible for households to have livestock and not consuming the milk they produce since milk production is seasonal in Mali and it is often the case that livestock travels in search for grazing land. Our inability to include all the potential households affected by the crisis is likely to under- estimate the actual effect of the trade shock on livestock households.

For the analysis, we consider six household outcomes: per capita total consumption, per capita purchased food, per capita grain consumption, poverty headcount ratio, poverty gap, and poverty severity measures. We use consumption per capita (at 2001 prices), since consumption is better measured than income in developing countries (Cogneau and Jedwab, 2012). Our total consumption variable includes both consumption of own food production, proxied by grain consumption, and purchased food. While food expenditure is likely to be sensitive to income shocks for the poor that is less likely to be the case for the rich. Not correctly observing the potential effect of the shock on rich households is likely to lessen its effects on livestock producers. In all sense, we can be sure that our observed impact is conservative.

We estimate different poverty measures following the concept of absolute poverty. A household is defined as poor if its per capita expenditure is lower than the official poverty line of 136,000 CFA in 2001 and 149,000 CFA in 2006. We also estimate additional robustness check measures of poverty using the world bank $1.25[11] per day poverty line and relative poverty line defined as 50% of average consumption in the sample. All poverty measures are estimated using the Foster-Greer-Thorbecke (FGT) class of poverty indices, defined as:

$$FGT_{\alpha} = \frac{1}{N}\sum_{t=1}^{N} I(x_i < z)\left[\frac{z-x_i}{z}\right]^{\alpha},$$

where N is the population size, z is the poverty line, x_i the per capita consumption of the $i\ th$ household, I is a dummy variables for whether the condition is true, and α a poverty aversion parameter.

The headcount ratio (P0) represents the share of poor in total population. It is a particular case of the FTG index when α is set to zero. As a result, it does not take into account the degree of poverty and it is not sensitive to policies that further impoverish the poor (Coello, et al., 2010). To take into account how the shock affects the poverty gap or the decree of poverty, we also estimate poverty gap index (P1) and poverty severity index (P2), all particular cases of the FGT index when α is set to one and two, respectively. They put more weight on the poorest and are sensitive to the distribution of poverty below the poverty line. While the poverty gap index can be thought of as the cost of eliminating poverty (relative to poverty line), the poverty severity index lacks intuitive

[11] The World Bank global poverty line was $1.25 per day in 2005. We use GDP deflator to get the 2001 and 2006 PPP equivalents.

appeal. It is simply the weighted sum of the poverty gaps, where the weights are the proportionate poverty gap themselves (Poverty Manual, All, JH, Revision of August 2005).

Given the focus of this paper, we exclude households from the capital and in the north of the country. While there are very few farm households in the capital, farmers in northern regions are nomadic, therefore, it is almost impossible to track households within a smaller geographic location across survey. Furthermore, in 2006 the country experiences a sporadic rebellion in the north, which is likely to affect livestock and non-livestock households differently since illegal armed groups tend to seize livestock in conflict zone.

2.3 **Difference-in-Difference Identification Strategies**

Motivated by the natural experiment provided by the 2002 political crisis in Côte d'Ivoire, we define a treatment group to be the sample of livestock farm households and contrast it with the sample of non-livestock farm households. As illustrated by figure 2 and 3, while the average total consumption of livestock farm households barely increased in 2006, non-livestock households total average consumption and average consumption of purchased food increased by 29 and 56 percent, respectively. The country average livestock export from 2002 to 2005 decreased by 45 percent and only start increasing in 2006, where total livestock export represents 62 percent of the pre-crisis total livestock exports. As displayed by figure 1, during the crisis livestock production in Mali has been increasing, therefore, the abrupt decrease of livestock export is most likely due to the crisis in Côte d'Ivoire rather than a shortage of supply.

To estimate the effect of the negative export shock on livestock farm households, we use the following difference in differences regression model:

(1) $Y_{it} = \alpha_t + \beta_1 livestock_{it} + \beta_2 livestock_{2006,it} + year_{2006} + X_{it} + \varepsilon_{it}$,

where Y_{it} is the outcome of interest for household i in year t ($t = 2001, 2006$). Region-year or village-year fixed effects is represented by α_t. These geographical fixed effects control for other factors common to livestock and non-livestock households living in the same geographical area in the same year. While $livestock$ is a dummy variable indicating whether the household belongs to the livestock treatment group, $livestock_{2006}$ interacts livestock dummy with a dummy for the post treatment year, $year_{2006}$. X represents other control variables including the sex and age of the head of household. Finally, ε is the error term clustered at the level of survey clusters, which will allow us to control for correlation across households within the same survey cluster.

To test whether the effect of the shock was limited to livestock household living in area that usually exports livestock to Cote d'Ivoire "livestock export shed", we extend equation (1) by including a dummy variable indicating whether the household is located in a livestock export shed. While the crisis should affect all livestock households in the country, those that usually export livestock to Côte d'Ivoire might be more affected if livestock market in the country is not well integrated. We use the following regression model:

(2)$Y_{it} = \beta_1 livestock_{it} + \beta_2 livestock_{2006,it} + \beta_3 Shed_{it} * livestock_{2006,it} +$

$year_{2006} + X_{it} + \varepsilon_{it}$, where $Shed$ is a dummy variable indicating whether the region is livestock export shed for Côte d'Ivoire. Except that X now include a dummy for livestock export shed, all the other variables are defined as in equation (1).

3. Empirical Analysis

3.1. Descriptive Statistics

Table 1 contains descriptive statistics for households, broken down by livestock producing status and year. The clean full sample includes 3,392 households in 2001 and 3,462 households in 2006. Given the very limited number of livestock households in the capital and the nomadic nature of livestock households in the north of the country, households from northern regions and Bamako are excluded from the final sample. The skewed distribution of key variables suggests that our sample is mainly composed of households of similar characteristics and very few outliers. The average consumption per capita for livestock and non-livestock households are respectively 73,960 CFA and 68,368 CFA in 2001 and 80,530 CFA and 97,519 CFA in 2006. Average household sizes are respectively 11.67 and 10.74 for livestock household and 11.71 and 9.55 for non-livestock households in 2001 and 2006, respectively.

Poverty headcount ratio for livestock and non-livestock households are respectively 73.8% and 77.2% in 2001 and 66.2% and 62.4% in 2006. Thanks to sustained economic growth, both type of households experience a decrease in poverty rate during the treatment period, although, non-livestock households perform better than livestock households. We observe similar trend in poverty gap and severity indices. In 2001 and 2006, while the poverty gap index for non-livestock households are respectively 0.26 and 0.23, they are 0.32 and 0.24 for livestock household. Similarly, the poverty severity index in 2001 and 2006 are respectively 0.12 and 0.11 for livestock household and 0.17 and 0.13 for non-livestock households.

As it is common in most developing countries, the head of most households are male. On average 94 percent of household heads are male while the average age of household head are 51.68 and 49.7 in 2001 and 2006, respectively. In our clean sample, while the number of livestock household decreases from 672 in 2001 to 435 in 2006, the number of non-livestock households increases from 2,720 to 3,027 during the same period.

3.2. Baseline Results

The empirical analysis proceeds in two parts. First, we estimate the impact of the shock on household total consumption per capita and consumption of purchased food per capita. In the second part, we then examine whether the shock has an implication on household poverty indices. Following the specification described above, the reported baseline estimates include region-year fixed effects or village-year fixed-effects, except when location is part of the identification strategy, and standard errors are clustered at the primary sampling unit level. To keep results simple, tables only report the coefficients of the treatment variable and a dummy indicating livestock farm household. In the main regression, the treatment variable is defined as the interaction between a dummy for livestock farm household and a dummy for post treatment year 2006. When analyzing the regional effects of the shock, we interact the treatment variable with a dummy indicating whether the household is located in livestock export shed or in the Malian region bordering Côte d'Ivoire (Sikasso).

3.2.1. Effects of Negative Trade Shock on Household Consumption

We start our empirical analysis by estimating the impact of the negative trade shock on the level of consumption of livestock farm household in Mali. To this end, we consider different measures of household consumption, including total consumption, consumption of purchased food, and grain consumption. While total household consumption per capita reflects the level of household income, grain and purchased food consumptions per capita are respectively good indicators of own produced food consumption and household spending on "luxury goods". We regress (log) consumption per capita on the treatment variable following the specification in equation (1). Regressions following equation (1) include region-year or village-year fixed effect and standard errors are clustered at village level. Table 2 presents the main results for the effect of the trade shock on different measures of household consumption per capita. We find economically meaningful and statistically significant effect of the shock on household consumption indicators. In columns (1) and (3), no other variables are controlled for except a dummy for livestock farm household and post treatment year. In columns (2) and (3), we include addition controls including a dummy for the age and the sex, of household head.

Results in table 2 suggest that the negative export shock was associated with a relative total consumption per capita loss for livestock farm households ranging between 10.8 and 13.6 percent depending on the specification used. Our preferred baseline result indicates that the crisis reduced household consumption per capita by 13.6 percent. The shock has a stronger negative effect on livestock household food purchased per capita. From our preferred baseline result, the shock induced a 32.6 percent decrease in household consumption of purchased food per capita. On the other hand, the shock seems to have either a positive or no impact on livestock household consumption of grain, depending on the specification used. When only region-year fixed effects are controlled, the crisis increased household consumption per capita of grain by 12.5%. However, this result is not robust to the control of village-year fixed effects. Our key results seem to suggest that, as any rational agent will do when faced by a liquidity constraint, livestock households maintain their consumption of foods that provide most calories (grain) at the expense of the consumption of "luxury goods" (food purchased). Moreover, households in the study area usually grow crops and raise livestock, with most of the crops used for own consumption and livestock for cash income or used for insurance and saving purpose. Therefore, a negative impact shock affecting the value of livestock is more likely to affect household expenditures on food rather than its consumption of own produced food. In general controlling for household key characteristics reduce the magnitude of the effects, suggesting that the effect of the shock on livestock farm household is heterogeneous. The main findings are robust whether we use a different specification, control for additional variables, or use the adult equivalent measure of household size to estimate the dependent variable. Moreover, the null hypothesis that the treatment has no effect on household is rejected in all the specifications.

3.2.2. Effects of Negative Trade Shock on Poverty Indices

The observed effects of the negative livestock export shock on consumption deteriorated the poverty situation of livestock farm households in Mali. To estimate the effects on poverty, we first estimated poverty indices following the Foster-Greer-Thorbecke (FGT) class of poverty indices. In addition to our main index, constructed using the national poverty line, we constructed two additions robustness check indices using the relative poverty line and the word bank global poverty line.

Results in table 3 are obtained by regressing poverty indices on the treatment variable and controlling for region-year fixed effects. As reported in panel A of table 3, the crisis is associated with an important increase in poverty headcount ratio (P0) of livestock farm households ranging between 5.7 and 10.6 percent depending on the poverty line used to estimate the poverty headcount ratio. Using our preferred baseline result, the negative trade shock increases the number of poor livestock household by 7.4 percent. This is a significant increase in poverty rate for a sub-group, especially given that the country as a whole experienced a 70% growth in nominal income per capita during the same period. We found a negative effect of the shock on other measures of poverty. Results in Panel B and C suggest that the shock increase poverty gap and poverty severity indices of livestock farm households by 0.042 and 0.032, respectively. While there is no clear intuitive interpretation of the later results, it is clear that the crisis did not only increase the likelihood of livestock households to be poor but also increase the degree of their poverty. Our main results are robust to different estimation of poverty indices and the hypothesis that the crisis has no impact on the poverty of livestock household is reject in all the baseline results.

3.2.3 Effect of the Shock In livestock Export Shed

To check whether livestock farm household in regions that usually export livestock to Côte d'Ivoire "livestock export shed", we use a triple difference in differences by including a dummy for livestock export shed. As presented in table 4, we found mix results. While the shock had a negative impact on total consumption per capita and increased poverty headcount rate among livestock farm households, it had no significant impact on other measures of food consumption and poverty indices. In column 1 and 4 of table 4, once we include livestock export shed treatment in the regression, expect for consumption of purchased food and poverty severity index the original treatment is no more statistically significant. The baseline results (preferred) that the shock is associated with a 14.3% decrease in total consumption per capita and a 15.6% increase in head account poverty rate among livestock farm households located in livestock export shed. The coefficients on food purchased per capita, poverty gap, and poverty severity have all the right sign but are not statistically significant.

The level of integration of livestock market in the country could explain the above mix results. If livestock market in Mali is well integrated then the shock will affect all livestock households no matter where they are located in the country. With an integrated livestock market, prices in different regions of the country in the same time period will only differ by the amount up to the transaction costs of livestock from one region to another as suggested by the law of one price (Dawson and Dey, 2002). On the other hand, if livestock market is not well integrated in the country, the shock will have a greater impact on livestock households in regions that rely on livestock exports to Côte d'Ivoire.

Given the absence of regional livestock prices during the treatment period, we use livestock price data from 2009 to 2012 to graph annual median livestock price in livestock shed region and other regions in the country. Figure 4 displays the evolution of cattle prices in livestock export shed and other regions of the country from 2008 to 2013. While we do not observe a perfect correlation between livestock prices in the two regions, there seem to be some signs of co-movement of livestock prices. From 2008 to 2011, we observe an increase in livestock prices in both regions, although the relative increase in livestock export shed is higher. While cattle prices in other regions kept increasing, prices in livestock export shed experienced a sharp decline between 2011 and 2012 and then started to increase again. We conclude that the mixt results obtained using the triple difference in differences is most likely due to the existence of some level of livestock market integration.

To put at rest the concern that our baseline results might include effects other than the effects of negative trade shock such as the direct impact of the conflict on households living close to the border with Côte d'Ivoire (e.g. flow of refugees, lost of remittances, etc.), we perform a robustness check to first estimate the impact of the crisis on all households in the border region (Sikasso) and then re-estimate the baseline results by restricting the sample to households living in non-border regions. Results of the robustness check are displayed in Table 5.

Panel A of table 5 shows how the crisis in general affected households living close to Côte d'Ivoire. We introduce a new treatment defined as the interaction between a dummy indicating whether the household is located in the border region and the post treatment year (2006). As expected, results in Panel A confirmed that the welfare of both livestock and non-livestock households living close to the border worsened as the result of the crisis. We found that the crisis led to a 21.8 percent decrease in total consumption per capita and a 11.6 percent increase in headcount poverty rate among all households living close to the border. Similarly, food purchased and grain consumed per capita respectively decreased by 77.5 and 7.4 percent, while poverty gap and poverty severity indices increased by 0.10 and 0.07, respectively. Another possible explanation of the observed effect of the crisis on non-livestock households is its effect on cotton producers. While we cannot identify cotton producers in our data, it is evident that cotton production in

Mali is most common in Sikasso. Given that Malian cottons were exported through the port of Abidjan (Côte d'Ivoire), the crisis negatively affected the price of cotton and consequently, cotton producing households in the border region.

Despite the evidence that the crisis might have affected household economic situation through other mechanisms than livestock trade, results in panel B of table 5 shows how robust our baseline results are to the other potential channels. To remove other potential economic effects of the crisis including the flow of refugees, pressure on local resources, lost of remittances, decrease in cotton prices, we exclude from our sample households from the border region that sends most seasonal workers to Côte d'Ivoire and hosted most of the refugees. The results are both qualitatively and quantitatively similar to baseline findings.

4. Additional Robustness Checks

To assess whether the established baseline relationship between export shock and livestock household is causal, we run additional robustness checks. Our identification strategy relies on the exogenous differential trends between treatment and control groups after controlling for yearly shocks that commonly affect both households in the same region. However, we need to assess whether the parallel trend assumption holds.

4.1 Pre-Shock Trends

To assess the exogenous differential trends assumption, we first compare our key dependent variables from the 1994 and 2001 survey data. While livestock breeder is a category of employment in the 1994 survey, livestock households are defined in the 2001 data as households with positive consumption of own milk. Since the 1994 survey does not contain information about purchased food, we only check the trend for per capita household consumption and poverty indices. Results in table 6 suggest that per capita consumption increases for livestock household, which led to a decrease in their poverty levels. Except the poverty headcount index (P0), all the double differences are statistically significant, suggesting that livestock farm households were doing well going into the crisis. The increase in the welfare of livestock household could be partly explained by the depreciation of the currency in 1994, which has been argued to increase the competitiveness of Malian livestock sector. At the aftermath of the devaluation, despite the increase in input prices, both livestock sales and the profitability of cattle production increased (Yade, et al., 1999).

Second, we follow Cogneau and Jedwab (2012) to use date of interview (month) to control for pre-shock differential trends. Although our pre-shock survey data is not a panel, the data collection spans for a year, from January 15, 2001 to January 15, 2002. Since the crisis really starts in September 2002, we run equation (1) using only data from 2001 and replacing the post treatment year by the time trend variable, defined as the number of months since the beginning of the survey, January 2001. The specification is as follow:

(3) $Y_{it} = \alpha' + \beta_1{}' livestock + \beta_2{}' T + \beta_3{}' livestock * T + \varepsilon.$

We test the pre-shock trend between livestock and non-livestock households, i.e. $H_0 \colon \beta_3{}' = 0$ and results are displayed in Table 7. In both specifications, using region-year or village-year fixed effects, we found no statistically significant effects of the pre-shock trend variable on any of the depend variables. Moreover, we fail to reject that the pre-shock trend is different from zero ($\beta_3{}' = 0$). Therefore, we conclude that there is no pre-shock trend between livestock and livestock households for any of the dependent variables. While using the 1994 data we found a positive trend for livestock household, which is partly explained by the increase in the competitiveness of livestock sector as the result of the 1994 devaluation of the regional currency (CFA), we found no signification pre-shock trend using the 2001 survey data and the date of the interview. If anything, the positive trend in 1994 reinforce our results, therefore we conclude that our identification do not suffers from time trend bias.

5. Conclusion

This paper analyzed the impact of a drastic decrease (-55 percent) in Malian livestock exports following the 2002 political conflict in Côte d'Ivoire on livestock farm households in Mali. Using national cross-section household surveys for 2001 and 2006 and difference in differences strategy, we estimate the effects of the negative export shock on changes in per capita consumption and the rate and severity of poverty among livestock households. We found a strong negative effect on five out of six household outcomes (total food consumption, purchased food, poverty headcount, poverty gap, and poverty severity) suggesting the welfare on rural households is sensitive to income shocks. While the shock has no impact on household per capita consumption of grain, the effect is stronger for household food purchased per capita, which in a rural context can be considered of as "luxury good". Our baseline results can be interpreted as an income shock, pushing households to cut on non-necessary food expenditures.

The effect of the shocks was not limited to only livestock household living in regions known for exporting livestock to Côte d'Ivoire, suggesting some signs of livestock market integration in Mali. Except consumption per capita and poverty headcount ratio, we found no stronger effect of the shock on livestock household living in export shed.

The income effect induced by the crisis seems to be greater than the consumption benefits from a lower livestock price. This can be explained by two factors. First, rural households consume little meat, therefore, mainly trade livestock or use it as a saving instrument. Second, while the shock led to a decrease in livestock prices, the price of meat did not change significantly. In other words, the increase in the supply of domestic livestock did not lead to a decrease in meat prices.

The findings of this paper have important implications. First, regarding the impact of trade, our results suggest that the welfare of rural households can be affected by negative trade shock. If domestic markets are well integrated, the effect can go beyond the localities that are directly involved in the trade. Second, if domestic trade includes many stages and is subject to arbitrage by middlemen, a negative trade shock is likely to have a stronger impact on rural producers. Consequently, it is critical for policy makers in developing countries to facilitate the well functioning of domestic market before opening to trade.

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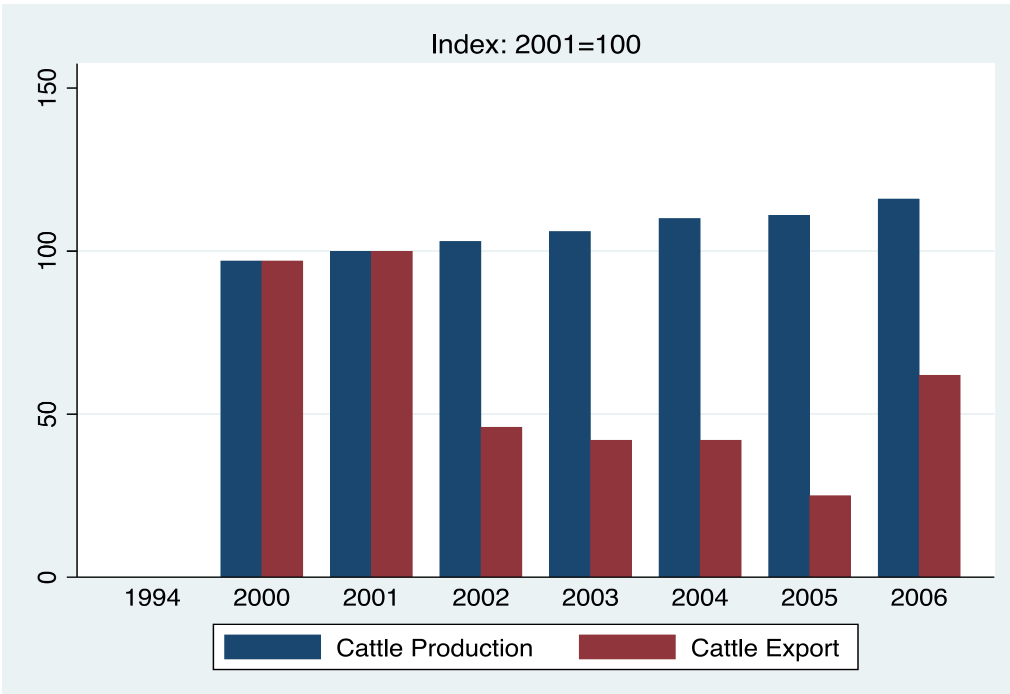
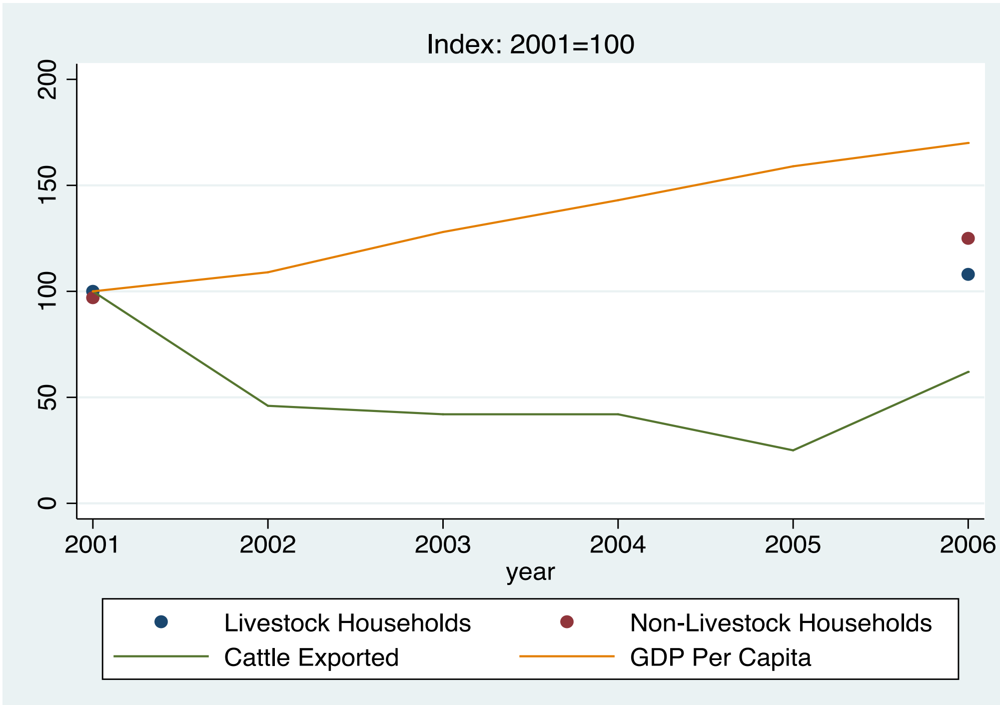
Figures:

Figure 1: Livestock Production and Export Quantity



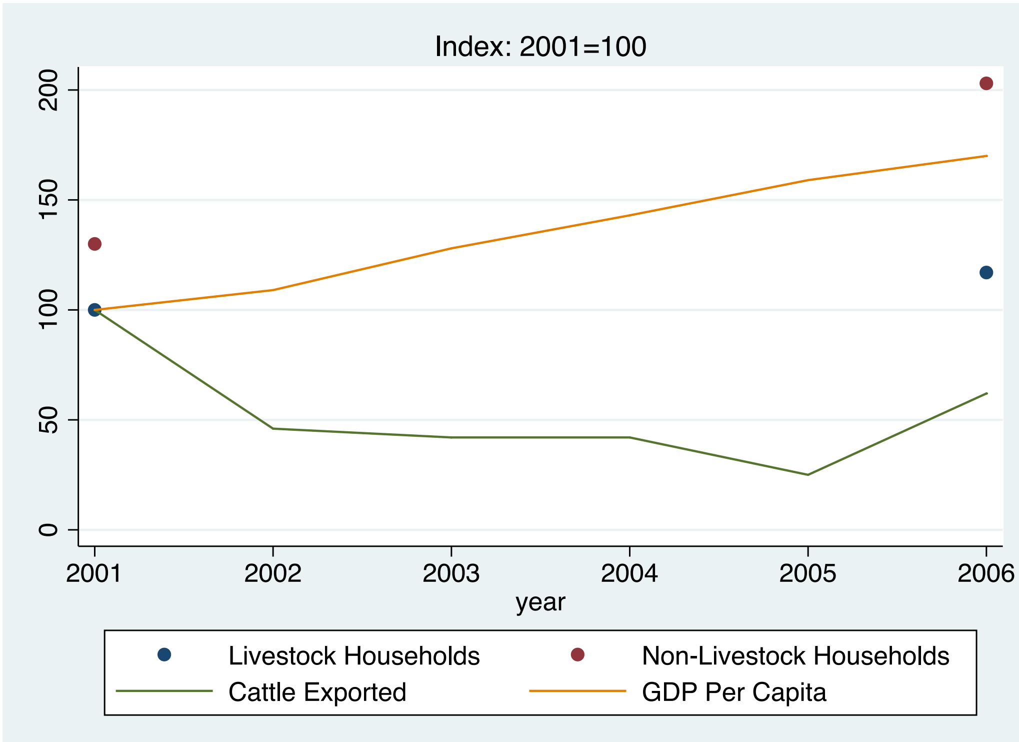
Source: Livestock export (2002-2005) are from Diarra et al., 2013 and export from other years are from the annual report of Direction National des Productions et des Industries Animales (DNPIA). Livestock production data (2000-2004) are from Direction Generale de la Reglementation et du Controle du Secteur du Developpement Rural (DGRC) and livestock production data (2005-2006) are from DNPIA.

Figure 2: Livestock Export Quantity, GDP Per Capita, and Mean Per Capita Consumption of Livestock and Non-Livestock Households



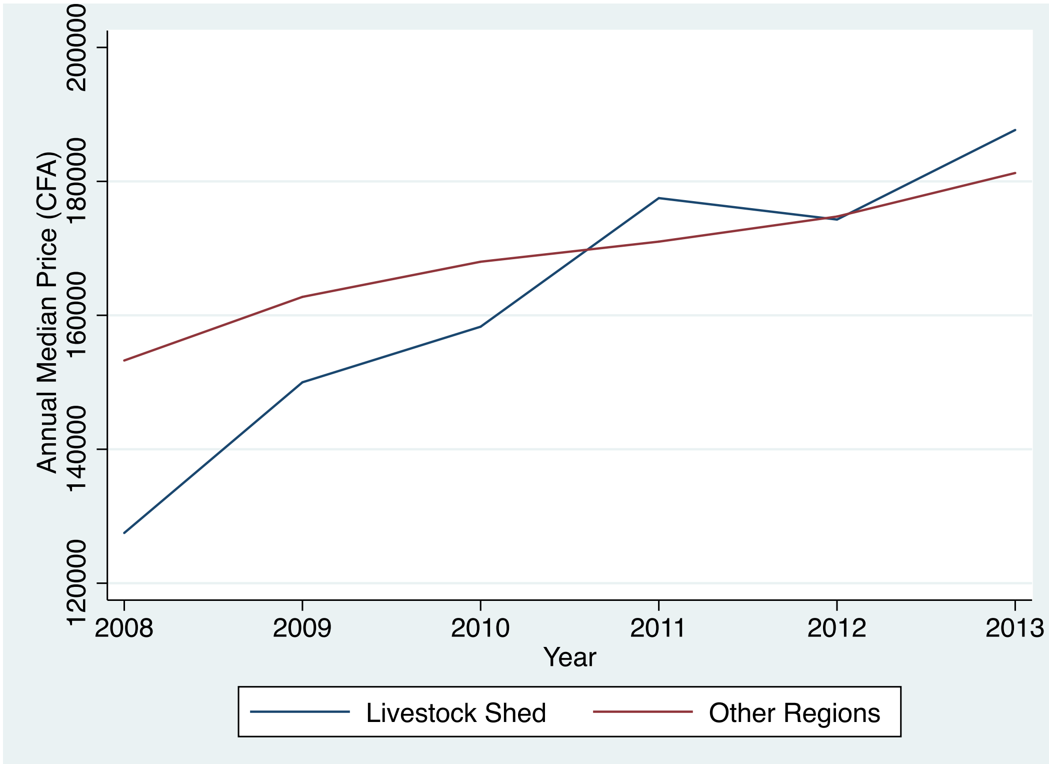
Source: consumptionper capita is author's own estimation. Livestock export (2002-2005) are from Diarra et al., 2013 and export from other years are from the annual report of Direction National des Productions et des Industries Animales (DNPIA).

Figure 3: Livestock Export Quantity, GDP Per Capita, and Mean Per Capita Food Purchased of Livestock and Non-Livestock Households



Source: food purchased per capita is author's own estimation. Livestock export (2002-2005) are from Diarra et al., 2013 and export from other years are from the annual report of Direction National des Productions et des Industries Animales (DNPIA).

Figure 4: Evolution of Livestock Prices



Source: author's own graph using livestock market price data collected under the Mali Livestock and Pastoralist Initiative (MLPI) project.

Tables:

Table 1: Descriptive Statistics of Livestock and Non-Livestock Households

	Livestock Household		Non-Livestock Household		All Household	
	2001	2006	2001	2006	2001	2006
HH Characteristics						
HH size	11.67	10.74	11.71	9.558	11.70	9.707
HH size (OECD adult equival.)	7.361	6.788	7.407	6.120	7.398	6.204
Male head of HH	0.978	0.982	0.934	0.934	0.943	0.940
Age Head of HH	49.42	48.69	52.24	49.84	51.68	49.70
Livestock export shed	0.487	0.501	0.528	0.560	0.519	0.553
HH Consumptions						
Per capita total consumption	73,960	80,530	68,368	97,519	69,476	95,384
Per capita purchased food	31,060	40,326	35,019	74,495	34,235	70,202
Per capita cereal consomption	38,176	22,951	34,438	18,907	35,179	19,415
HH Poverty						
Poverty count (P0)	0.738	0.662	0.772	0.624	0.765	0.629
Poverty gap (P1)	0.260	0.227	0.322	0.245	0.310	0.243
Poverty severity (P2)	0.122	0.109	0.175	0.128	0.165	0.126
N	672	435	2,720	3,027	3,392	3,462

Note: all monetary values are in 2001 prices and in CFA. 1 USD is roughly about 550 CFA. Livestock export shed is a dummy for regions that usually export livestock to Côte d'Ivoire. Per capita consumption measures are estimated using the normal household size. Poverty measures are estimated using the national poverty line for 2001 and 2006.

Table 2: Negative Livestock Export Shock and Household Consumption

	Region-Year FE		Village-Year FE	
	(1)	(2)	(3)	(4)
Panel A: Total consumption per capita				
Livestock_2006 (Treatment)	-0.136***	-0.125***	-0.117***	-0.108**
	(0.044)	(0.044)	(0.044)	(0.044)
Livestock dummy	0.114***	0.105***	0.135***	0.124***
	(0.033)	(0.033)	(0.030)	(0.030)
Other controls	NO	YES	NO	YES
N	6,854	6,854	6,854	6,854
F-test (Treatment=0)	9.446	7.967	6.948	6.050
Prob>F	0.00232	0.00510	0.00885	0.0145
Panel B: Purchased food per capita				
Livestock_2006 (Treatment)	-0.326***	-0.305***	-0.160**	-0.145*
	(0.078)	(0.078)	(0.079)	(0.079)
Livestock dummy	-0.012	-0.022	0.038	0.020
	(0.062)	(0.061)	(0.064)	(0.063)
Other controls	NO	YES	NO	YES
N	6,846	6,846	6,846	6,846
F-test (Treatment=0)	17.70	15.14	4.115	3.379
Prob>F	3.47e-05	0.000124	0.0434	0.0671
Panel C: Grain consumption per capita				
Livestock_2006 (Treatment)	0.125*	0.124*	-0.083	-0.084
	(0.070)	(0.070)	(0.077)	(0.077)
Livestock dummy	0.146***	0.149***	0.161***	0.163***
	(0.033)	(0.034)	(0.029)	(0.029)
Other controls	NO	YES	NO	YES
N	6,720	6,720	6,720	6,720
F-test (Treatment=0)	3.214	3.159	1.162	1.177
Prob>F	0.0741	0.0766	0.282	0.279

Note: the dependent variables in panel A, B, and C are respectively household total consumption per capita, household purchased food per capital, and household grain consumption per capita. Only treatment and livestock coefficients are reported. Treatement is the inteaction between livestock household and post treatment year 2006. The other variables are: a constant, a dummy for the post treatment year 2006, and a livestock household dummy. In columns (2) and (4) there are additonal control variables: a dummy for the age and sex of the head of the household. Village is proxied by survey clusters. Standard errors are clustered at vllage level. *** p<0.01, ** p<0.05, * p<0.1

Table 3: Negative Livestock Export Shock and Household Poverty

	National Poverty Line	Relative Poverty Line	Global Poverty Line
	(1)	(2)	(3)
Panel A: Absolute poverty count (P0)			
Livestock_2006 (Treatment)	0.074**	0.106***	0.057*
	(0.034)	(0.038)	(0.030)
Livestock dummy	-0.027	-0.096***	-0.095***
	(0.021)	(0.025)	(0.023)
N	6,854	6,854	6,854
Region-Year FE	YES	YES	YES
F-test (Treatment=0)	4.736	7.605	3.566
Prob>F	0.0304	0.00620	0.0600
Panel B: Poverty gap (P1)			
Livestock_2006 (Treatment)	0.042**	0.016	0.032***
	(0.019)	(0.011)	(0.012)
Livestock dummy	-0.057***	-0.036***	-0.051***
	(0.013)	(0.008)	(0.010)
N	6,854	6,854	6,854
Region-Year FE	YES	YES	YES
F-test (Treatment=0)	4.964	2.126	7.424
Prob>F	0.0267	0.146	0.00683
Panel C: Poverty severity (P2)			
Livestock_2006 (Treatment)	0.032**	0.007	0.019**
	(0.013)	(0.007)	(0.008)
Livestock dummy	-0.050***	-0.019***	-0.030***
	(0.010)	(0.006)	(0.007)
N	6,854	6,854	6,854
Region-Year FE	YES	YES	YES
F-test (Treatment=0)	5.918	0.954	6.097
Prob>F	0.0156	0.329	0.0141

Note**:** dependent variables in panel A, B, and C are respectively absolute poverty count (P0), poverty gap measure (P1), and severe poverty measure (P2). In Columns (1)-(3), poverty measures are defined using respectively national poverty line, relative poverty line, and global poverty line. Relative poverty line is defined as 50% of national average yearly income per capita while global poverty is the world bank $1.25 per day. Only treatment coefficients are reported. Treatement is the inteaction between livestock household and post treatment year 2006. The other variables are: a constant, a dummy for the post treatment year 2006, and a livestock household dummy. Standard errors are clustered at survey cluster level. *** p<0.01, ** p<0.05, * p<0.

Table 4: Effect of Trade Shock on Households in Livestock Export Shed

	Cons. PC	Food Purch. PC	Grain Cons. PC	P0	P1	P2
	(1)	(2)	(3)	(4)	(5)	(6)
Livestock_2006	-0.078	-0.295***	0.074	0.004	0.026	0.026*
	(0.055)	(0.088)	(0.079)	(0.044)	(0.023)	(0.016)
Livestock_2006*Shed	-0.143*	-0.198	0.128	0.156***	0.049	0.022
	(0.074)	(0.125)	(0.114)	(0.061)	(0.032)	(0.022)
Livestock*Shed	0.148***	0.170*	0.170***	-0.082**	-0.062***	-0.035**
	(0.049)	(0.089)	(0.049)	(0.038)	(0.021)	(0.015)
Livestock dummy	0.053	-0.032	0.061*	0.006	-0.033**	-0.036***
	(0.038)	(0.065)	(0.037)	(0.025)	(0.015)	(0.012)
Shed dummy	0.039	-0.014	0.166***	-0.009	-0.018*	-0.017**
	(0.025)	(0.048)	(0.024)	(0.016)	(0.010)	(0.008)
N	6,854	6,846	6,720	6,854	6,854	6,854
F-test (all treatments=0)	10.81	20.96	3.404	7.488	6.196	6.000
Prob>F	0.0000	0.0000	0.0333	0.0005	0.0020	0.0024

Note: the dependent variables in columns (1)-(6) are respectively household consumption per capita, household purchased food per capital, household grain consumption per capita, head account poverty, poverty gap, and poverty severity. Livestock_2006 is the inteaction between livestock household and post treatment year 2006. Livestock_2006*Shed is the inteaction between the treatment and a dummy for whether the household is located in a region that exports livestock to Cote d'Ivoire. The other variables are: a constant, and a dummy for the post treatment year 2006. Standard errors are robust. *** p<0.01, ** p<0.05, * p<0.1

Table 5: Robutsness Check for Living Close to the Border of Côte d'Ivoire

	Cons. PC	Purch. Food PC	Grain Cons. PC	P0	P1	P2
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Border Treatment						
Border_2006	-0.218***	-0.775***	-0.074***	0.116***	0.105***	0.071***
	(0.029)	(0.063)	(0.027)	(0.017)	(0.012)	(0.010)
Border dummy	-0.109***	0.235***	-0.043	0.061**	0.025	0.020
	(0.041)	(0.078)	(0.060)	(0.025)	(0.017)	(0.014)
N	6,854	6,846	6,720	6,854	6,854	6,854
F-test	6.935	9.027	0.512	5.827	2.118	2.104
Prob>F	0.00847	0.00267	0.474	0.0158	0.146	0.147
Panel B: Remove border region						
Livestock_2006	-0.131***	-0.272***	0.115	0.085**	0.047**	0.033**
	(0.048)	(0.079)	(0.079)	(0.038)	(0.020)	(0.014)
Livestock dummy	0.096***	-0.052	0.129***	-0.032	-0.049***	-0.042***
	(0.036)	(0.067)	(0.037)	(0.023)	(0.015)	(0.011)
Region-Year FE	YES	YES	YES	YES	YES	YES
N	5,664	5,656	5,549	5,664	5,664	5,664
F-test	7.523	11.94	2.122	5.030	5.283	5.612
Prob>F	0.00657	0.000654	0.147	0.0259	0.0224	0.0187

Note: the dependent variables in columns (1)-(6) are respectively (log) household consumption per capita, (log) household purchased food per capital,(log) household grain consumption per capita, head account poverty, poverty gap, and poverty severity. Border_2006 is a treatment variable, defined as the interaction between dummy for living at the border of Côte d'Ivoire and post treatment year, 2006. Livestock_2006 is a treatement variable, defined as the inteaction between livestock household and post treatment year 2006. Livestock is a dummy for livestock household and Border is a dummy for living in the border region. Post treatment year is controlled in all regression. In panel B, region-year fixed effects are controlled and Standard errors are clustered at survey cluster level. *** p<0.01, ** p<0.05, * p<0.1

Table 6: Pre-Shock Trends, 1994-2001

	Cons. PC	P0	P1	P2
	(1)	(2)	(3)	(4)
Pre-Shock Trend (T)	0.184***	0.003	-0.102***	-0.106***
	(0.018)	(0.010)	(0.007)	(0.005)
Livestock dummy	-0.149***	0.147***	0.081***	0.037***
	(0.031)	(0.016)	(0.012)	(0.009)
Livestock*T	0.261***	-0.177***	-0.138***	-0.086***
	(0.041)	(0.025)	(0.016)	(0.012)
N	9,109	9,109	9,109	9,109
Region-Year FE	YES	YES	YES	YES
F-test	41.21	51.09	77.02	50.23
Prob>F	1.44e-10	0	0	0

Note: the dependent variables in columns (1)-(4) are respectively (log) household consumption per capita, head account poverty, poverty gap, and poverty severity. T is a dummy for year 2001, Livestock is a dummy for livestock household. Standard errors are clustered at survey cluster level. *** p<0.01, ** p<0.05, * p<0.1

Table 7: Pre-Shock Trends, January 2001 - December 2002

	Cons. PC	Purch. Food PC	P0	P1	P2
	(1)	(2)	(3)	(4)	(5)
Panel A: Region-Year FE					
Pre-Shock Trend (T)	-0.001	-0.001	0.005	-0.005	-0.003
	(0.023)	(0.053)	(0.014)	(0.010)	(0.007)
Livestock dummy	0.012	0.212	0.118	-0.007	-0.010
	(0.156)	(0.415)	(0.129)	(0.068)	(0.045)
Livestock*T	0.018	-0.039	-0.025	-0.009	-0.007
	(0.027)	(0.072)	(0.022)	(0.012)	(0.008)
N	3,392	3,392	3,392	3,392	3,392
F-test	0.420	0.289	1.292	0.526	0.747
Prob>F	0.518	0.592	0.257	0.469	0.388
Panel A: Village-Year FE					
Pre-Shock Trend (T)	0.022	0.107	-0.023	-0.015	-0.007
	(0.032)	(0.066)	(0.020)	(0.014)	(0.010)
Livestock dummy	0.086	0.199	-0.045	-0.052	-0.018
	(0.161)	(0.411)	(0.138)	(0.069)	(0.047)
Livestock*T	0.008	-0.029	0.004	-0.002	-0.006
	(0.028)	(0.073)	(0.024)	(0.012)	(0.008)
N	3,392	3,392	3,392	3,392	3,392
F-test	0.0935	0.156	0.0283	0.0278	0.639
Prob>F	0.760	0.693	0.866	0.868	0.425

Note: the dependent variables in columns (1)-(5) are respectively (log) household consumption per capita, (log) household purchased food per capital, head account poverty, poverty gap, and poverty severity. T is the number of months between household interview and December 2002. Livestock is a dummy for livestock household. In panel A and B, region-year and village-year fixed effects are respectively controlled. Standard errors are clustered at survey cluster level. *** p<0.01, ** p<0.05, * p<0.1

Essay 3.

Credit Conditions, Trade Credit, and Firms Performance during Financial Crisis: Evidence from a Post-Electoral Conflict in Côte d'Ivoire

1. Introduction

The 2011 post election conflict in Côte d'Ivoire led to the collapse of the country financial system. Evidence from the literature suggests that credit constraints can significantly reduce firm performance (Minetti and Zhu, 2011; Manova, 2013; Harrison et al. 2014; Paravisini et al., 2014), yet, the impact of the Ivoirian financial crisis on firm's activities was surprisingly lower given the extent and the severity of the crisis. In this paper, we study the impact of credit contraction on firm performance and examine the role of trade credit as an alternative source of financing during and after a financial crisis.

We take advantage of the natural experiment provided by the 2011 post electoral conflict in Côte d'Ivoire to study the effect of the resulting financial crisis on firm revenues, proxied by firm sales, and survival during and after the crisis. The literature suggests that financial crisis can affect firms through the deterioration of credit conditions. Using a matched credit-export data of Peruvian firms, Paravisini et al. (2015) found that credit shocks adversely affect the intensive margin of exports during the 2008 financial crisis. Similarly, Coulibaly et al. (2012) documented that the decline in extern financing during the recent global financial crisis led to a reduction in firm sales in six emerging Asian countries. As suggested by Figure 1, during the three months of the crisis, aggregate bank credit in Côte d'Ivoire dropped to zero. At firm level, the downturn in firm external financing coincided with a significant increase in trade credit (Figure 2).

Motivated by the above aggregate behavior of external source of finance and trade credit and previous evidences on the mitigating role played by trade credit during financial crisis (Love et al., 2007, Coulibaly et al., 2012), we examine the implication of trade credit in moderating the impact of severe contraction of bank credit on Ivoirian firms performance during and after the 2011 financial crisis.

To study the determinants of firm performance during the crisis, our identification strategy relies on the exogenous drop in external financing opportunities and use two types of explanatory variables. First, we use pre-crisis indicators of firm's vulnerability to financial crisis including, external finance, liquidity ratio, leverage, trade credit to explain firm sale performance and survival during and after the crisis. Second, we construct a firm-specific indicator of substitution between bank credit and trade credit to analyze how well firms that were able to substitute bank credit for trade credit or receive more of both perform compared to firms with reduced access to both sources of finance.

Our main findings suggest that pre-financial conditions were not a key determinant factor of firm performance during and after the crisis, although firms that enter the crisis with better liquidity position perform relatively better. Surprisingly, neither firms dependence on external finance, nor leverage level affects their sales during the crisis. We found that during and after the crisis, firms relied on trade credit to cope with the financial crisis. Moreover, firm pre-financial conditions were not important in getting trade credit suggesting that business network plays a role in firms getting trade credit. Our result seems to provide an insight about the resilience of African firms during the past global financial crisis. When the melt down of global financial market affected firms all over the world, African firms were mostly isolated from the effect of the crisis.

The panel nature of our data and the unexpected crunch of bank credit provide us with a unique opportunity to overcome many of the endogeneity and identification challenges that could bias the results of such study. Our data spans a range of manufacturing and commerce firms with different level of dependence to external finance and trade credit. Moreover, controlling for firm fixed effects, allow us to control for firm specific time invariant characteristics. This unique feature of the data allows us to exploit the exogenous variation in bank credit obtained by firms to study the determinants of firm performance during and after the financial crisis.

The rest of the paper is organized as follows: in section 2, we describe the study background and the data. In section 3, we provide the empirical framework. In section 4, we offer the empirical results. In the last section, we conclude and provide policy implications.

2. Background and Data

2.1 Background

The 2011 post election crisis in Côte d'Ivoire led to a melt down of the financial system of the country. While the head of the independent election commission declared the candidate of the opposition as winner of the election in the second round with 54.1% of the votes against 45.9% for the seating president, the constitutional council declared the seating president winner with 51.45%. In early December of 2010, both candidates were sworn in for a five-year term and subsequently form a government. The double victory claims and the refusal of the seating president to leave power led to international sanctions and armed conflict between pro-opposition militia and security forces.

The political crisis led a great financial crisis. The West African Monetary Union (UEMOA) recognizes the opposition leader as the winner of the election and cut all financial ties with the seating government. This led the country to default on a $ 2.3 billion bond and the closing of some major banks. The resulting cash crisis due to the lack of inflows and runs on banks led the government of Gbagbo to nationalize four major banks on February 17, 2011 (Kpokou, 2015). From January 2011 to April 2011, banks stopped landing to firms (see figure 1). Bank lending only resumes in May when president Gbagbo was removed by pro-opposition forces backed by the UN and French troops.

Figure 1 maps total monthly and annual bank credits received by firms, before, during, and after the crisis. The figure shows a clear decrease in aggregate bank credits during the crisis and a sharp increasing after the crisis. While sporadic conflict and violent manifestation started in mid-December 2010, the financial crisis actually started in January 2011 when the conflict intensified and Gbagbo's government was cut from funding sources. Since the post election conflict was not expected, let alone the induced financial crisis, we will assume that the 2011 melt down on the country financial system was an exogenous shock.

As displayed in Figure 2, the drastic drop in bank credits coincided with an increase in trade credits. The graph shows a 21% drop in total annual external finance received by firms in the sample in the crisis year and a 10% increase in the post crisis year. During the same period, total annual trade credit received by increased by 42% and 8%, respectively. In other words, while total external finance received by firms in the sample in the post crisis period were 11% lower than their pre-crisis amounts, trade credits received were 50% higher. The level of outstanding bank credit in firm balance sheet is likely to be explained by the difficulty in repayment of previous loan than the contraction of new loans. Anyhow, it is clear from Figure 2 that when external finance became rare, firms relied on trade credits as an alternative source of financing.

Timing of Events

For the purpose of our analysis, 2011 is defined as the year of the crisis. Although the country experience sporadic violence toward the end of December 2010, the crisis started to affect the real economy in January 2011 when the country faced international sanctions, especially the regional economic union. Consequently, 2010 is considered as the pre-crisis year and 2012 the post-crisis year.

2.2. Data and Descriptive Statistics

Our empirical analysis uses firm-level data collected by the Ivorian National Institute of Statistics. Aggregate bank credit information is collected by the Banque Central des Etats de l'Afrique de l'Ouest (BCEA). Our sample covers the universe of registered firms in the country from 2010-2013. Since almost all the establishments have only one branch, we will refer to establishment as firm instead of plant. The data contains information on sales, operating costs, financial information, asset, employment, and ownership status of all formal manufacturing and trade establishments in the country. The records distinguish between public enterprises, private domestic firms, and foreign firms.

Given the focus of our analysis, we exclude firms with zero or missing values of key variables as well as firms with values outside the range of 1 to 99 percentile. Because of permanent firm's exit and possibly the temporary lapses of some firms in filing their balance sheet information, the structure of the data is unbalanced panel. All monetary variables used in the analysis are converted in real terms using the country GDP deflator from the World Bank. This help to mitigate the input-quality or markup differences across times that are incorporated in prices.

Table 1 provides an overview of the firm data. The clean full sample includes 2,820 unique firms or 7,340 firm-year observations. The skewed distribution of key variables in the sample, as common to firm data from most developing countries, suggests that our economy is mainly composed of small firms and few very large firms. From 2010 to 2012, the average firm revenues (sales) and total assets are $1,117 and $436 respectively., while the average size is 16 employees. Average firm exit rate over the 4 years is 10%. Information on firm's financial health also displays a great deal of heterogeneity. While firm average leverage and liquidity ratio indices are respectively 0.75 and -0.88, the average trade credit and external finance ratio are 41 and 0.11, respectively.

Key Variables

Using the census of firms, our panel data is constructed as fallows. The independent variable is the performance of firms, measured by the logarithm of the total sales and the probability of firm exit. While sales are reported in the data, we constructed the exit variable. Using firms unique account number as identifier, we are able to distinguish permanent exit from temporary lapse in reporting or change in the name of the firm. The ability to detect true exit and entry provide a significant advantage for our data compared to similar data from other countries (Klapper, 2015).

Our key explanatory variables are firm pre-crisis financial conditions, including firm external finance dependence, liquidity ratio, leverage ratio, trade credit, all measured using 2010 firm balance sheet information. Trade credit variable shows the amount of credit that firms obtained from suppliers and clients. We follow the tradition in the literature to scale the trade credit variable using the cost of goods sold and multiply the ratio by 360 (Love et al., 2007; Levchenko et al., 2010, Coulibaly et al., 2013). Consequently, trade credit indicates the number of days firms take to pay their credit. Firm external finance dependence is proxied by the total short term and long term debt that firms obtain from banks. Liquidity is represented by the ratio of working capital (difference between short-term asset and short term debt) and total assets and leverages the ratio of short-term debt and short-term asset.

Other control variables include dummy for firm size, age above medium, ownership status, export status, and asset above medium. We constructed two categories for firm's size. Using the national classification of firms, firms with less than 10 employees and between 10 and 50 employees are respectively defined as micro and small firms. For more details about the construction of other key variables, check the note in the appendix.

3. Empirical Framework

To estimate the effect of the financial crisis on firm performance and trade credit, we employ a panel-data approach using firm fixed affect model. Applying a fixed effect model captures the unobserved heterogeneity in firm-specific levels of performance and trade credits and allows us to isolate the crisis and post-crisis effects from pre-crisis behavior of firms and trade credits.

3.1 Aggregate behavior

To study the aggregate behavior of firms during and after the crisis, we follow the specification model used by (Love et al., 2007) to define dummy variables, CRISIS and

POST, for the crisis and post-crisis years respectively. Controlling for firm fixed effects, these dummies capture changes in firm performance and trade credits relative to pre-crisis period. To fix idea, we use the following specification:

(1) $Y_{it} = \alpha_i + \delta_s + \beta_1 * CRISIS + \beta_2 * POST + X_{it} + \varepsilon_{it},$

where Y represent one of the firm performance measures, log sales or exit. Firm fixed effects, industry fixed effects are respectively represented by α and δ. While firm fixed effects control for time invariant firm characteristics, industry-year fixed effects control for shocks inherent to each industry in a given year, such as output and input price shocks and technological shocks within the industry. X is a vector of firm time specific controls. Finally ε is the error term clustered at firm-year to control for the spatial correlation across firms in a given year.

3.2 Heterogeneous Firm Response

To understand the effect of the increase in trade credit and the decrease in external finance on firm performance, we analyze firms' heterogeneous response to the crisis. Our identification relies on the exogenous drop of bank credit following the 2011 political crisis and firm's pre-crisis financial health indicators. Financial health measures, including firm leverage ratio, liquidity ratio, and use of external finance and trade credit are defined using firm pre-crisis balance sheet information. Our empirical specification uses the interaction of the pre-crisis financing variable with crisis and post crisis dummies. In other word, we use the following modification of equation (1):

(2) $Y_{it} = \alpha_i + \delta_s + \beta_1 * CRISIS + \beta_2 * POST + \beta_3 FIN_{i(-1)} * CRISIS + \beta_4 FIN_{i(-1)} * POST + X_{it} + \varepsilon_{it},$

where $FIN_{i(-1)}$ represents one of the indicators of firm pre-crisis financial health. FIN is not time varying, therefore, its level is included into the fixed effects. When FIN is zero, the changes in crisis and pre-crisis performance/trade ratio relative to the pre-crisis average is given by β_1 and β_2 as in model1. On the other hand, the effect of crisis and post-crisis on performance/trade varies for firms with different levels of FIN.

3.3 Substitution Across Sources of Finance

To assess the role of trade credit in firm performance during the financial crisis period, we follow Coulibaly et al. 2013 to explore firms' ability to substitute external finance for trade credit to relax their financial constraint. As such, we control the dynamic trade-off between firms trade credit and external financing in addition to pre-crisis trade credit and external finance dependence indicators.

Figure 3 illustrates the trade-off between external finance and trade credit in crisis period in our sample. On the horizontal axis we have the change in external finance between 2010 and 2011, normalized by total assets. On the vertical axis, the difference in trade credit normalized by the cost of goods sold represents the change in trade credit received during the same period. While positive values on the axes correspond to firms that obtained more trade credit or external finance during the crisis compared to the pre-crisis period, negative values correspond to firms that experience a decrease in trade credit or external finance during the crisis year relative to the previous year.

Following Figure 3, we classified firms into the four quadrants delimited by the axes. The resulting classifications are as follow: (1) firms in quadrant 1 experienced an increase in trade credit but a decrease in external finance, thus substituting external financing with trade credit during or after the crisis. (2) Firms in quadrant 2 posted an increase in both trade credit and external finance, thus becoming less constrained during or after the crisis. (3) Quadrant 3 consists of firms, which experienced a decrease in trade credit but an increase in external financing, thus substituting trade credit for external financing during or after the crisis. (4) Finally, quadrant 4 includes firms with zero or decline in both trade credit and external financing, thus becoming more credit constraint during or after the crisis. Online appendix Table 1 includes information on the number of firms in each quadrant.

In spirit of the above analysis, we study the extend to which the substitution between trade credit and external finance affect firm performance during and after the crisis by extending specification (2) with a set of dummies ($Quad_{qi}, for\ q = 1{,}2{,}3$) reflecting the distribution of firms across the first tree quadrants. Since we are interested to estimate the effect of the substitution between external finance and trade credit on the decline of sales from peak to trough period (2010-2011), the specification does not include firm fixed effects. We, however, control for 2-digit sector fixed effects and firms pre-crisis characteristics, in order to avoid potential omitted variable issues. The specification used is as follow:

(3) $\%\Delta Sale_i = \delta_s + \beta FIN_{i(2010,)} + \sum_{q=1,2,3} \theta Quad_{qi} + X_{i(2010)} + \varepsilon_i.$

4. Baseline Results

The empirical analysis proceeds in 5 steps. The first step examines the effect of the crisis and post crisis period on firm's revenues and survival. The second step analyzes the role of firm's pre-financial health conditions in their performance during the crisis and post crisis period. The third step pays particular attention to the role played by trade credit in firm performance. The fourth step investigates the determinants of firm's access to trade credit. Finally, the last step runs additional robustness checks

4.1 Aggregate Patterns

Table 2 presents the baseline results of the impact of the crisis and post crisis periods on firm's revenues and survival. After controlling for firm fixed effects and other firm characteristics, the coefficients on the crisis and post crisis dummies show a significant decrease in firm's revenues during the crisis and then a sharp increase in the post crisis period. On the other hand, firm exit rate increases during both the crisis and post crisis periods. In term of magnitudes, we found that during the crisis firm's revenues decreased by 15.8% while the likelihood of exit increased by 7.9%. The higher exit rate observed during the post crisis period is probably due to the lagged impact of the crisis on firms. On the other hand, firm's post crisis revenues and exit increased by 3.1% and 15.3%, respectively.

4.2 Heterogeneous Firm Response

To understand firm's heterogeneous responses to the financial crisis, we examine the role of firm's pre-crisis financial conditions, leverage ratio, liquidity ratio, trade credit, and external finance dependence, on their revenues and survival during and after the crisis.

Firm Liquidity Ratio

We start by looking at the role of firm's pre-crisis liquidity ratio in mitigating the impact of the crisis. To this end, we regress (log) revenues and a dummy variable indicating firm exit on firm's pre-crisis liquidity ratio, defined as the ratio of working capital and total assets, following the specification in equation (2). The specification includes firm size, export status, ownership status, asset, productivity, 2-digit sector fixed effects, as well as firm fixed effects. Standard errors are clustered at firm-year pair to control for spatial correlation across firms in a given year.

As reported in Table 3, we find that firm pre-crisis liquidity level was not a major player in its performance during or after the crisis. Results in column (2) suggest that a 1-point increase in firm's pre-crisis liquidity ratio is associated with 0.1% increase in revenues in the crisis period. Our main results suggest that while firm that enter the crisis with more liquidity posted more sale, liquidity has no significant effect on firms exit during the crisis. Moreover, liquidity has no impact on both firm's revenues and exit during the post-crisis period.

Firm Leverage Ratio

Following the same specification as above, we estimate the effect of firm's pre-crisis leverage ratio on its revenues and survival during and after the crisis. Firm leverage ratio is defined as the ratio of short-term debt and short-term asset. Table 4 contains results of the estimation. Except during the post crisis period where pre-crisis leverage level is associated with an increase in revenues, pre-crisis leverage level had no impact on firm's revenues and survival probability during the crisis. In column (1) of Table (4), we find that 1-point increase in firm's pre-crisis leverage ratio is associated with a 0.4% increase in post-crisis revenues.

Firm External Finance Dependence

To understand the impact of firm reliance on bank credit on their performance during and after the crisis, we estimate equation 2 following similar specification as above and using firm's pre-crisis ratio of bank credit to total assets as an indicator of external finance dependence. Surprisingly, in Table 5 we find that firm's pre-crisis levels of external finance dependence were not instrumental in their performance during the crisis and post period, except that 1-point increase in financial dependence ratio is associated with a 0.5% increase in firm exit rate during the post crisis period.

Firm Trade Credit Ratio

Finally we study the impact of firms pre-crisis trade credit standing on their performance during the crisis and post-crisis period. Following specification in equation (2), we define trade credit as the ratio of the amount of trade credit received by firms and the cost of goods sold. Then we follow the tradition in the literature to multiply the ratio by 360 so that it indicates the number of days firms take to pay their trade credit. Unlike in the case of leverage ratio, extending repayment of pre-crisis trade credit has statistically significant effect on firm performance, although the coefficients are very small. Results in column (1) and (2) of Table 6 suggest that being granted hundred more days to repay pre-crisis trade credit is associated with a 0.009% and 0.02% in firm's crisis and post crisis revenues, respectively. On the other hand, while increasing the number of repayment days of pre-crisis trade credit has no impact on post-crisis firm survival, it is associated with a very tiny positive increase in firm exit during the crisis (0.00004%). Similar qualitative results are found when we run a robustness check using an alternative measure of trade credit.

The main results in this section suggest that firm pre-crisis financial health status was not very instrumental in how they were affected during and after the crisis. Neither firm leverage ratio nor its dependence to external finance has an impact on its revenues or survival rate during the crisis. On the other hand, the economic meaning of the effect of trade credit on firm performance seem very small compared to the important increase in aggregate trade credit during and after the crisis as depicted in Figure 2. During the crisis and post crisis period, aggregate trade credit increased by 40% and 50% relative to the pre-crisis level. Two things could explain this puzzling result. Trade credit is not an important determinant of firm performance or pre-crisis trade credit standing is not a good indicator of firm's use of trade credit during and after the crisis. The next section will pay more attention to how the use of trade credit as an alternative source of financing during and after the crisis affected firm performance.

4.3 Substitution Across Sources of Finance

To understand the role that trade credit played on firm performance during the crisis and the post crisis period, we estimate equation 4 where our key variable of interest are indicators for firm's ability to substitute bank credits for trade credits during the crisis and post crisis period. Table 7 shows the baseline results for equation 3, where the key dependent variables are dummies for the substitution quadrants. The coefficients on all the quadrants are statistically significant and large in magnitude. The coefficient on quadrant 1 suggests that firms that managed to get more trade credit experienced a smaller decrease in their sales and were less likely to exit during the crisis and post crisis period relative to firms which observed a decrease in both bank credits and trade credits during the same period. The positive and statistically significant coefficient on quadrant 2 suggests firms that obtained more of both trade credits and bank credits were actually less affected during the crisis and post crisis period relative to firms which experienced a decrease in both trade credits and bank credits. In terms of magnitude, firms that were able to substitute external finance for more trade credit (quadrant 1) or obtain more of both (quadrant 2) experienced a smaller decline in their sales (37 and 45 percentage points, respectively) compared to firms which, obtained less trade credit and external finance (quadrant 4). The coefficient on quadrant 3 (firms with less external finance and less trade credit) is not statistically significant, suggesting the importance of trade credit in firm performance during the crisis.

We believe that the results for the quadrants are not driven by reverse causality. It seems implausible that the deterioration of bank credit during the crisis is exclusively driven by the to the anticipation of poor firm performance, but not related to the exogenous deterioration of credit conditions induced by the financial crisis (Coulibaly et al., 2013). Moreover, controlling for industry fixed effects, trade credit, and other firm characteristics allows us to control for firm specific effects that are constant over time.

4.4 Determinants of Trade Credit

Motivated by the fact that access to more trade credit improves firm performance during and after the crisis, we investigate the role of firms' pre-crisis financial conditions (leverage, liquidity, and external finance dependence) on their ability to obtain more trade credit during the crisis and post crisis period. We regress (log) trade credit on firm's pre-crisis financial health status (liquidity ratio, leverage ratio, and external finance dependence) following specification in equation (2). The specification includes firm size, export status, ownership status, asset, productivity, 2-digit sector fixed effects, as well as firm fixed effects. Standard errors are clustered at firm-year pair to control for spatial correlation across firms in a given year.

As reported in Table 8, the baseline results suggest that none of the pre-crisis financial indicators predicts the firm ability to get trade credit during and after the crisis, except that the coefficient on pre-crisis external finance ratio is statistically significant.

Using an alternative measure of trade credit in a robustness check, we found similar result. On the surface, our findings seem to contradict the intuition that the most financially vulnerable firms increase their trade credit during the crisis as an alternative source of finance likely due to the difficulty of rolling over their matured short-term debt during the crisis (Coulibaly et al., 2012). Based on this intuition, one might expect leverage ratio to be positively associated with trade credit. However, this contradiction is resolved when one takes into account the high demand for trade credit during a crisis and the importance of informal business network in doing business in most developing countries. When the demand for trade credit is higher than the supply, then business network might be the most viable channel to determine who gets more trade credit rather than firm's financial health status. Unfortunately, our data does not allow us to investigate the role of social network in firm's access to trade credit.

4.5 Additional Robustness Checks

To confirm whether the established baseline finding on firm behavior during the financial crisis is causal, we run additional robustness checks. We construct an alternative measure of trade credit by normalizing account payable by total fixed asset (rather than the cost of good sold) as in Coulibaly et al. (2012) and Fisman and Love (2003). The new trade credit variable is immune to potential endogeneity issues that might arise with using trade credit normalized by the cost of good sold (as mainly done in the literature) since firms sales during crisis and post crisis periods are not normal. Using the new trade variable, we re-estimate the effect of trade credit on firm performance followed by an analysis of the determinants of trade credits during and after the crisis. Results of the robustness check are respectively in Table A2 and Table A3. Using the new definition of trade credit (trade credit is normalized by assets rather than the cost of goods sold), the coefficients on the interaction of pre-crisis trade credit and crisis and post crisis dummies are no more significant. While the results are different from the baseline results, it does not contradict the key finding that pre-crisis trade credit situation were not important determinant of firm performance during the crisis. We, therefore, conclude that our baseline results are robust.

To assess whether firms anticipate the financial crisis and accordingly got more external finance going to the crisis to be used as financial cushion, we tested the trend of credit obtained by large firms from 2005 to the pre-crisis year, 2010. Since large firms are more likely to anticipate the crisis than smaller firms (partly because of their level of organization), we define them as the treatment group. We construct two pre-crisis differential trends. We first construct a continuous time variable defined as the number of years between 2005 and the pre-crisis year (2010). In a second robustness check, we replace the time trend variable by a dummy for the pre-crisis year, 2010. The specification is as follow:

(4) $LogExtfin_{it} = \delta_i + \gamma_1 firm_{large} + \gamma_2 T + \gamma_3 firm_{large} * T + X_i + \varepsilon_i,$

where the dependent variable is the logarithm of the amount of external finance obtained by firms, $firm_{large}$ is a dummy for firms with the number of employees above the 75th percentile, T is the time trend variable, and X_i represent a set of controls including 2-digit firm sector, export and ownership status, asset, and productivity. The standard error, ε_i, is clustered at firm year level.

Results of the pre-crisis trend test (e.g. $H_0: \gamma_3{}' = 0$) are in online appendix Table A4. In both regressions, column (1) and (2), we found no statistically significant effects of the pre-crisis trend variable on external finance. Moreover, we fail to reject the hypothesis that the treatment variable different from zero, although, large firms tend to get more external finance overtime. Given the above result, we conclude that our results do not suffer from the trend bias.

5. Conclusion

In this paper, we analyze the determinant of firm's performance during and after an unexpected melt down of the bank credit following the 2011 political crisis in Côte d'Ivoire. Using a detailed panel data of firm from 2010-2013, we find that better pre-financial conditions were not key defining factors of firm performance during the crisis. Amid the crunch of external financing opportunities, firms relied more on trade credit from suppliers and clients to post more sales. Firm pre-crisis conditions were not important in getting trade credit, therefore, we argue that business network rather than financial soundness plays a major role in firms accessing trade credits.

Our results seem to provide an insight about the resilience of African firms during the past global financial crisis. When the melt down of global financial market affected firms all over the world, African firms were mostly isolated from the effect of the crisis. Since trade credit seems to be an effective substitute for formal source of financing, policy makers should include the development of trade credit in broader financial inclusion initiative. While trade credit might not be the first best source of financing for firms in normal period, it seems to be useful in time of financial crisis.

Future research should pay particular attention to the role of business network in firm's access to trade credit. Our findings support that firms pre-crisis financial status has no impact on their access to trade credit during the crisis. Given the importance of trade credit in firm's performance during and after the crisis, it is worth understanding the determinant of trade credit. We believe that an interesting research would be to analyze the role of business network in firm's access to trade credit during a financial crisis.

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Figures:

Figure 1. Aggregate annual and monthly credits to firms

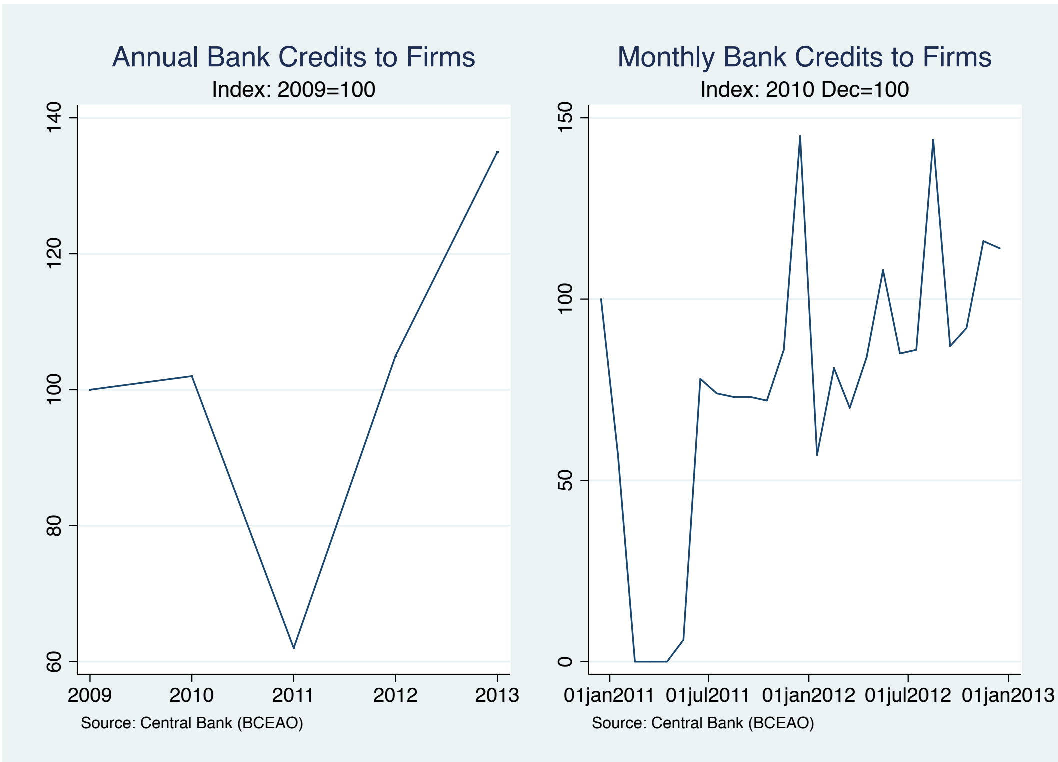


Figure 2. External Finance and Trade Credit Received by Firms in the Sample

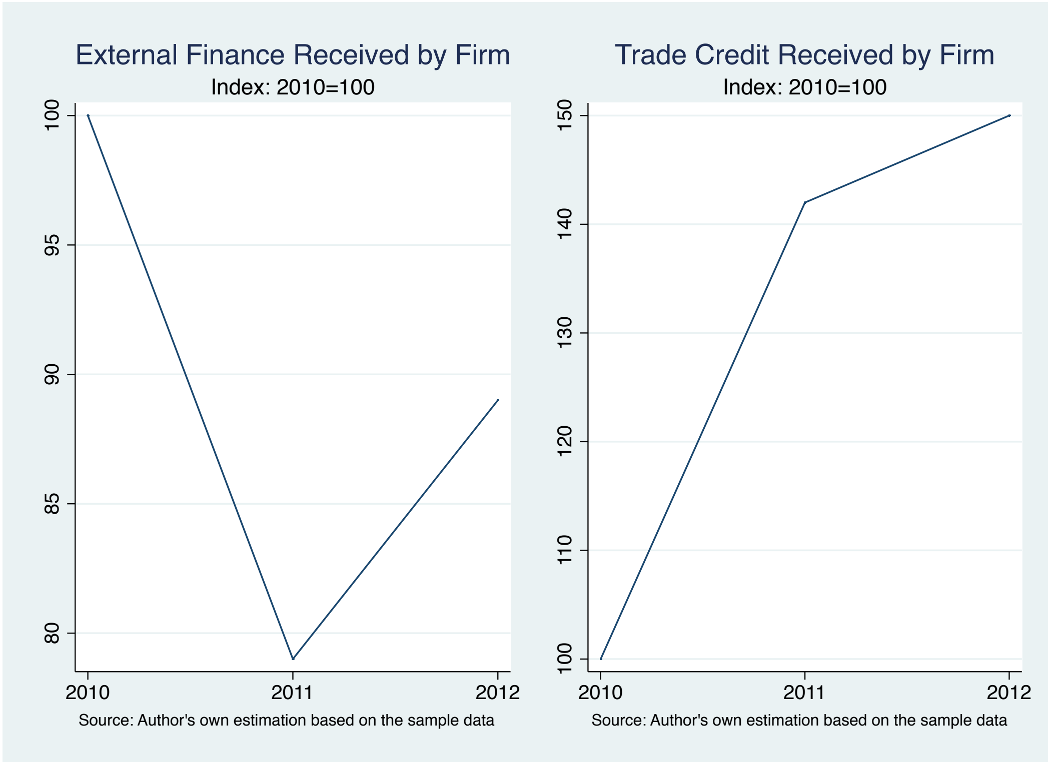
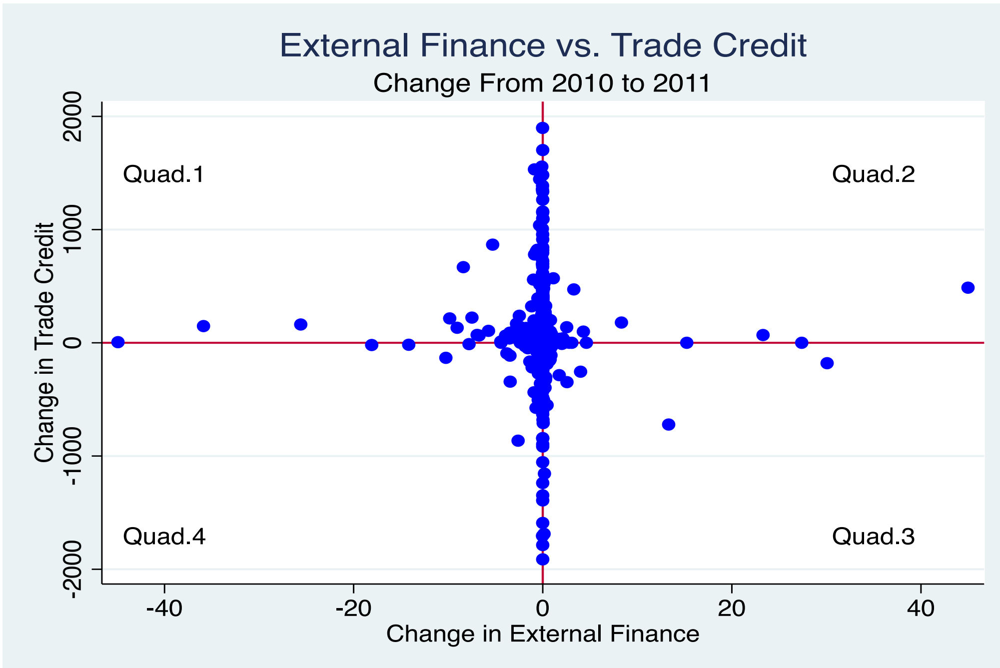


Figure 3: Illustration of the Trade off between External Finance and Trade Credit using Data in the Sample



Tables:

Table 1: Summary Statistics (Firm Year data)

Variables	Obs	Mean	SD	Min	Max	Unit
Revenue	7,340	1,117	3,120	0.931	47,359	US $mil
Total Asset	7,340	436.3	1,050	0.282	16,260	US $ mil
Labor	7,340	16.43	45.76	1	1,136	Person
Firm Exit	7,340	9.9	-	-	-	%
Value added per capita	7,340	0.497	5.170	-192.9	289.1	$
Exporters	7,340	4.1	-	-	-	%
Foreign Firms	7,340	24.6	-	-	-	%
% Change Sale (2010-2011)	2,370	-15.4	214.4	-7045	99	%
Pre-Crisis Financial Health Indicator (2010)						
Liquidity Ratio	7,340	-0.878	9.536	-385.7	1.967	Index
Leverage Ratio	5,949	0.746	9.958	0	437.8	Index
Trade Credit	7,340	41.11	232.5	0	12,105	Days
External Finance Ratio	7,340	0.124	1.794	0	97.69	Index
Post-Crisis Financial Health Indicator (2012)						
Liquidity Ratio	7,340	-0.851	10.64	-465.8	1.735	Index
Leverage Ratio	5,949	0.685	9.433	0	437.8	Index
Trade Credit	7,340	37.95	227.2	0	12,754	Days
External Finance Ratio	7,340	0.111	1.773	0	97.69	Index
Number of Firms	2,820	2,820	2,820	2,820	2,820	Firms

Data sources: Ivoirian national institute of statistics and author's own calculation. Firms that start producing after 2010 are dropped from the sample. See data section for details.

Table 2: Revenue and Firm exti in aggregate, specification (1)

	(1)	(2)
	Revenue	Firm Exit
Crisis	-0.158***	0.079***
	(0.012)	(0.005)
Post1	0.031**	0.153***
	(0.014)	(0.006)
Exporters	0.140***	-0.020
	(0.053)	(0.018)
Foreign firm	0.017	0.002
	(0.036)	(0.014)
Micro firm	-0.541***	0.088***
	(0.084)	(0.018)
Small firm	-0.371***	0.044***
	(0.074)	(0.011)
Asset above median	0.321***	-0.045***
	(0.041)	(0.017)
Value added per capita	0.004***	0.000
	(0.001)	(0.000)
Constant	12.495***	0.334*
	(0.122)	(0.173)
Observations	7,340	7,340
R-squared	0.062	0.105
Firm FE	YES	YES
2-Digit Sector FE	YES	YES
F-test (Crisis=0, Post1=0)	155.5	360.5
Prob>F	0	0

Notes: dependent variables for column (1) and (2) are respectively (log) revenue and frim exit. Crisis and Post1 are respectively dummy for the crisis year (2011) and the psot crisis year (2012). Other controls include, firm fixed effects, 2-digit sector fixed effects, dummies for firm size and status, and firm productivity. Micro firms are firms with less than 10 employees and small firms are firms with number of employees between 10 and 50. Standard errors are clustered at firm-year level. *** p<0.01, ** p<0.05, * p<0.1

Table 3: Determinants of firm sales and exit, specification (2). Role of firm pre-crisis liquidity Ratio

	(1)	(2)
	Revenue	Firm Exit
Crisis	-0.154***	0.080***
	(0.012)	(0.005)
Post1	0.032**	0.152***
	(0.013)	(0.005)
Crisis*liquidity2010	0.001*	0.000
	(0.001)	(0.000)
Post1*liquidity2010	0.000	-0.000
	(0.001)	(0.000)
Exporters	0.140***	-0.020
	(0.053)	(0.018)
Foreign firm	0.016	0.002
	(0.036)	(0.014)
Micro firm	-0.540***	0.088***
	(0.084)	(0.018)
Small firm	-0.371***	0.043***
	(0.074)	(0.011)
Asset above median	0.324***	-0.045***
	(0.041)	(0.017)
Value added per capita	0.004***	-0.000
	(0.002)	(0.000)
Constant	12.493***	0.334*
	(0.122)	(0.172)
Observations	7,340	7,340
R-squared	0.063	0.105
Firm FE	YES	YES
2-Digit Sector FE	YES	YES
F-test (all liquidity=0)	1.524	0.898
Prob>F	0.218	0.407

Notes: dependent variables for column (1) and (2) are respectively (log) revenue and frim exit. Crisis and Post1 are respectively dummy for the crisis year (2011) and the psot crisis year (2012). The key independent variables are the interaction between crisis, post crisis and firm pre-crisis liquidity ratio. Liquidity ratio is defined as the difference between current asset and current liability, scaled by total assets. Other controls include, firm fixed effects, 2-digit sector fixed effects, dummies for firm size and status, and firm productivity. Micro firms are firms with less than 10 employees and small firms are firms with number of employees between 10 and 50. Standard errors are clustered at firm-year level. *** p<0.01, ** p<0.05, * p<0.1

Table 4: Determinants of firm sales and exit, specification (2). Role of firm pre-crisis leverage Ratio

	(1)	(2)
	Revenue	Firm Exit
Crisis	-0.146***	0.080***
	(0.012)	(0.005)
Post1	-0.008	0.143***
	(0.013)	(0.006)
Crisis*leverage2010	0.002	0.000
	(0.001)	(0.000)
Post1*leverage2010	0.004**	-0.000
	(0.002)	(0.000)
Exporters	0.144***	-0.016
	(0.051)	(0.019)
Foreign firm	0.004	-0.001
	(0.039)	(0.016)
Micro firm	-0.492***	0.088***
	(0.082)	(0.018)
Small firm	-0.338***	0.041***
	(0.071)	(0.011)
Asset above median	0.294***	-0.052***
	(0.043)	(0.018)
Value added per capita	0.088***	-0.012*
	(0.019)	(0.006)
Constant	12.910***	0.328**
	(0.102)	(0.164)
Observations	5,949	5,949
R-squared	0.080	0.102
Firm FE	YES	YES
2-Digit Sector FE	YES	YES
F-test (all leverage=0)	3.273	7.540
Prob>F	0.0380	0.000536

Notes: dependent variables for column (1) and (2) are respectively (log) revenue and frim exit. Crisis and Post1 are respectively dummy for the crisis year (2011) and the psot crisis year (2012). The key independent variables are the interaction between crisis, post crisis and firm pre-crisis leverage ratio. Firm leverage ratio is calculated by dividing firm current liability its current asset. The sample for this estimation is reduced since it includes only firms with non-zero current asset. Other controls include, firm fixed effects, 2-digit sector fixed effects, dummies for firm size and status, and firm productivity. Micro firms are firms with less than 10 employees and small firms are firms with number of employees between 10 and 50. Standard errors are clustered at firm-year level. *** p<0.01, ** p<0.05, * p<0.1

Table 5: Determinants of firm sales and exit, specification (2). Role of firm pre-crisis external finance dependence

	(1)	(2)
	Revenue	Firm Exit
Crisis	-0.156***	0.080***
	(0.012)	(0.005)
Post1	0.033**	0.151***
	(0.013)	(0.005)
Crisis*extfin2010	-0.004	-0.000
	(0.005)	(0.001)
Post1*extfin2010	-0.005	0.005**
	(0.006)	(0.002)
Exporters	0.140***	-0.020
	(0.053)	(0.018)
Foreign firm	0.017	0.002
	(0.036)	(0.014)
Micro firm	-0.541***	0.089***
	(0.085)	(0.017)
Small firm	-0.371***	0.043***
	(0.074)	(0.011)
Asset above median	0.321***	-0.045***
	(0.041)	(0.017)
Value added per capita	0.004***	0.000
	(0.001)	(0.000)
Constant	12.495***	0.333*
	(0.122)	(0.172)
Observations	7,340	7,340
R-squared	0.063	0.106
Number of id	3,089	3,089
Firm FE	YES	YES
2-Digit Sector FE	YES	YES
F-test (all external finance=0)	0.466	3.495
Prob>F	0.628	0.0304

Notes: dependent variables for column (1) and (2) are respectively (log) revenue and frim exit. Crisis and Post1 are respectively dummy for the crisis year (2011) and the psot crisis year (2012). The key independent variables are the interaction between crisis, post crisis and firm pre-crisis external finance ratio. External finance ratio is calculated by dividing firm total external financial debts by its total assets. Other controls include, firm fixed effects, 2-digit sector fixed effects, dummies for firm size and status, and firm productivity. Micro firms are firms with less than 10 employees and small firms are firms with number of employees between 10 and 50. Standard errors are clustered at firm-year level. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 6: Determinants of firm sales and exit, specification (2). Role of firm pre-crisis trade credit

	(1)	(2)
	Revenue	Firm Exit
Crisis	-0.170***	0.074***
	(0.013)	(0.005)
Post1	0.005	0.151***
	(0.014)	(0.006)
Crisis*trade	0.00009*	0.00004***
	(0.000)	(0.000)
Post1*trade	0.0002***	0.000
	(0.000)	(0.000)
Exporters	0.142***	-0.020
	(0.053)	(0.018)
Foreign firm	0.021	0.003
	(0.036)	(0.014)
Micro firm	-0.547***	0.088***
	(0.085)	(0.018)
Small firm	-0.372***	0.044***
	(0.074)	(0.011)
Asset above median	0.320***	-0.045***
	(0.040)	(0.016)
Value added per capita	0.004**	-0.000
	(0.001)	(0.000)
Constant	12.505***	0.336*
	(0.121)	(0.173)
Observations	7,340	7,340
R-squared	0.069	0.106
Firm FE	YES	YES
2-Digit Sector FE	YES	YES
F-test	15.22	3.451
Prob>F (all trade=0)	2.54e-07	0.0318

Notes: dependent variables for column (1) and (2) are respectively (log) revenue and frim exit. Crisis and Post1 are respectively dummy for the crisis year (2011) and the psot crisis year (2012). The key independent variables are the interaction between crisis, post crisis and firm pre-crisis trade credit. Trade credit is the ratio of supplier and client credits received by firms and the cost of production. The ratio is multiplied by 360 to get the number of extended days for the credit. Other controls include, firm fixed effects, 2-digit sector fixed effects, dummies for firm size and status, and firm productivity. Micro firms are firms with less than 10 employees and small firms are firms with number of employees between 10 and 50. Standard errors are clustered at firm-year level. *** p<0.01, ** p<0.05, * p<0.1

Table 7: Determinants of firm sales and exit, specification (3). Dependent variable: % decline in sales, 2010-2011

	(1)	(2)	(3)
	Baseline	Robustness, control for initial sales	Robutness, drop firms with zero ext. finance or trade credit in both periods
Trade Credit_2010	-0.000	0.000	-0.000
	(0.000)	(0.000)	(0.000)
Ext. Finance_2010	0.006	0.012***	0.014**
	(0.005)	(0.005)	(0.007)
Quad.1	0.368***	0.333***	0.545*
	(0.109)	(0.106)	(0.294)
Quad.2	0.449***	0.404***	0.630**
	(0.096)	(0.091)	(0.295)
Quad.3	0.096	0.028	0.210
	(0.145)	(0.139)	(0.308)
Exporters	0.242	0.044	-0.034
	(0.150)	(0.131)	(0.104)
Foreign firm	-0.040	-0.129	-0.102
	(0.100)	(0.105)	(0.083)
Micro firm	-0.312**	0.610***	0.658
	(0.147)	(0.217)	(0.401)
Small firm	-0.078	0.348***	0.447*
	(0.107)	(0.134)	(0.254)
Value added per capita	0.005**	0.005**	0.003
	(0.002)	(0.002)	(0.002)
Log. Sales_2010		0.292***	0.296**
		(0.078)	(0.141)
Constant	-0.603	-4.713***	-4.712**
	(0.421)	(1.200)	(2.292)
Observations	2,370	2,370	1,179
R-squared	0.022	0.054	0.051
Control	YES	YES	YES
2-Digit Sector FE	YES	YES	YES
F-test (all quadrant=0)	9.009	8.293	4.541
Prob>F	0	0	0.003

Notes: the dependent variable is the decline in firms sales from peak to trough (2010-2011). Trade credit and external finance are indicators for firms pre-crisis trade credit and external finance dependence. Quadrants are dummies for firm substitution between external finance and trade credits (see specification 2 for details). Other controls include, firm fixed effects, 2-digit sector fixed effects, dummies for firm size and status, and firm productivity. Micro firms are firms with less than 10 employees and small firms are firms with number of employees between 10 and 50. Standard errors are clustered at firm-year level. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 8: Determinants of firm trade credits, specification (2). Role of firm pre-crisis financial indicators, liquidity, leverage, and external finance

	(1)	(2)	(3)
Crisis	36.866***	41.014***	35.630***
	(5.139)	(5.499)	(5.327)
Post1	13.103**	16.969***	10.254
	(6.121)	(5.196)	(6.329)
Crisis*liquidity2010	0.561		
	(0.531)		
Post1*liquidity2010	0.389		
	(0.511)		
Crisis*leverage2010		0.156	
		(0.168)	
Post1*leverage2010		-0.007	
		(0.173)	
Crisis*extfin2010			-0.960
			(1.965)
Post1*extfin2010			4.398*
			(2.566)
Observations	7,340	5,949	7,340
Firm FE	YES	YES	YES
2-Digit Sector FE	YES	YES	YES
F-test (liquid., lever., ext. fin.=0)	0.601	0.614	3.157
Prob>F	0.548	0.541	0.0426

Notes: the dependent variable is trade credit. Trade credit is the ratio of supplier and client credits received by firms and the cost of production. The ratio is multiplied by 360 to get the number of extended days for the credit. Crisis and Post1 are respectively dummy for the crisis year (2011) and the psot crisis year (2012). Liquidity, leverage, and external finance ratios are firm financial health indicators. For space reason, controls, including dummies for firm size and status, and firm productivity, are excluded from this table. Standard errors are clustered at firm-year level. *** p<0.01, ** p<0.05, * p<0.1

Online Appendix

A. Tables

Table A1: Number of firms by quandrant

Quadrant	Firm	
	Frequency	Percent
Quad.1	1052	18.48
Quad.2	316	13.33
Quad.3	235	8.73
Quad.4	767	32.36
Total	2370	100

Note: number of firms with zero trade credit or zero external finance in both periods are respectively 188 and 1143.

Table A2: Determinants of firm sales and exit, specification (2). Robustness check using amount of trade credit scaled by assets

	(1)	(2)
	Revenue	Firm Exit
Crisis	-0.154***	0.079***
	(0.012)	(0.005)
Post1	0.034***	0.152***
	(0.013)	(0.006)
Crisis*trade	-0.002	-0.000
	(0.001)	(0.001)
Post1*trade	-0.001	0.001
	(0.001)	(0.001)
Exporters	0.140***	-0.020
	(0.053)	(0.018)
Foreign firm	0.016	0.003
	(0.036)	(0.014)
Micro firm	-0.540***	0.088***
	(0.084)	(0.018)
Small firm	-0.371***	0.043***
	(0.074)	(0.011)
Asset above median	0.322***	-0.045***
	(0.041)	(0.017)
Value added per capita	0.004***	-0.000
	(0.002)	(0.000)
Constant	12.493***	0.334*
	(0.122)	(0.172)
Observations	7,340	0.913
R-squared	0.063	0.401
Firm FE	YES	YES
2-Digit Sector FE	YES	YES
F-test	1.436	94.03
Prob>F (all trade=0)	0.238	0

Notes: All variables are defined as in Table 6, except that trade credit is now defined as total credit received in USD scaled by the value of total fixed capital. Standard errors are clustered at firm-year level. *** p<0.01, ** p<0.05, * p<0.1

Table A3: Determinants of firm trade credits, specification (2). Role of firm pre-crisis financial indicators, liquidity, leverage, and external finance

	(1)	(2)	(3)
Crisis	36.866***	41.014***	35.630***
	(5.139)	(5.499)	(5.327)
Post1	13.103**	16.969***	10.254
	(6.121)	(5.196)	(6.329)
Crisis*liquidity2010	0.561		
	(0.531)		
Post1*liquidity2010	0.389		
	(0.511)		
Crisis*leverage2010		0.156	
		(0.168)	
Post1*leverage2010		-0.007	
		(0.173)	
Crisis*extfin2010			-0.960
			(1.965)
Post1*extfin2010			4.398*
			(2.566)
Observations	7,340	5,949	7,340
Firm FE	YES	YES	YES
2-Digit Sector FE	YES	YES	YES
F-test (liquid., lever., ext. fin.=0)	0.601	0.614	3.157
Prob>F	0.548	0.541	0.0426

Notes: All variables are defined as in Table 8, except that trade credit is now defined as total credit received in USD scaled by the value of total fixed capital. Moreover liquidity, leverage, external finance are all adjusted to excude the value of trade credit. Standard errors are clustered at firm-year level. *** p<0.01, ** p<0.05, * p<0.1

Table A4: Pre-Crisis Credit Trends, 2005-2010

	(1)	(2)
	Time defined continuously, 2005-2010	Time is a dummy for pre-crisis year, 2010
Pre-crisis Trend (T)	-0.012	-0.001
	(0.017)	(0.105)
Large firm dummy	1.506***	1.468***
	(0.118)	(0.062)
Treat (Large firm * T)	-0.010	-0.001
	(0.027)	(0.063)
Exporters	0.851***	0.859***
	(0.080)	(0.080)
Foreign Firm	0.332***	0.337***
	(0.053)	(0.053)
Asset above Median	1.126***	1.130***
	(0.057)	(0.057)
Value added per capita	0.000**	0.000**
	(0.000)	(0.000)
Constant	9.249***	9.195***
	(0.225)	(0.213)
Observations	8,533	8,533
R-squared	0.339	0.339
Control	YES	YES
Firm FE	YES	YES
2-Digit Sector FE	YES	YES
F-test	0.147	0.00003
Prob>F (Treat=0)	0.701	0.995

Notes: the dependent variable for both regressions is (log) external finance. In column (1), T is defined as the number of until 2010 (2005=1, 2006=2, …2010=6) and in coulumn (1) T is a dummy for year 2010 (last year until the crisis). Large firm is a dummy for firms with the number of employees above the 75th percentile (16 employees). Standard errors are clustered at firm-year level. *** p<0.01, ** p<0.05, * p<0.1

B. Definition of the key variables

Sales: sum of domestic and foreign sales
Exporter: if the firm export a positive amount.

Total assets: sum of firm's fixed asset (tangible and intangible) and current assets.

Current assets: sum of stock, trade credit provided, cash and equivalents, and other current assets.

Current liabilities: are defined as the sum of short-term debt, trade credit received, and other current liabilities.

Short-term debt: are defined as the sum of debt fiscal, debt social, short-term bank loans, and other short-term debts.

Liquidity ratio: ratio between the firm's current assets minus its current liabilities and its total assets
External finance: ratio of firm's total financial debts (short and long term bank loans and overdraft) scaled by total assets.

Leverage ratio: ratio between the firm's short-term debt and current assets.

Trade receivable: is the ratio between trade credit that the firm provides to its suppliers and customers and total sales. Following the literature the ratio is multiplied by 360 and accordingly interpreted as the number of days credit is extended.

Trade payable: is the ratio between trade credit that the firm obtained from its supplier or customers and costs of good sold. Following the literature the ratio is multiplied by 360 and accordingly interpreted as the number of days credit is received.

Deflators: all monetary variables are deflated using aggregate GDP deflator.