Agricultural, Financial and Behavioral Changes on the Path to Sustainable Technology Adoption in Rural Mozambique

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INTRODUCTION

This dissertation builds on a project implemented in the rural province of Manica in Mozambique. The project combines voucher subsidies for an improved seeds and fertilizer package, with an intervention that offers a financial education that encourages the opening of savings accounts and a 50% match on savings between harvest and the planting season. Both the agricultural and the financial intervention are randomized in order to evaluate their impact and their complementarity. The agro-input subsidy aims generating revenues for the recipient and informing him about the benefits of using improved seeds and fertilizer. However, the ability for the beneficiaries to carry forward the benefits of the package by re-investing it over the years relies on their ability to save part of the revenues between harvest and the time to purchase the inputs, which is why the subsidy is combined with an encouragement to use savings accounts. Hence the two interventions are designed to create a sustainable path out of poverty through a change in farming and saving practices.

Many developing countries have poured a large portion of their agricultural budget into subsidies for fertilizer and other inputs. These subsidies aim at technology adoption, food security and poverty reduction, but have been the object of many criticisms from the international community. Yet until now the ongoing debate has lacked solid empirical evidence from the evaluation of such subsidies. The first essay of this dissertation analyzes the impact on maize production of receiving a voucher that offers a 73% subsidy on an improved maize seeds and fertilizer package for of a half hectare of maize cultivation. We found that only 28% of the farmers who were offered the subsidy used the content of the package for their maize production. This reduced the precision of the estimate of the average impact, making it difficult to draw clear conclusions on the profitability of the package when it is used. However, we observe a substantial heterogeneity of impact among beneficiaries. The farmers with more prior experience using fertilizer, and the ones who use irrigation most benefited from the subsidy, which casts some doubts about the subsidy's potential to spur widespread adoption of improved seeds and fertilizer.

Matched Savings Accounts, better known as Individual Development Accounts in the United States, offer a match on the savings of the beneficiary, in order to encourage asset accumulation and reduce financial exclusion. The Mozambican experiment is among the first application and evaluation of Matched Savings in the developing world, and hopes to contribute to the development of a new tool for the development of micro-savings. The theoretical part of the second essay uses a poverty trap model and simulation with dynamic optimization to decompose the channels through which Matched Savings can contribute to a long term reduction in poverty. It is followed by the empirical section, which evaluates the impact of a Savings Treatment (ST) which provides financial education sessions and encouragements to open a savings account; and a Matched Savings Treatment (MST) which adds a 50% match on savings to the previous intervention. We find that the MST has increased the proportion of participants who hold a savings account by 20 percentage points, and increased their formal savings 2.7 times more than the ST alone. This increase in formal savings mostly comes from a reduction in informal savings. Other changes in consumption and asset portfolio are also observed. The MST has reduced the consumption of durable goods and the stock of maize grains of the participants, in favor of other forms of assets. The long term impact of such changes remains to be investigated in the following years.

While the first two essays analyze "mechanical" economic consequences of the project, the third essay investigates a behavioral change that results from the two interventions. It offers a new theoretical model, based on the psychology literature on cognitive dissonance and time discounting, which explains how the poor can close their eyes on the future in order to reduce the distress that is caused by the anticipation of future poverty. This shortening of their planning horizon, increases consumption at the expense of asset accumulation and can thus cause a behavioral poverty trap. Hence for the poor who benefited from the agricultural and financial intervention, it is expected that the improvement in their future prospects reduces the cost for them to be forward looking and increases their planning horizon. This prediction is tested empirically with each one of the two interventions of the Mozambican experiment. We find that both the agro-input subsidy treatment and the Matched Savings treatment resulted in a significant increase in the beneficiaries' planning horizon. It provides a new analysis of the reasons behind the apparent time inconsistencies of individuals, and the first empirical evidence of the endogenous determination of time preference.

Together the three essays contribute to a better understanding of the economic and human factors behind the decision to change one's agricultural and financial practices. It provides an analysis that will allow policy makers to make better informed decisions in the use of subsidies for agriculture and improve the design of the interventions that aim at promoting financial integration, technology adoption and a change in the long term poverty dynamics in the rural developing world.

The Heterogeneous Impact of Agro-Input Subsidies on Maize Production: A Field Experiment in Mozambique

Introduction

The use of improved seeds and fertilizer have contributed to large productivity gains in the developing world during the Green Revolution, yet at a very different pace across regions, with the slowest increase in yield from 1960 to 2000 occurring in Sub-Saharan Africa [34]. Today, Sub-Saharan Africa remains a net food importer, despite its agricultural potential, largely untapped because of the limited use of existing technologies. In 2009, farmers in Africa used only 13 kg of fertilizer per hectare on average, compared with an average of 94 kilograms per hectare in developing countries[1]. A major increase in improved seeds and fertilizer is required to improve soil fertility and reach both food security and a higher income for the farmers, but the evidence on its returns are inconclusive. Hassan, ed [41] finds that Kenyan farmers apply less fertilizer than optimal, resulting in a 30% yield gap. Duflo et al. [32] find a return to fertilizer that reaches 36% over a season when the correct quantity is applied, but only 5% or even negative returns with alternative fertilizer intensities. Foster and Rosenzweig [37] argue that, on average, underinvestment in fertilizer is not high given its limited returns. Therefore, further evidence is needed to resolve the question of the potential returns and underuse of improved seeds and fertilizer in the developing world. Furthermore, given the increasing evidence of the heterogeneity of returns to improved seeds and fertilizer [79], the average return is not particularly informative for policy making. Our study provides a unique chance to evaluate the success of an agro-input subsidy program, but also to look at the distribution of the returns derived from and exogenous increase in improved seeds and fertilizer.

The traditional literature has provided multiple theoretical explanations for the low adoption of a profitable technology: credit constraints [23], risk aversion [71, 85], information barriers on how to use the technology [36], or its returns [22] and supply availability. In theory, a temporary agro-input subsidy has the potential to overcome most of these barriers. Making the input affordable during a limited period can allow farmers to experiment and familiarize themselves with the technology, while making a profit that will allow them to save enough to afford further inputs in the future. As a result, the expected demand for the input would increase, which would stimulate a reliable supply. The recent trend toward "smart subsidies," which offer vouchers targeted to small farmers, ensures that the scheme is equitable and promotes among the tareted small scale producers at an efficient cost. Yet this

[1] FAO (Food and Agriculture Organization of the United Nations) statistics, accessible at http://faostat.fao.org/site/422/ default.aspx#ancor

rosy scenario relies on multiple assumptions besides the input's profitability, including the government's ability to efficiently administrate the program, the small farmers' ability both to learn rapidly despite the stochasticity of production and to save their profits. and the high responsiveness of the supply chain. Hence the debate on argo-input subsidies remains heated but largely speculative given the scarcity of evidence on one of the most important policy questions in agriculture in the developing world.

We implemented an experiment where a 73% subsidy voucher for an improved maize seed and fertilizer package has been randomly distributed among an initial sample of 1,593 households in rural Mozambique (and 1,436 households in the follow-up survey). We evaluate the extent to which the subsidy modifies the agricultural practices of the beneficiaries and their maize production. The study reveals important leakages, with only 28% of the selected beneficiaries using their voucher for maize production. Conditional on using it, the average return does not appear to be significant, partly because the low take-up of the subsidy resulted in very large confidence intervals of the estimates. However the average hides huge disparities of impact on production. The data allow us to identify two main sources of heterogeneity of impact: the beneficiary's prior experience with fertilizer and the use of irrigation.

Context and Intervention

Background

Agriculture and subsidies in the region

In the 1970's and early 80's in a majority of African countries, fertilizer was subsidized and sold through state-owned enterprises in order to address the under provision of fertilizer by the market. However, blamed for being costly, inefficient, overwhelmingly beneficial to large farmers, and detrimental to the private sector, most of the public monopolies of agro-inputs were eliminated during the structural adjustments of the late 80's. Yet in the late 90's, agro-input subsidies have re-emerged under what is now called "smart subsidies". Typically, vouchers are distributed to poor farmers, giving them access to an agro-input package, which will be provided by the private sector at a subsidized price (the providers then trade the vouchers against the amount of the subsidy, at an intermediary bank or agency). This scheme has been claimed to offer the previously-mentioned advantages of traditional fertilizer subsidy while stimulating rather than undermining the private sector, and targeting the poor more effectively. On the other hand, some agencies have indicated failures to target the poor, and the low cost effectiveness of the intervention [61]. Hence the debate on agro-input subsidy remains very active.

The use of voucher subsidy in Mozambique was inspired by neighboring Malawi's agro-input subsidy program. The Starter Pack Scheme (SPS), implemented in 1998, followed by the Target Input Program (TIP) in 2000 and the

Farmer Input Subsidy Program (FISP) in 2005, were large scale input subsidies, targeting mostly maize but also tobacco production in Malawi. While these subsidies contributed to a significant increase in fertilizer use and maize production, helping achieve both national and household food self-sufficiency, their potential for long-term growth and poverty reduction remains unclear. Levy [53] finds evidence that the households most dependent on maize production were most affected by the 2001-2003 crisis, substantiating worries that the reduction of diversification caused by the subsidy has increased the vulnerability of the beneficiaries. Chibwana et al. [21] find that the FISP failed to target the most vulnerable members of the communities (i.e. asset poor households and households with female heads) because the selection of the coupon recipients was affected by political factors. Whether the subsidy programs strengthened or weakened the private provision of agro-inputs remains unknown, and the claim that the subsidized learning of farmers will stimulate commercial demand has not yet been confirmed empirically at this point. At its peak in 2008/09, subsidy costs accounted for around 16% of Malawi's national budget and 74% of its agricultural budget [29]. Hence the agro-input subsidies brought food self-sufficiency to Malawi at a substantial cost, which threatens its viability. The case for the subsidy depends on whether it can generate long lasting benefits for recipients, which we investigate using a field experiment in Mozambique.

Mozambique's economy shares similarities with Malawi, both being low income countries with more than 75% of their population working in small-scale agriculture. Following its independence in 1975, Mozambique went through 15 years of civil war, from 1977 to 1992. Despite an annual GDP growth of 8% on average between 1994 and 2006, it remains one of the poorest countries in the world. In 2011, its Human Development Index was ranked 184th out of 187 countries rated (compared to 160th for Malawi). In Mozambique, the agriculture is dominated by small farm farming, with little to no use of tractors, ploughs, fertilizer, pesticides, irrigation and other agro-inputs. The most common crops include maize, cassava, sweet potatoes, cotton, tobacco, sesame and groundnuts. The use of mineral fertilizer among small households is primarily limited to cash crops and scarce on cereal crops, leading to low yield, generally below one ton per hectare for maize production (compared to up to 8 tons per hectare in the most productive developing countries). The nascent input market is small and its network unsubstantial. Between 1996 and 2003, agricultural production grew by an average of 6% per year, leading to a decrease in the rural poverty headcount, from 69% to 54% during the same period. However, Nankani et al. [64] note that this growth mainly resulted from the expansion of area cultivated and labor due to the return of migrants, while technological improvements have been modest and yields almost stagnant, which threatens the sustainability of agricultural growth in the absence of future technological progress.

Research Design

Inspired by the Malawian experience, Mozambique launched a two-year fertilizer subsidy program for maize and rice production funded by the European Union. At the request of Mozambique's Ministry of Agriculture, the Food and Agriculture Organization (FAO) and the International Fertilizer Development Center (IFDC) implemented an agro-input subsidy program over the years 2009-10 and 2010-11. The program involved the distribution of 25,000 vouchers, offering a 73% subsidy on an improved seed and fertilizer package. 10,000 vouchers targeting rice production were distributed in two provinces, while 15,000 vouchers directed at maize production were distributed in three other provinces. The impact evaluation occurred in Manica province, located in the center west of Mozambique, sharing a border with Zimbabwe on its west side. We sampled 1,593 households among three districts of the Manica province, where only maize vouchers were distributed[2]. Within each of the 75 villages included in this study, one half of the households were randomly selected to receive a voucher, that offers a subsidized package of 12.5 kg of improved seeds (either OPV or hybrid), and 100kg of fertilizer (50 kg of urea and 50 kg of NPK 12-24-12). To acquire these inputs designated for a half hectare of maize production, farmers were required to contribute MZN 860 (USD 32) of their own funds. Given the market value of the package of MZN 3163 (USD 117), the voucher offered a 73% subsidy on the agro-input package. The Voucher Treatment was combined with a financial intervention, which is analyzed in a separate paper. Therefore the access to the financial institution Banco Oportunidade was a criteria for the selection of villages. All villages that combined access to Banco Oportunidade and participation to the voucher program were included in the study, which spreads over three districts of the Manica province: Barue, Manica, and Sussundenga.

The selection of the beneficiaries of the maize voucher subsidy program was officially based on the following criteria:

- Farming between 0.5 hectare and 5 hectares of maize

- Being a "progressive farmer", meaning aiming for modernization of their production methods and commercial farming

- Access to agricultural extension and access to input and output markets

- Ability and willingness to pay for the remaining 30% of the package cost

Given the absence of prior data on maize cultivated and other necessary information, the criteria were communicated to the public extension and IFDC as guidelines for the selection of beneficiaries, but were not strictly followed.

[2]Given a potential heterogeneity in the impact across provinces and between maize and rice, we do not claim that the results are representative of the subsidy program over the five provinces. The sample is not representative of any geographical entity either.

Progressive small farmers were targeted, rather than the most vulnerable ones, in order to facilitate the diffusion of a technology that is new to most small maize farmers in Mozambique. The lists of beneficiaries were created jointly by agricultural extension, local leaders, and agro-input retailers, under the supervision of the IFDC. Farmers were asked to register only if they had the money to complete the subsidy, which was the most limiting factor, and only one person per household was allowed to register. The farmers were informed that a lottery would occur and only half of those on the list would be offered a voucher. After official approval of the Provincial Service of Agriculture of Manica, the lists of possible participants were used to randomly assign vouchers to 50% of the households in the list of each village. Hence during the year 2010-2011, the entitlement to receive a voucher was randomized at the individual level and stratified at the village level.

Data Collection and Sample

This study evaluates the second year of the two year subsidy program, which occurred in 2009-2010 and 2010-2011. The timing of the interventions and data collection is as follows. The list of participants was made in August 2010. The agro-input vouchers were distributed to the farmers at the end of November and early December. In Manica province, the planting season for rain fed maize runs from November 2010 to January 2011, and the harvest from April to June 2011. The late distribution of the vouchers forced farmers to plant the seeds and use the fertilizer relatively late in the planting season, which had important consequences to be discussed later. The baseline survey, involving 1,593 households, occurred in March/April 2012[3], after planting but before harvest, for most maize farmers.

In July and August 2011, after the maize harvest, a first follow-up survey, completed by 1,436 households[4] was implemented. The questionnaires included a detailed section on maize practices, input use, and production for the 2009/10 season and the 2010/2011 season. Participants were also asked about formal credit and savings, consumption, time discounting, risk aversion, migration, remittances, social networks, and cognitive skills and, at the end of the questionnaire, the use of vouchers. An additional survey was conducted at the community level to collect data on prices, availability and distances to agro-input providers, Banco Oportunidade, and schools.

Table 1 provides basic statistics on the population of the sample collected in the baseline. Among the heads of household, 84% are male and 76% are literate (compared to 66% male heads of household and a 45% alphabetization

[3]We designate the first survey a baseline survey although it is not a true baseline with regard to the agro-input subsidy since it occurred after the distribution but before harvest.

[4]The attrition rate was 9.9% and the probability to respond was not affected by the treatments (the p-value of the f-test is 0.58), hence the results of the first follow-up survey are not confounded by a selection bias.

rate in rural Manica[5]), indicating that the targeted households are relatively less vulnerable compared to the rest of the region. However, with an average 10.3 hectares of land owned (the median being 5 hectares), only 11% of households having electricity at home, and 19% having used fertilizer in at least one of their maize fields during the 2009-2010 agricultural campaign[6], it remains a population dominated by relatively poor small scale farmers with a limited use of modern agro-inputs.

Impact of the Agro-input Subsidy

Regression Specification

This section investigates the impact of the subsidy on the use of fertilizer, improved seeds and maize production. In household level regressions, the following reduced form provides a direct measure of the impact of the lottery on the outcome of interest.

$$Y_{iv} = a_0 + a_1 Z_{iv} + X_{iv}^{'} a_2 + \theta_v + \epsilon_{iv} \quad (0.1)$$

where Y_{iv} is the outcome of household i in village v , Z_{iv} is an indicator equal to 1 if individual i was assigned to the treatment group (i.e. who won the voucher lottery) and 0 otherwise, θ_v is a village fixed effect, X_{iv} is a vector of control variables (which generally includes the outcome at the previous period and the maize area cultivated), and ϵ_{iv} is a mean zero error term of household i. Since the randomization of the treatment ensures that Z_{iv} and ϵ_{iv} are orthogonal, the ordinary least squares provide an unbiased estimator of a_1, the Intention To Treat (ITT) effect. Village fixed effects and control variables are not necessary to obtain unbiased results, but are used to reduce the variance of the estimator.

The voucher lottery operated as an encouragement design that affected the probability of the beneficiary to receive a voucher (which was conditional on being able and willing to complete the subsidy) and use the subsidized package for maize production. We are interested in the impact of the package conditionally on being used for maize production. Therefore a dummy for whether the household received the package and used it for maize production is instrumented by the result of the lottery in the following first and second stage regressions.

$$D_{iv} = b_0 + b_1 Z_{iv} + X_{iv}^{'} b_2 + \tau_v + \eta_{iv} \quad (0.2)$$

[5]The Manica data used for comparison is from the 2007 "Terceiro Recenseamento Geral da População e Habitação", provided by Mozambique's National Institute of Statistics, accessible online at http://www.ine.gov.mz/home_page/censo2007

[6]Many of them may have benefited from the first year of the same voucher program, of which the beneficiaries overlap with the population of this sample, but we only randomized the distribution in the second year.

$$Y_{iv} = c_0 + c_1 \hat{D_{iv}} + X_{iv}^{'} c_2 + \theta_v + \varepsilon_{iv} \tag{0.3}$$

where D_{iv} is a dummy equal to one if the household declares having used some inputs from the package obtained with the voucher in his maize production[7]. $\hat{D_{iv}} = \hat{b_0} + \hat{b_1} Z_{iv} + X_{iv}^{'} \hat{b_2} + \hat{\tau_v}$ gives the first stage fitted values of D_{iv} estimated in regression 0.2. The two stage least square provides a consistent estimate of c_1, the Local Average Treatment Effect (LATE) of using a voucher subsidy for the compliers (those who used the package only if they won the lottery). In an alternative specification, D_{iv} represents the quantity of fertilizer that is used by household i on maize production. In this case c_1 provides an estimate of the return of one kilogram of fertilizer when it is used jointly with the improved seeds.

Regressions at the plot level offer an alternative approach, which permits the inclusion of variables that vary among parcels for a given household (such as irrigation). The parcel regression equation to obtain the ITT is as follows:

$$Y_{piv} = \alpha_0 + \alpha_1 Z_{iv} + X_{iv}^{'} \alpha_2 + K_{piv}^{'} \alpha_3 + \theta_v + \epsilon_{piv} \tag{0.4}$$

where Y_{piv} is the outcome of interest in parcel p of household i in village v, $K_{piv}^{'}$ are parcel level control variables, and ε_{piv} is a mean zero error term. In the plot level regressions, the standard errors are clustered at the household level, given that it is the level of assignment of the lottery [63]. The IV regressions are also adapted to obtain the LATE at the parcel level:

$$D_{piv} = \beta_0 + \beta_1 Z_{iv} + X_{iv}^{'} \beta_2 + K_{piv}^{'} \beta_3 + \tau_v + \eta_{piv} \tag{0.5}$$

$$Y_{piv} = \gamma_0 + \gamma_1 \hat{D_{piv}} + X_{iv}^{'} \gamma_2 + K_{piv}^{'} \gamma_3 + \theta_v + \varepsilon_{piv} \tag{0.6}$$

When studying the different impacts of interest, the results are quite sensitive to outliers. Extreme changes in the outcomes are very influential and are often due to unrealistic answers or imperfect recording from the enumerators. Hence, similar to DeMel et al. [25] and Dupas and Robinson [33], the regressions present the results with different levels of trimming. In production regressions, trimming consists of removing the observations with the highest absolute variation in yield between the first and second rounds on the basis that such extreme variations are unrealistically high and most likely caused by measurement errors. The production regressions (and yield regressions

[7] The exact condition is that the household answers that it received a voucher, redeemed it, and used the fertilizer for its maize production and also that the quantity of fertilizer used in its maize plots is strictly positive (to avoid inconsistent replies).

in the annex) are presented with 1% and 5% trimming[8], and regressions on inputs (fertilizer and improved yield), which are less likely to be subject to measurement errors, are presented with no trimming and 1% trimming.

We also examined the impact of the program on the households' maize production. As we did not know a priori in which parcel the inputs from the package would be applied, we compare the total maize production of the households in the treatment groups to the total production of the households in the control group. The area of cultivated maize varies considerably among farmers. Farmers were instructed to use the package in a half hectare of maize production; hence, if they followed the instructions and the returns to the package were equal in all half hectare parcels cultivated, the measured impact on total production would be equal among all farmers, but the impact on yield would be a decreasing function of the area. As a consequence, in our study, it is more meaningful to examine the impact on total production[9]. The annexes present all the equivalent tables with the regressions on yield per hectare for comparison. Using total production also presents the advantage of not relying too heavily on the measure of the area, which is relatively noisy given the farmers' limited familiarity with the use of a hectare or other alternative measures of area in the survey. On the other hand, farmers with a more extensive cultivated area of maize tend to weight more on the results on production in the regressions, despite the fact that, for these farmers, the impact of the voucher in a half hectare may be trumped by the stochasticity of the maize production on the rest of their farms.

Impact of the Subsidy on Agro-input Use

Farmers in the treatment group were entitled to receive a voucher distributed by the public agricultural extension. Under the supervision of our team in IFDC, in each village, the extension invited all the winners of the lottery in order to distribute the vouchers. The beneficiaries were asked to pickup their voucher only if they have the money to complete the subsidy and are planning to use it themselves. Among the households in the study, winning the lottery increased their chances of receiving at least one voucher[10] from 12% to 50%, and it increased the chances of obtaining a voucher and using it for maize production from 6% to 28% (regressions 2A.5 and 2A.6). Hence the use of the package among those who were entitled to receive the voucher is alarmingly low. When entitled to receive a voucher, only half of beneficiaries received it and, conditional on receiving the voucher, only 57% redeemed it and actually used the content of the package for their maize production. We have not observed any case of farmer

[8]In regressions on maize production 1% and 5% trimming removes plots with absolute variations in yield above 8,314 and 2,907 kg/ha, respectively.

[9]Even in cases in which farmers did not follow the recommendation, if the impact of fertilizer on yield is a linear function of their fertilizer per hectare, then it would result in a constant impact on production, independent of the surface on which farmers spread the fertilizer; hence, the use of production as the outcome variable remains more appropriate than the use of yield.

[10]Regression 2A.5 uses a dummy equal to one if the household used at least one voucher. Among the households who received at least one voucher, 93% received one voucher, 6% received two vouchers and 1% received more than two vouchers.

who won the lottery but was denied his voucher, hence not receiving the voucher always results from the farmer's decision.

At the same time, some of the participants in the control group tried to negotiate for an exception to the rule with the government's extension service. Additionally, the agricultural extension, in charge of the distribution of the vouchers, was also facing pressures from the organizations implementing the program who wanted all vouchers to be used; every voucher not picked up by a beneficiary had to be redistributed to another household. In this case, we pushed for a redistribution of the spare vouchers outside of the area of the study in order not to contaminate our sample. However, despite our efforts, the result of the lottery was not perfectly enforced, and 12% of the control group managed to obtain a voucher. The limited compliance rate[11] indicates the difficulties of implementing a randomized control trial in a real life setting with multiple stakeholders.

Despite the fact that the program preselected the progressive farmers, only 28% of those who were offered a voucher received it, redeemed it and used the package for their maize production. As a result, compared to the control group, the treatment group used on average 14.7 additional kilograms of fertilizer and 3.3 kg of improved seeds. The effect is econometrically highly significant, but below expectations given that the package subsidized 100 kg of fertilizer and 12.5 kg of improved seeds. Since the vouchers that were not received by a designated farmer benefited another one (all vouchers were distributed at the end), the increase input use conditional on receiving the voucher tells us about the overall impact of the project. Table 2B displays the increase in input use conditional on receiving a voucher, which is 38.6 kg for the use of fertilizer and 8.1 kg for improved seeds. Even when farmers declare that they used the package, the increase in the use of the improved seeds is very close to the entire 12.5 kilos that are subsidized, but the increase of fertilizer use is about 68kg, which is below 100, both because some farmers only used part of the package, and because others just substituted part of the fertilizer that they would have purchased without the voucher.

The results on input use show the difficulty in broadening the use of modern inputs to a population with little prior experience using it. On a positive note, it appears that a large majority of the maize producers who were unable or unwilling to complete the subsidy opted to not receive their voucher, rather than selling their input to the black market, which seems to have been very infrequent.

In order to investigate the reasons for not using fertilizer, we use key principles of Theory Based Impact Evaluation [84], where a causal chain from inputs to outcomes points out the assumptions that are necessary for the impact to

[11] If we define using the package for maize production as the treatment then the compliance rate is equal to 16%. It is given by the difference between the percentage of individuals who used the package for their maize production in the treatment group compared to the same percentage in the control group.

materialize, to shed light on the reasons for the successes and failures of this project. Figure 1 presents the causal chain of the Mozambican Savings and Subsidies project. The causal chain indicates the necessary assumptions that would allow the project to be successful, from the acquisition of vouchers to a long term increase in maize production. At each step, the failure to thoroughly satisfy the assumptions listed causes a leakage which dissolves the impact of the project. To analyze the leakages, we track the different intermediary outcomes from winning the lottery to the use of agro-inputs.

The lack of money to complete the agro-input subsidy was mentioned by 46% of farmers who did not receive a voucher when they had the right to receive one. Other farmers mentioned not being present at the time of voucher distribution (17% of cases) or the late distribution of vouchers (16% of cases) as the main reasons for not picking up their vouchers. Among those who received a voucher, 83% redeemed it, and 57% used the fertilizer obtained by the voucher for their maize production. Among those who received the voucher but did not redeem it, 54% reported not having the necessary amount of money to complete the subsidy, and 36% reported non availability or late arrival of the agro-inputs at the agro-dealer or the distance to the closest agro-dealer as reasons for non-participation. Among those who redeemed the voucher but did not use the fertilizer for maize production, 67% reported using it on other agricultural production (e.g., tobacco, horticulture), 25% claimed they had not yet used it, and 4% stated they sold their fertilizer, yet the latter may be under-reported. Finally, an additional potential "leakage" is caused by the fungibility, for farmers who would have purchased the same amount of seeds and fertilizer even without receiving the voucher. In this case, the voucher's fertilizer is used but does not generate an increment in the use of fertilizer and operates only as a cash transfer to the beneficiary.

Figure 1 presents the necessary conditions for the input to be used for maize production by the recipients. These conditions all played a role in the reduction of the use of inputs generated by the program, the main ones are the farmers credit constraint, the late availability of the inputs (and sometimes the distance to retrieve them), and the relatively low expected returns from the fertilizer (which may or may not be well-founded). Rather than being particular to the Mozambican context, these flaws tend to mark structural weaknesses of agro-input subsidy programs. As explained in section , a delay in distribution is not infrequent in similar programs. Furthermore, when there are possible alternative uses of the fertilizer (e.g., alternative production, black market), the fact that a relatively high initial willingness to pay for the fertilizer is a necessary condition creates a paradox that limits the potential of agro-input subsidies as a tool to diffuse learning about the benefits of fertilizer.

Impact of the Subsidy on Maize Production and Yield

The encouragement design provided by the lottery had an econometrically significant impact on the use of agro-inputs, allowing us to use the instrumented variable to analyze both the impact of using the voucher as well as the impact of increasing the use of fertilizer by one kg (jointly with an increase in improved seeds). Production regressions (and yield regressions in the annex) are presented with 1% and 5% trimming in order to reduce the influence of measurement errors. Using household level regressions, Table 3A presents the ITT effect of the result of the lottery on maize production and yield. The LATE effect of using the voucher for maize production appears in 3B, and below, Table 3C presents the impact of fertilizer use, instrumented by the result of the lottery. The coefficients on fertilizer must be interpreted as the impact of an exogenous increase in the joint use of fertilizer and improved seeds as a technological package. The correlation between the two inputs is relatively high (0.41). Econometrically, with only one instrument for the two inputs, it is not possible to distinguish the causal effect of fertilizer from the improved seeds.

Before examining the production and yield outcome, some back of the envelope calculations will facilitate interpretation of the results. Given the market price of the input package (MZN 3,163)[12] and of maize (MZN 5), the total impact of the voucher on maize production must be at least 632.5 kg for the return of the package to be positive, corresponding to an impact of 6.325 kg of maize per kg of fertilizer. This number is a lower bound on the necessary return for the investment to be worthwhile, given the risk associated with the investment and the high cost of capital.

The impact on production is shown at household level (Table 3) and disaggregated by maize plot (Table 4). In each case, Columns 1 and 2 present the impact on maize production for all farmers (besides the trimming), and the next two columns present only the small maize farmers defined as the households who cultivated an area lower or equal to five hectares of maize during the previous period. The area cultivated in the previous period (rather than the current one) is used to ensure that the definition of small farmer is not affected by the result of the lottery. Being a small maize farmer who cultivates between a half hectare and five hectares of maize was a selection criteria to receive a voucher, hence large farmers are an additional form of leakage, compared to the initial objective. Furthermore, as shown in Table 1, the average large farmer cultivated 9.5 hectares of maize and had an average production of 6,482 kg, compared to 2,251kg among small maize farmers. Therefore, the impact of a package on a half hectare is likely to be small relative to the annual variation of the large farmer's production and thus difficult to perceive econometrically.

[12] The exchange rate at the time of the intervention was about USD 1 = MZN 27

We find that when including all farmers, the confidence interval of the impact of the treatment is large, and the estimation of the impact varies extensively depending on the amount of trimming, which confirms our concern that the impact of the package is trumped by the stochasticity in the rest of the production[13]. The trimming reduces the noise by removing the most influential observations which are mostly driven by measurement errors. The probability for an observation to be removed by the trimming is orthogonal to the assignment of the lottery[14], which reduces the risk of any bias caused by the trimming. Even a 5% trimming removes changes in absolute yields that are higher than 2,907 kg/ha which is more than twice the average yield, and is thus unlikely to reflect a real change in production, whether it is triggered by the voucher or not, even in the scenario of a total collapse in production caused by a misuse of the input.

Column 6 shows that with a 5% trimming, and including only households with a previous cultivated area lower than five hectares, the impact of the treatment is positive, but remains non significant. Regression 3B.5 shows that using the voucher increased the maize production of small maize farmers by 589 kg, which is 93% of its market price (a negative rate of return). However the 95% confidence interval is large and allows for an impact on production that can vary from a negative impact to an increase in production that is more than 2.5 times the market value of the package. Regression 3C.5 shows a return to fertilizer (jointly with improved seeds) which reaches 5.6 kg of maize per kg of fertilizer, which is slightly below its market price. Table 4 presents results of the same order of magnitude, using plot level data, but it also suffers from a high variance in the estimates of the returns to the package. Hence these preliminary results seem to indicate a relatively low return to the package, but do not allow for clear conclusions given that the confidence intervals remains very large.

The Late Provision of Input and Late Drought

This project faced the combination of a late distribution of vouchers and a late drought. The planting season runs from November to the January. However, the long lasting negotiations about the price of the package and the margins of the providers, wholesalers, and retailers resulted in a distribution of vouchers that started only at the end of November 2010, and the fertilizer being available at most retailers only in the first week of December (the improved seeds are generally available throughout the year, but farmers may also have waited for the subsidy to purchase them). In addition, the rainfall had been abundant until mid-January and suddenly stopped from January 15 to the end of February. Therefore, during the 2010-2011 agricultural season, the return to fertilizer was reduced by the lack of water, in particular in the fields seeded later in the planting season. The agencies involved in the

[13]This can also be due to a different reaction to the subsidy from large farmers

[14]The p-value of the probability that being removed by the 1% and 5% trimming is correlated with the result of the lottery is 0.70 and 0.93 respectively.

program believe that this factor reduced the benefits for voucher recipients. As discussed previously, many farmers refused to use the voucher due to its late distribution. This subsection investigates a potential loss of production caused by this delay with simple OLS regressions using parcels as the unit of observation to examine the impact of fertilizer and improved seeds on maize production, conditional on the date the parcel was seeded.

The first two columns of Table 5A show a return to fertilizer that, though highly significant, is apparently low since it would offer negative rates of return to farmers who paid the full price of the inputs. Simple OLS regressions are subject to endogeneity bias. The bias is generally expected to be positive given the expected positive correlation between the use of other inputs and the fertilizer (and seeds). However, in the field, farmers sometimes stated that fertilizer is useful in infertile land more than fertile ones. Whether this belief is accurate or not, it can cause a downwards bias if farmers tend to use the fertilizer in less fertile land.

Regressions 5A.1 to 5A.2 indicate an average return per kg of fertilizer of approximately 3.5kg. The 95% confidence interval on the impact of fertilizer is about 3.67 kg of maize per kg of fertilizer, and its 95% confidence interval remains below what is required for the fertilizer to be profitable. Since rational producers would not pursue the use of an input which repeatedly yields negative returns, it is likely that the return to fertilizer was lower in the 2010-2011 agricultural campaign than in the previous campaigns because of the highly irregular rainfall. Also the improved seeds (OPV and hybrid) both have a non significant and often negative impact on yield and production, which potentially indicates that improved seeds have a higher vulnerability to water stress than traditional seeds.

Additionally, regression 5B.1 and 5B.2 provide further evidence that the impact of fertilizer was hampered by the lack of water, since the returns on yield to a kg of fertilizer jumped from approximately 3 to 10 kg of maize for parcels with irrigation, making it a profitable investment only if irrigation was used. This effect is more significant in yield regressions (Table A5) than production regressions, potentially because farmers tend to irrigate small parcels and yield regressions put more weight on variations in production among smaller parcels. The coefficient on yield is significant despite the small number of parcels with irrigation: only 57 parcels in the previous period and 43 in the current one. This result is subject to endogeneity, which is addressed in Section 4, where we investigate whether using a voucher had a stronger impact in plots that were irrigated in the previous year. However, since the Hausman test does not reject the exogeneity, the coefficients obtained in Tables 5 and A5 are thus informative and potentially more efficient than the IV regressions.

In order to examine the potential harm caused by the late distribution, we now investigate the differential in return to fertilizer between fields planted both before the end of November and after the beginning of December. As a reminder, the vouchers were distributed at the end of November, and the majority of retailers were only able to provide the inputs to voucher recipients in early December. The dummy variable “Period 2” is equal to one when the parcel was planted on or after December 1st, 2011. Assuming no correlation between the planting dates and unobserved characteristics of the plots that can influence the impact of fertilizer, regressions 5A.3 and 5A.4 show a return to fertilizer that drops from between 4 and 5 kg of maize per fertilizer in the first period to a return that is not significantly different from 0 in the second period[15]. As noted in the previous subsection, the late distribution reduced the use of the subsidized inputs. In addition, the delay in the distribution of the vouchers and inputs, combined with the late drought, considerably reduced the impact of the fertilizer on production.

While the late drought is an unfortunate realization of the covariate shock, the limited impact cannot be entirely blamed on the weather. The delay is not specific to this year and context; the 2010-2011 campaign was the second year of implementation of the program, and the same delay occurred in the previous year. Also, in Malawi, in an evaluation of the 2000-2001 Targeted Inputs Program, Van Donge et al. [28] conclude that “the production impact of TIP was negligible, primarily because inputs had arrived too late to be useful for the main farming season”[16]. The delay in the distribution of vouchers and availability of inputs highlights not only a failure from the government and organizations involved to efficiently carry out the implementation of the project, but also an inherent weakness of “smart subsidy” programs. The determination of the beneficiaries, the suppliers, the retailers, the price of the inputs, and the share of the benefits from the sale due to each actor of the supply chain tend to overwhelm a top down administration with insufficient presence in the field. This places a heavy burden on the country’s administrative capacity, often resulting in a harmful delay in the provision of inputs.

Heterogeneity of Impact

The previous section examined the average impact of the voucher and the return to improved seeds and fertilizer. However, the beneficiaries’ intention to pursue the use of fertilizer for maize production is conditional on their individual experience and thus depends on the distribution of the impact, which is explored in this section. We also investigate which farmers most benefited from the subsidy through a differential effect on input use and its return depending on farmer and plot characteristics.

Change in the Distribution Among the Compliers

The heterogeneity of impact of being entitled to receive the subsidy can be observed by comparing the distribution of any outcome variable Y_i for the treatment group versus the control group. Yet to obtain the impact of the use of

[15] This cannot be totally asserted in the absence of an exogenous instrument for the use of fertilizer during the first period
[16] p:42 of the report

the package (rather than the assignment to a group), econometric methods must be used to isolate the impact on the compliers. In order to obtain the causal impact of the treatment on the distribution of production outcomes, we use the methodology developed by Imbens and Rubin [45], who showed that under the same assumptions as those required to obtain LATE[17], it is possible to retrieve the distribution of any outcome for the compliers who received the treatment and those who did not receive it. Let $Y_i(d, z)$ be the observed outcome of interest of household i given the instrument dummy $Z_i = z$ and the treatment dummy $D_i(Z_i) = d$. Each household can be either "always taker" $D_i(0) = D_i(1) = 1$, "never taker" $D_i(0) = D_i(1) = 0$, or "complier" $D_i(0) = 0, = D_i(1) = 1$. By assumption there is no "defier" $D_i(0) = 1,\ D_i(1) = 0$. It is not possible to identify which households are compliers because we can never observe both $D_i(0)$ and $D_i(1)$ simultaneously. However, it is possible to retrieve the distribution of the compliers who are treated and those who are not by filtering out the distribution of the non compliers. Let $f_{zd}(y)$ be the estimable distribution of y for instrument $Z_i = z$ and treatment $D_i = d$. Then $f_{10}(y)$ is the distribution of the outcome for the never takers and $f_{00}(y)$ is a mixture of non treated compliers and never takers. Since, by assumption, the proportion and distribution of never takers is unaffected by the instrument, one can subtract $f_{10}(y)$ from $f_{00}(y)$,[18], adjusting for the proportions, in order to obtain the distribution of the compliers who were not treated. A similar subtraction of $f_{01}(y)$ to $f_{11}(y)$ allows us to filter out the distribution of the always takers to obtain the distribution of the compliers who were treated. See Imbens and Rubin [45] for a more detailed description of the methodology. Applying this to our data, Figure 2 provides a comparison of the distribution of production of compliers who were treated versus those who were not treated. All results presented in this section are restricted to small farmers (who cultivated an area lower or equal to 5 hectares in the previous year) and excludes the 10% highest absolute variations in yield outcomes. In this empirical application, Z_i is a dummy equal to one if the household won the voucher lottery and 0 otherwise; D_i is a dummy equal to one if the household received a voucher, redeemed it, and used the fertilizer for its maize production.

Figures 2A and 2B show the distribution of production for compliers who won the lottery (and thus used the package for their maize production), and those who lost (and thus did not use the package for their maize production). The two distributions are compared without any control variable. Figure 2B shows that the 20% of small farmers who produced the most, almost entirely reaped the benefits from the program, while it barely affected the distribution of the lowest 80% of the small farmers. Figures A2A and A2B in the annex examine the impact on yield over the

[17] The assumptions are 1) SUTVA (the Stable Unit Treatment Value Assumption posits that households are not affected by the treatment received and instrument assigned to other households), 2) The exclusion restriction, that $Y_i(z, d)$ does not depend on z, 3) Strict monotonicity (no "defier" $D_i(0) = 1,\ D_i(1) = 0$), and 4) Z_i is randomly assigned.

[18] The densities are first predicted at regular intervals of the outcome, using kernel densities, and then the subtraction is made at each interval, adjusting for the proportions

entire sample and also confirm an impact that is strongest among the most productive farmers. Therefore, it is not the size of the area cultivated that determines who benefits most, but rather the level of productivity of the household. The results cannot be caused by the higher compliance rate among the best farmers, since the method compares the difference among compliers, hence the less productive farmers who used the package for their maize production have not been able to derive the same benefits from it as the more modern farmers. Figures 2C and 2D illustrate the impact of the treatment on the change in production compared to the previous period. Figure 2C shows that a chunk of the non treated farmers lost between 2 and 4 tons of their production in the current year compared to the previous one, possibly because of the highly irregular rainfall. However, less loss occurred among the treated group, hence this important loss seems to have been attenuated by the program. Losses of this magnitude can affect only the largest producers since the median of maize production in the previous period among the sample of small farmers was 1,426 kg. Therefore, the reduction in these consequent losses is compatible with the program benefiting modern farmers most of which seemed to have compensated losses caused by the poor weather conditions. Figure 2C shows a sizable increase in the proportion of farmers who increased their production between one and five tons, and Figure A2C shows an increase in the proportion of farmers with an increase in yield that lies between 800 and 2,000 kilograms, as could be expected when the package is used successfully.

The use of the Instrumental Variable Quantile Treatment Effect (IVQTE) allows us to include control variables and test the significance of the changes at each quantile. We use the estimator developed by Abadie et al. [1], which provides the causal impact of the treatment (i.e., the use of the voucher package for maize production) on the quantiles of maize production for the compliers among the small maize farmers. The estimator basically uses quantile regressions, weighted by the estimated proportion of compliers conditional on the control variables (i.e., maize production, area, and fertilizer use, all in the previous year). Table 6 displays the coefficients and standard errors obtained by bootstrap of the QTE on production at every decile. Figure 3 graphs the QTE at every percentile and the 95% confidence intervals. Both show a clear upward and almost monotonic increasing trend on the QTE, meaning that the highest quantiles were most affected by the treatment and, thus, that the voucher program increased the absolute difference in production among farmers in the lower quantiles and those in the upper quantile. Therefore, even though the program intended to target "progressive farmers", among them, the most modern farmers benefited most from the agro-input package. The difference is quite substantial, since among small farmers the QTE on the 10th percentile is only 251kg, compared to 1,118 kg in the 90th percentile.

A look at the distribution of the impact is particularly informative in order to predict and understand the effect of the subsidy on the technology adoption decisions of the beneficiaries, yet it requires rank preservation, which is a relatively strong assumption. Rank preservation assumes that if $Y_i(D_i = 1) > Y_j(D_j = 1)$ then $Y_i(D_i = 0) >$

$Y_j(D_j = 0)$, meaning that the ranking among the production of two households is the same if both are treated as if none are treated. This assumption is often discussed in the literature on Quantile Treatment Effects since it is a requirement to obtain the distribution of the individual treatment effects. Heckman et al. [42] show that it requires an unlikely one to one relationship between $Y_i(D_i = 0)$ and $Y_i(D_i = 1)$. Whether the hypothesis is realistic or not is context dependent. In the context of our experiment, it is relatively intuitive to expect the unobserved ability to affect both production and the impact of using the package in the same direction, which would result in rank preservation if the ability is unidementional. However, if the ability (or other unobservables which can affect both production and the impact of the package) is multidimensional, and two individuals with the same $Y_i(D_i = 0)$ may have a different allocation in abilities, then the rank preservation will be violated. However, if the assumption is violated, the results obtained with rank preservation provide a lower bound on the heterogeneity of impact, since any alternative ordering increases the variance of the distribution of $Y_i(D_i = 1) - Y_i(D_i = 0)$.

Figure 4 shows the distribution of the impact of the treatment (assuming rank preservation) among small farmers. The first vertical line indicates the minimum additional production required to compensate for the subsidized price of the package (172 kg of maize). Only 3% of beneficiaries gained less than 172 kg after using the package; the other 97% are better off thanks to the program. The second vertical line shows the additional production required for the package to be profitable at its market price (633 kg). Only 25 % of the beneficiaries can expect a positive return from the package, which can be expected to be a necessary but not sufficient condition for them to want to use the improved seeds and fertilizer in the following year (in which the subsidy will not be offered). Given that learning is progressive, and that the benefits must exceed the cost of capital and the risk associated with the investment, the condition is far from sufficient. On the other hand, it appears that the returns can be quite high for a subgroup of the population. Among the farmers who derive a positive return from the package (at its market price), the average return is as high as 117%. The results show a strikingly high heterogeneity of impact of the program among the beneficiaries who used the package, with the farmers who were initially most productive reaping the most benefits when using the package for maize production.

Sources of Heterogeneity: Experience and Irrigation

This section examines the farmer and plot characteristics which drive the heterogeneity of impact. Farmers who are aware of the heterogeneity of impact will react differently to the subsidy depending on their characteristics. Therefore, the difference of impact in winning the voucher lottery can be attributed to the difference in its impact on fertilizer use or the difference in the returns to fertilizer (or a combination of both). We explore this heterogeneity of impact and its components for both prior experience with fertilizer use and the use of irrigation.

The Impact Conditional on Prior Experience with Fertilizer Use

We first look at whether past experience using fertilizer affects the impact of the program. Early on, the literature on technical change in agriculture emphasized that productivity of a user of a specific technology is affected by his acquaintance with it. [36] provide evidence of learning by doing and learning spillovers in the use of High Yielding seed Varieties (HYV) in rural India. They found that while the profits per hectare using HYV were negative during the first two to three years, they became positive and substantial in the following years. We test this effect in our data using the answer to the question "During the last 10 years, how many years did your household use fertilizer for maize production?"[19]. Regression 7A.6 shows that the impact of winning the lottery increases the maize production of inexperienced small farmers by 218 kg, and this impact increases by 99kg for each year of experience. Therefore, assuming an impact that is linearly affected by the number of years[20], the impact of winning the lottery on production can vary from 55 kg to 1009kg, depending on the number of years of experience of the beneficiary (Regression 7A.5). Furthermore regression 7C.5 shows a return to fertilizer that can vary from 3.5kg to 17.9kg for the highly experienced farmer (i.e., the farmer who used fertilizer for maize production in all of the previous nine years). This last regression is not significant, but the Hausman test rejects the presence of an endogeneity bias in the OLS regression, which shows an impact of fertilizer use that is significantly higher among experienced farmers with a return to fertilizer that can go from 2.2kg for the inexperienced farmer to 7.1kg for the experienced farmer.

While non-negligible, the difference in returns to fertilizer cannot fully explain the difference of impact between the less experienced farmers and the highly experienced ones. To better understand this, Table 9A shows the impact of winning the lottery on the probability of using the package for maize production, and on the amount of fertilizer used for maize production, conditional on experience. Winning the lottery increased the inexperienced farmer's probability of using the package by 18% and increased his use of fertilizer by 12.4 kg on average. In contrast, winning the lottery increased the the highly experienced farmer's probability of using the package by approximately 63% and his use of fertilizer by 41kg. Therefore, more experienced farmers have been able to derive a much higher benefit from being entitled to receive a voucher, both because their increase in fertilizer use is 3.3 times higher than the that of the inexperienced farmer, and because their return per kg of fertilizer is 3.2 times higher.

[19] To exclude the inclusion of the current year, we then subtract one from the number given when the household used fertilizer in the current year, hence, the number of years of experience goes from zero to nine.

[20] Using the number of years of experience assumes a linear impact of number of years, which is admittedly a naive approximation. Using experience and experience squared reduced the significance and stability of the results.

The Impact Conditional on the Use of Irrigation

We now examine the potential heterogeneity of impact between irrigated and non-irrigated plots. As found using OLS regressions in Section 3, the late drought has considerably reduced the return to fertilizer, which is higher in irrigated plots. The possibility of exploring this question is relatively limited given that only 57 parcels were irrigated in the previous campaign, yet the results in Table 8 and A8 still show an impact of winning the voucher lottery on production and yield that is higher in plots that were irrigated in the previous period[21]. Table A8 in particular shows that the impact of using the voucher has almost no effect on yield in a non irrigated plots but increases it by 1,242kg in an irrigated plot[22], making it a non profitable investment for non-irrigated areas, but a highly profitable one in irrigated plots. In this relatively bad year, the impact of using the package is 4.3 times higher in irrigated lands compared to non-irrigated ones (regression 8B.5). Notice that this ratio is of the same order of magnitude as in the result obtained in OLS regressions in Table 5. Although they need to be interpreted with caution given the small number of irrigated plots, the results highlight the complementarity between irrigation and fertilizer, given that irrigation prevents the drop in the returns to fertilizer in a bad year. Though the difference is not surprising, its magnitude is remarkable and reinforces the need to address complementarities in the different inputs.

We now investigate the relative contributions of the change in the use of fertilizer and the differential in the returns to fertilizer on the difference in the impact of the program. Table 9B shows that winning the lottery increased the probability of using the package by 53% for farmers who own at least one irrigated parcel, compared to 21% for the others. However, it does not translate into a significantly higher increase in fertilizer use among farmers with an irrigated parcel. Therefore, farmers may have simply substituted the package to the inputs that they would have purchased even without the subsidy, although no clear conclusion can be reached here given the large standard errors of the coefficient on the multiplicative variable *won lottery * irrigation* (due to the small number of farmers with irrigated plots).

Summary of Results and Conclusions

We conducted a field experiment where half of the Mozambican households in the sample were entitled to receive a 73% subsidy for an improved seeds and fertilizer package for a half hectare of maize production during the

[21]We use irrigation of the parcel in the previous agricultural campaign rather than irrigation during the current agricultural campaign because the latter may have been influenced by the result of the lottery. The correlation between irrigation in the previous and current agricultural campaign is 0.64.

[22]The difference in the impact of using the voucher in irrigated versus non irrigated plots is not significant in the production regression but significant in the yield regression presented in A8B

agricultural campaign 2010-2011. We first find important leakages given that in the treatment group, only 28% actually used the package for their maize production. The overall impact on maize production appears to be relatively low but the confidence interval is relatively large, allowing for zero impact as well as a an impact that is high enough for the package to be quite profitable. The small compliance rate (being selected to receive a voucher increased the probability of using the package by only 26%) has strongly reduced the power of the tests and thus reduced the precision of our estimates of the returns to the subsidized package. Furthermore, the combination of a late distribution and a late drought reduced the return to the package, highlighting implementation issues that are a frequent feature of "smart subsidy" programs due to their administrative requirements.

The fact that the subsidy contributed to a temporary increase in production and self-sufficiency among small maize famers is a very valuable outcome, with potential impact on long term productivity, in particular through the effect of nutrition on children ([77, 44]). However, this paper identifies many inherent limitations to "smart subsidies" in simultaneously attaining all their objectives. First, given both the significant amount of leakage and the regressive benefits, the subsidy appears to be an inefficient way to reach poverty reduction objectives (although this approach must be compared with alternatives). By nature, this type of subsidy primarily benefits the households with highest abilities, making it difficult to combine the objectives of equity and technology adoption. Second, when alternative uses of the package are possible (e.g., use for other crops, sale on the black market), the use of the package for maize production is conditional on a relatively high initial expectation of its returns, thus limiting the scope for learning among farmers with initially low expected returns. Finally, smart subsidies place a heavy burden on the government's capacity, often resulting in delays in the provision of the input, as was the case not only in both years of implementation of this project both years, but also in Malawi.

Our results contrast significantly with Duflo et al. [32], who find a strong positive return to fertilizer (when used in the appropriate quantity) in Kenya, but little heterogeneity of impact. These differences are due to many distinctions in its circumstances and the way that the studies were implemented. First, the weather conditions were very irregular during the year of our experiment [23]. In fact, since the weather is a highly covariate shock, any study of the returns to agro-inputs where only one year of harvest is observed is unlikely to provide the full distribution of the potential outcomes. Because the soil organic matter affects the soil water retention, the heterogeneity caused by the characteristics of the land may be higher in a year with highly irregular rainfalls. Second, the authors do find that the returns vary considerably depending on the quantity of fertilizer applied, which may drive part of the heterogeneity of impact of the package found in the current study, if the farmers did not follow the recommendation

[23] Duflo et al. [32] do not provide any information on weather conditions during their experiment

to apply the package in a half hectare. This brings us to a more fundamental difference between the two studies. Duflo et al. [32] explain that "ICS [International Child Support] paid for the cost of the extra inputs (fertilizer and hybrid seed) and ICS fieldworkers applied fertilizer and seeds with the farmers, followed the farmers throughout the growing season, assisted them with the harvest, and weighed the maize yield from each plot". Hence, the Kenya study was somewhat between a lab and a field experiment. They benefited from perfect compliance, having control over the exact quantity applied as well as when and how it was applied and in which plot. All these elements increase the precision of the estimates and contribute to answering important questions, such as the potential returns to fertilizer when properly used. However, if the misuse of fertilizer by the inexperienced farmer[24] contributes to the heterogeneity of impact, then it would appear in our study, but not in the Kenyan one. Our study investigates the policy of the agro-input subsidy in conditions which we intended to be as similar as possible to other subsidy programs in the developing world. As a consequence, the power of the test is reduced by the use of an encouragement design (compared to perfect compliance) and by the noise in the total maize production of the farmers, generated by a combination of real production shocks and measurement errors. However, it provides new insights regarding who is more likely to use the agro-input subsidy, to benefit the most from it, and why.

We find two main sources of the heterogeneity of impact of the subsidy. The first is that, conditional on using the package, the returns vary tremendously, and more modern farmers with higher average production and yield manage to derive a higher return to the package. The second is that the least productive farmers are also significantly less likely to use the package if they obtain the subsidy. We find that the number of years of prior experience (in the past nine years) and the use of irrigation both significantly increased the impact of the subsidy. The effect is primarily driven by an increase of the returns to fertilizer in the case of irrigation and by a combination of an increase in fertilizer use and an increase in its return in the case of prior experience. The increased returns could be caused by greater knowledge of how to apply the fertilizer, by the complementarity with other inputs more available among experienced farmers, or by farmers' continued fertilizer use due to its higher return, which can result from the quality of the soil. Our results coincide with Marenya and Barrett [58] who find that the response to fertilizer is increasing in the soil organic matter, which is more abundant in the plots of more productive farmers, concluding that fertilizer interventions are likely to reinforce ex-ante income inequality.

We estimate that 97% of the small farmers who used the package were better off because their additional production exceeded the subsidized cost of the package. For only 25% of the beneficiaries did the value of the additional

[24] According to our agronomist, the use of fertilizer in the wrong timing, quantity, or location (relative to the plant) can have an important effect on production. The next round of this survey will include questions regarding knowledge of fertilizer application in order to evaluate whether this knowledge influences the returns to fertilizer, and whether the subsidy generated some learning.

production exceed the market price of the package. These results are in line with Suri [79], who found returns to hybrid maize in Kenya that can vary from negative to 150%. In the presence of heterogeneity of returns, it may still be efficient to subsidize the farmers' learning about the potential returns in their own parcels, which should lead to more efficient choices in the following season among those with positive returns who were not using improved seeds and fertilizer previously. Nonetheless, the fact that less experienced farmers are less likely to use the package and derive a negative rate of return in a large majority of cases strongly compromises the possibility for the subsidy alone to generate a widespread technology adoption among small farmers. In fact, the widespread use of fertilizer may not be a desirable target, unless it is accompanied with substantial learning by doing or an increase in the use of complementary inputs that can markedly boost the returns to improved seeds and fertilizer among less modern farmers. More comprehensive strategies (which can include subsidies) are required to address the different constraints faced by this diverse range of farmers. Further data collection will allow us to pursue the impact of the subsidy on long term input use decisions, the learning about the benefits and correct usage of fertilizer, which will provide further evidence on whether the agro-input subsidy has the potential to generate long-lasting changes in farming practices and overall well-being.

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Figure 1: Causal Chain for Saving Subsidies and Sustainable Food Security in Mozambique Project:

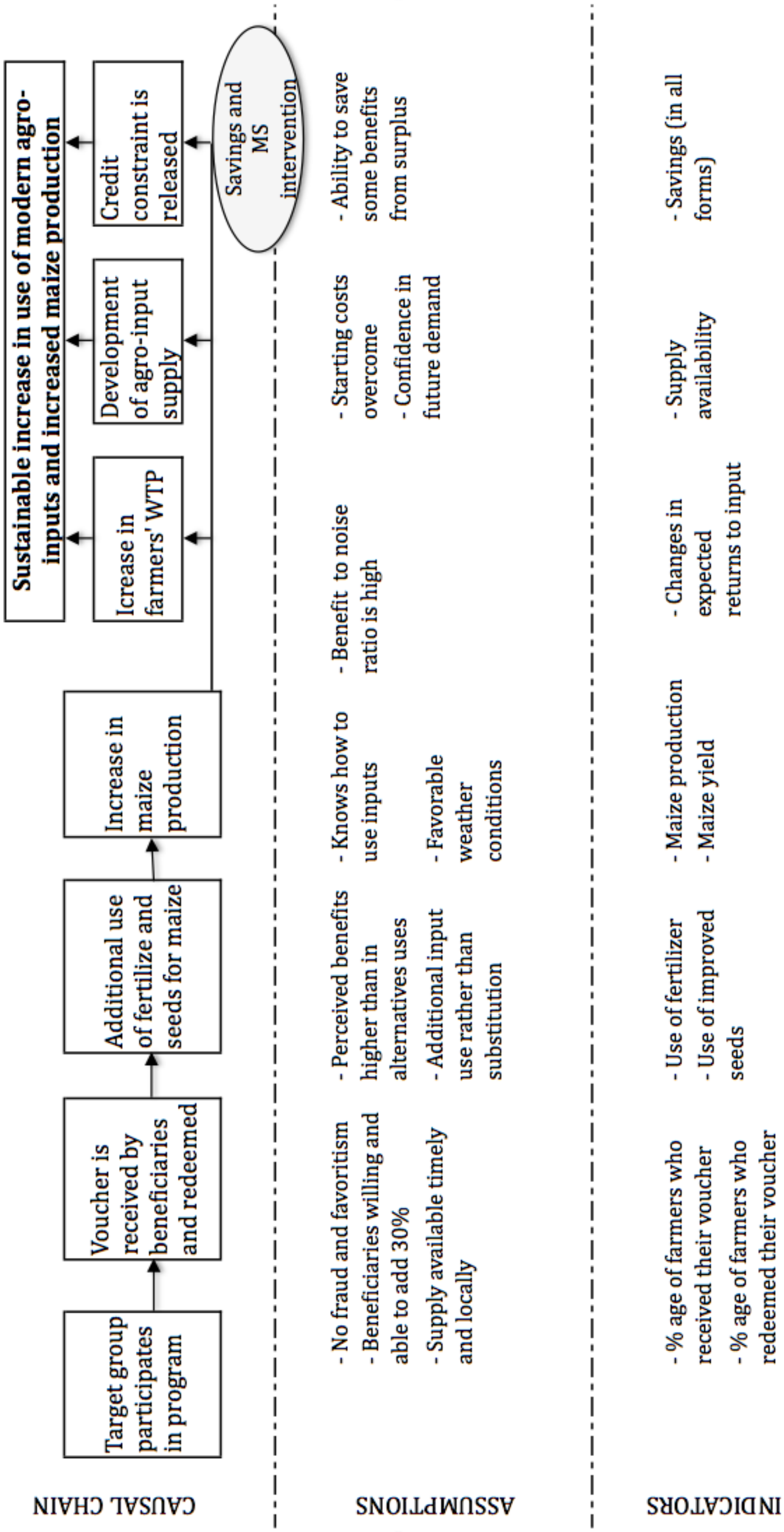


Figure 2: Impact of the treatment on the distribution of theYield for the Compliers

Figure 2A: Impact on PDF of the Production

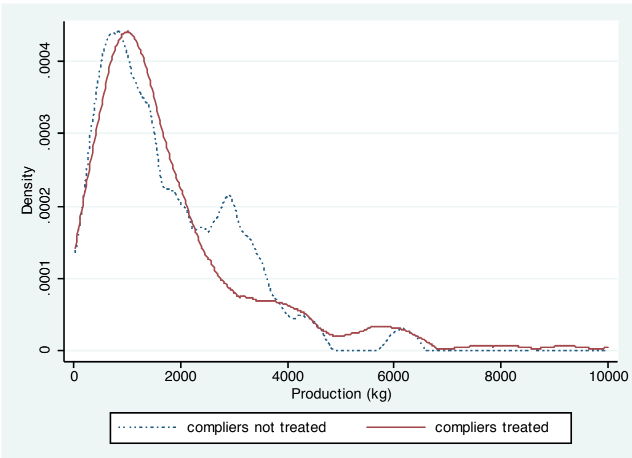


Figure 2B: Impact on the CDF of the Production

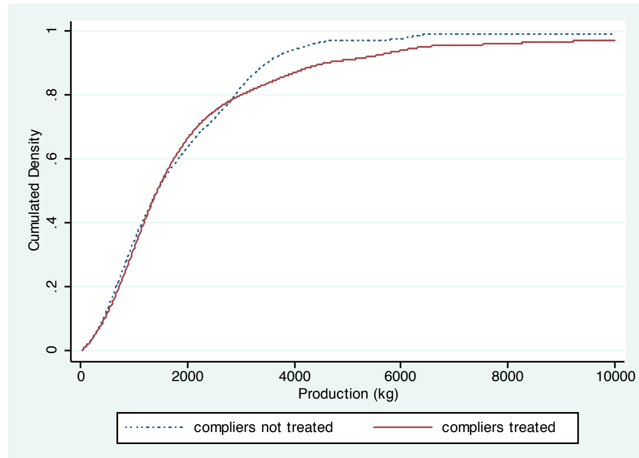


Figure 2C: Impact on PDF of Change in Production

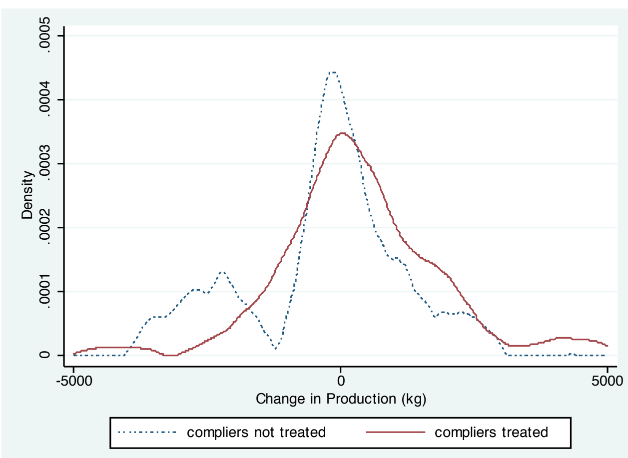
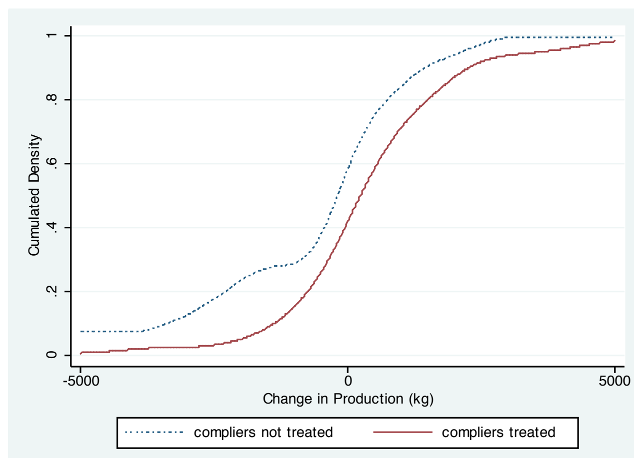


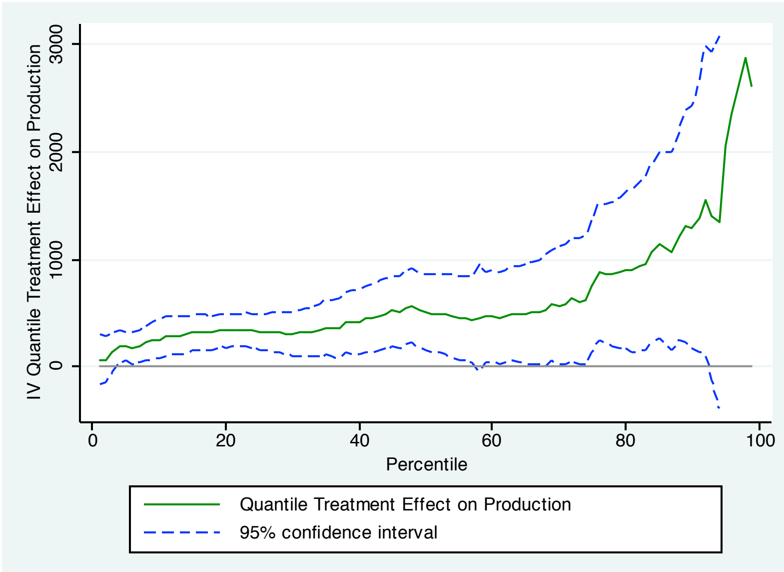
Figure 2D: Impact on CDF of the Change in Production



Compliers are defined as the households who obtained a voucher, redeemed it, and used the fertilizer for their maize production only if they were treated (i.e won the voucher lottery). The distribution of the outcome for the compliers who are treated versus those who are not, is revealed using the method described byImbens and Rubin [45].

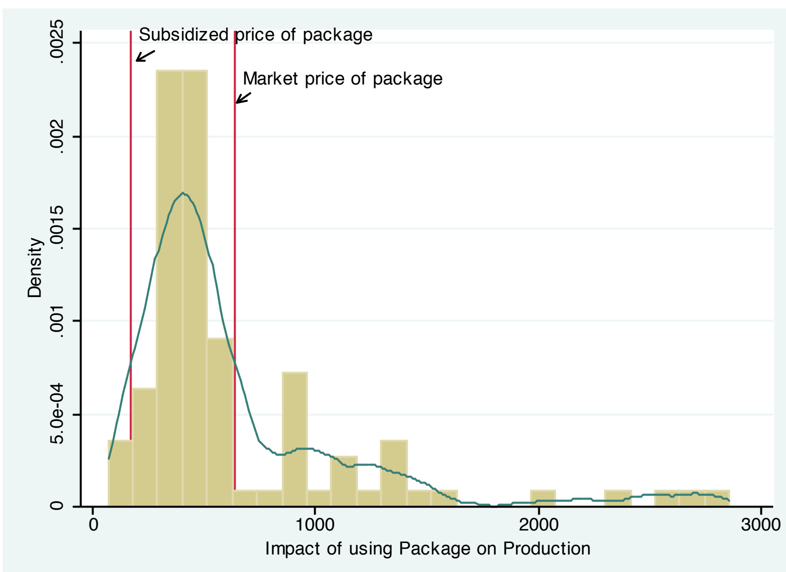
The 10% of the data with highest absolute change in their yield (absolute change higher than 2,022 kg/ha) have been trimmed.

Figure 3: Instrumental Variable Quantile Treatment Effects on Production of Compliers



Only includes households with maize area <= 5 hectares in previous period

Figure 4: Distribution of the Impact the Subsidy on Production of Compliers



Only includes households with maize area <= 5 hectares in previous period

Compliers are defined as the households who obtained a voucher, redeemed it, and used the fertilizer for their maize production only if they were treated (i.e won the voucher lottery). The distribution of the impact assumes that the treatment does not affect order of the outcome. The 10% of the data with highest absolute change in their yield (absolute change higher than 2,022 kg/ha) have been trimmed. The control variables are maize production in the previous period, area cultivated in the previous period, and fertilizer used in the previous period.

Table 1 Basic Statistics for each Treatment Group and Verification of Randomization

	Verification of Randomization				Comparison of small and large maize producers	
	All groups	Lost voucher lottery	Won voucher lottery	p-value of difference	Maize area <=5	Maize area >5
hh size	7.65	7.58	7.73	0.39	7.2	9.89
	[3.41]	[3.20]	[3.60]		[2.97]	[4.32]
hh head educ (yrs)	4.7	4.74	4.66	0.63	4.7	4.76
	[3.27]	[3.31]	[3.24]		[3.31]	[3.03]
hh head male (%)	0.84	0.85	0.83	0.21	0.84	0.88
	[0.36]	[0.35]	[0.38]		[0.37]	[0.33]
hh head age	46.22	46.28	46.16	0.92	45.9	47.57
	[13.90]	[13.97]	[13.85]		[13.88]	[13.38]
hh head literacy (%)	0.76	0.76	0.75	0.61	0.76	0.79
	[0.43]	[0.43]	[0.43]		[0.43]	[0.41]
electricity (%)	0.11	0.11	0.11	0.95	0.11	0.12
	[0.32]	[0.32]	[0.32]		[0.32]	[0.33]
bank account (%)	0.2	0.19	0.2	0.7	0.18	0.29
	[0.40]	[0.40]	[0.40]		[0.38]	[0.45]
land size (ha)	10.28	12.02	8.57	0.22	8.36	19.31
	[55.69]	[76.79]	[18.16]		[59.80]	[32.44]
Area maize (ha)	3.57	3.61	3.53	0.64	2.26	9.52
	[3.84]	[3.61]	[4.06]		[1.38]	[5.47]
Fertilizer (kg)	24.77	26.5	23.04	0.46	19.58	49.17
	[95.68]	[119.45]	[63.86]		[52.27]	[195.17]
Fertilizer (kg/ha)	12.66	11.36	13.95	0.31	14.27	5.36
	[45.69]	[39.53]	[51.08]		[49.03]	[24.22]
fert use (%)	0.19	0.18	0.2	0.23	0.18	0.22
	[0.39]	[0.38]	[0.40]		[0.38]	[0.41]
Production (kg)	3004.8	3042.3	2967.4	0.74	2251.3	6489.2
	[5212.5]	[4387.8]	[5923.6]		[2550.7]	[10406.3]
Yield (kg/ha)	1087.8	1054.4	1121.2	0.23	1180.6	658.8
	[1096.1]	[997.7]	[1185.8]		[1150.3]	[645.2]
Irrigation (%)	0.03	0.04	0.03	0.61	0.03	0.02
	[0.18]	[0.18]	[0.17]		[0.18]	[0.16]
Fert experience	0.79	0.8	0.79	0.88	0.83	0.7
(yrs in last 9 years)	[1.88]	[1.89]	[1.86]		[1.91]	[1.71]
Number of observations	1593	795	798		1286	283

Standard deviations in brackets
Agricultural data are for agricultural campaign 2009-2010, prior to assignment to any treatment
For yield and production data, the top 1% of yield values have been trimmed, to remove unrealistic values (yield higher than 7,854kg/ha and production higher than 19,108kg)

Table 2: Impact of Voucher on Input Use

Explained variable: 2A: ITT	Fertilizer (kg) 2A.1	2A.2	Improved seeds (kg) 2A.3	2A.4	Voucher received 2A.5	Voucher Used 2A.6
Won lottery	**11.62***	**14.75*****	**2.67**	**3.33****	**0.38*****	**0.22*****
	[5.85]	**[2.20]**	**[1.87]**	**[1.27]**	**[0.02]**	**[0.02]**
Fertilizer (kg) t-1	1.99***	0.79***				
	[0.61]	[0.13]				
Improved seeds (kg) t-1			0.83***	0.87***		
			[0.06]	[0.05]		
Area (ha) t-1	-3.49*	0.30	-0.01	0.04		
	[2.05]	[0.42]	[0.38]	[0.31]		
Constant	-7.25	2.66	3.02	1.55	**0.12*****	**0.06*****
	[10.27]	[3.30]	[1.87]	[1.40]	**[0.01]**	**[0.01]**
Observations	1,408	1,393	1,414	1,399	1,429	1,436
R-squared	0.70	0.54	0.61	0.76	0.17	0.08
Trimming	0%	1%	0%	1%	0%	0%

2B: IV - Impact of receiving voucher	**2B.1**	**2B.2**	**2B.3**	**2B.4**
Voucher received	**30.11***	**38.61*****	**6.39**	**8.12*****
	[15.44]	**[5.85]**	**[4.27]**	**[3.05]**
Fertilizer (kg) t-1	1.98***	0.75***		
	[0.60]	[0.10]		
Improved seeds (kg) t-1			0.83***	0.86***
			[0.07]	[0.05]
Area (ha) t-1	-3.44	0.40	-0.02	0.03
	[2.11]	[0.42]	[0.31]	[0.25]
Observations	1,398	1,383	1,405	1,391
R-squared	0.70	0.57	0.61	0.76
Trimming	0%	1%	0%	1%

2C: IV - Impact of using voucher for maize	**2B.1**	**2B.2**	**2B.3**	**2B.4**
Voucher used for maize	**52.23****	**68.32*****	**12.07**	**15.21*****
	[26.54]	**[9.34]**	**[7.43]**	**[5.34]**
Fertilizer (kg) t-1	1.97***	0.70***		
	[0.61]	[0.12]		
Improved seeds (kg) t-1			0.83***	0.86***
			[0.07]	[0.05]
Area (ha) t-1	-3.32	0.60	0.03	0.09
	[2.14]	[0.40]	[0.30]	[0.25]
Observations	1,403	1,388	1,410	1,396
R-squared	0.70	0.64	0.61	0.76
Trimming	0%	1%	0%	1%

Robust standard errors in brackets
*** p<0.01, ** p<0.05, * p<0.1
All regressions include village fixed effects, except 2A.5 and 2A.6
Trimming removes observations with highest absolute variation in the explained variable between current and previous period
In table 2B, voucher received is instrumented by won lottery
In table 2C, voucher used is instrumented by won lottery

Table 3: Impact on Maize Production Household Level Regressions

3A: ITT	3A.1	3A.2	3A.4	3A.5
	Maize Production (kg)			
VARIABLES	All farmers		With prior area <= 5ha	
Won lottery	**431.98**	**-116.45**	**136.35**	**144.80**
	[372.90]	**[165.55]**	**[142.38]**	**[114.61]**
Production (kg) t-1	1.42**	0.39***	0.38***	0.55***
	[0.68]	[0.11]	[0.09]	[0.09]
Area (ha) t-1	14.06	150.75**	215.52***	102.58
	[130.42]	[71.81]	[74.08]	[76.38]
Observations	1,320	1,267	1,082	1,031
R-squared	0.51	0.29	0.19	0.29
Trimming	1%	5%	1%	5%
3B: IV - Impact of using voucher	**3B.1**	**3B.2**	**3B.4**	**3B.5**
Voucher used	**1,891.04**	**-506.99**	**559.75**	**589.24**
	[1,939.06]	**[740.88]**	**[599.61]**	**[526.32]**
Production (kg) t-1	1.42**	0.39***	0.37***	0.55***
	[0.66]	[0.09]	[0.08]	[0.09]
Area (ha) t-1	16.95	149.54***	220.33***	110.95
	[123.92]	[57.12]	[67.35]	[68.21]
Observations	1,316	1,263	1,077	1,026
R-squared	0.51	0.28	0.20	0.30
Trimming	1%	5%	1%	5%
3C: IV Impact of Fertilizer Use	**3C.1**	**3C.2**	**3C.4**	**3C.5**
Fertilizer (kg)	**34.58**	**-10.48**	**4.92**	**5.56**
	[40.50]	**[16.57]**	**[7.43]**	**[6.57]**
Production (kg) t-1	1.45**	0.35***	0.36***	0.53***
	[0.65]	[0.09]	[0.08]	[0.07]
Fertilizer (kg) t-1	-74.33	25.06	2.60	1.00
	[90.42]	[35.20]	[6.40]	[5.73]
Area (ha) t-1	134.33	114.95	215.07***	116.49*
	[165.24]	[75.40]	[67.97]	[68.17]
Observations	1,312	1,259	1,073	1,022
R-squared	0.38	0.11	0.24	0.34
Trimming	1%	5%	1%	5%

Robust standard errors in brackets. Regressions include village fixed effects
*** p<0.01, ** p<0.05, * p<0.1
Trimming removes observations with highest absolute variation in yield between current and previous period
Regressions include village fixed effects
In table 3B, voucher used is instrumented by won lottery
In table 3C, fertilizer is instrumented by won lottery

Table 4: Impact on Maize Production Plot Level Regressions

4A: ITT VARIABLES	**4A.1**	**4A.2**	**4A.4**	**4A.5**
	Maize Production (kg)			
	All farmers		**With prior area <= 5ha**	
Won lottery	**276.42**	**-44.03**	**78.48**	**75.18**
	[248.02]	**[88.35]**	**[87.41]**	**[70.48]**
Production (kg) t-1	1.69**	0.38***	0.30***	0.41***
	[0.70]	[0.10]	[0.08]	[0.07]
Area (ha) t-1	-28.85	251.23***	275.67***	259.07***
	[192.83]	[66.65]	[74.73]	[67.57]
Observations	2,245	2,154	1,703	1,619
R-squared	0.60	0.37	0.26	0.32
Trimming	1%	5%	1%	5%
4B: IV - Impact of using voucher	**4B.1**	**4B.2**	**4B.4**	**4B.5**
Voucher used	**1,056.93**	**-168.14**	**265.74**	**253.38**
	[952.20]	**[338.40]**	**[294.78]**	**[236.82]**
Production (kg) t-1	1.69**	0.38***	0.29***	0.40***
	[0.70]	[0.10]	[0.08]	[0.07]
Area (ha) t-1	-23.19	249.83***	279.26***	263.83***
	[190.61]	[66.66]	[73.95]	[67.71]
Observations	2,245	2,154	1,703	1,619
R-squared	0.60	0.37	0.27	0.32
Trimming	1%	5%	1%	5%
4C: IV Impact of Fertilizer Use	**4C.1**	**4C.2**	**4C.4**	**4C.5**
Fertilizer (kg)	**27.77**	**-4.93**	**5.33**	**6.93**
	[27.11]	**[10.64]**	**[7.62]**	**[7.24]**
Production (kg) t-1	1.72**	0.36***	0.28***	0.40***
	[0.71]	[0.10]	[0.07]	[0.07]
Fertilizer (kg) t-1	-35.73	8.97	2.22	-3.87
	[33.49]	[11.99]	[5.56]	[4.33]
Area (ha) t-1	-61.39	258.18***	269.25***	253.14***
	[205.56]	[69.72]	[75.38]	[69.11]
Observations	2,241	2,150	1,699	1,615
R-squared	0.58	0.36	0.29	0.31
Trimming	1%	5%	1%	5%

The standard errors in brackets are clustered at the household level.
Regressions include village fixed effects
*** p<0.01, ** p<0.05, * p<0.1
Trimming removes observations with highest absolute variation in yield between current and previous period
Regressions include village fixed effects
In table 4B, voucher used is instrumented by won lottery
In table 4C, fertilizer is instrumented by won lottery

Table 5: OLS Regressions on Returns to Fertilzer (plot level regressions)

OLS Maize Production	5A.1 All	5A.2 Area <=5	5A.3 All	5A.4 Area <=5
VARIABLES				
Fertilizer (kg)	**3.67***** **[0.92]**	**3.53***** **[0.93]**	**4.12***** **[1.04]**	**4.85***** **[1.03]**
Fertilizer (kg) * Period2			**-5.68***** **[2.17]**	**-4.20***** **[1.33]**
Period2 (dummy)			-4.83 [103.54]	8.14 [86.00]
OPV (dummy)	-25.83 [115.43]	-150.71 [109.00]	-10.38 [117.46]	-177.60* [107.64]
Hybrid (dummy)	-57.82 [119.14]	-127.66 [80.00]	-24.34 [121.10]	-136.62* [79.47]
Area (ha) t-1	460.32*** [76.74]	498.56*** [65.86]	459.88*** [78.21]	493.70*** [66.84]
Observations	2,150	1,615	2,108	1,588
R-squared	0.28	0.20	0.28	0.21
Trimming	5%	5%	5%	5%
p-value of Hausman exogeneity test	0.3163	0.4783	0.5342	0.7258

OLS Maize Production	5B.1 All	5B.2 Area <=5	5B.3 All	5B.4 Area <=5
VARIABLES				
Fertilizer (kg)	**3.70***** **[0.93]**	**3.19***** **[0.92]**	**2.13**** **[1.00]**	**2.22*** **[1.17]**
Fertilizer (kg) * Irrigation	**-3.98** **[5.31]**	**7.64** **[4.64]**		
Fertilizer (kg) * Experience			**0.67** **[0.50]**	**0.54*** **[0.32]**
Irrigation (dummy)	516.39 [336.69]	-22.52 [344.41]		
Fertilizer experience (yrs)			-52.90* [31.13]	-17.15 [18.99]
opv	-31.02 [115.59]	-144.30 [108.94]	-4.07 [115.62]	-136.74 [108.95]
hybrid	-65.34 [119.63]	-130.04 [80.69]	-34.15 [118.44]	-117.56 [79.68]
Area (ha) t-1	461.04*** [76.81]	498.96*** [65.91]	456.01*** [77.04]	496.17*** [66.03]
Observations	2,150	1,615	2,149	1,614
R-squared	0.28	0.21	0.28	0.20
Trimming	5%	5%	5%	5%
p-value of Hausman exogeneity test	0.6382	0.7291	0.6266	0.6546

The standard errors in brackets are clustered at the household level
*** p<0.01, ** p<0.05, * p<0.1
Trimming removes observations with highest absolute variation in yield between current and previous period
Regressions include village fixed effects

Table 6: Instrumental Variable Quantile Treatment Effects

	6.1	6.2	6.3	6.4
Treatment:	**Received the voucher**		**Voucher used for maize**	
Maize Production (kg)	**All**	**previous area <= 5**	**All**	**previous area <= 5**
Quantile				
q10	87.5	265.0***	130.2	251.0***
	[243.5]	[78.8]	[107.0]	[92.7]
q20	127.6	250.4***	77.1	330.1***
	[79.8]	[73.7]	[138.7]	[75.1]
q30	92.6	194.2**	-24.2	296.4***
	[253.2]	[77.7]	[155.9]	[91.6]
q40	5.2	297.1**	30.6	399.2***
	[212.9]	[115.7]	[151.0]	[132.6]
q50	-3.8	291.9**	26.0	412.2***
	[126.7]	[128.5]	[205.9]	[156.6]
q60	-21.5	294.1*	-13.3	439.2**
	[152.3]	[160.0]	[179.7]	[182.6]
q70	24.2	400.4**	-57.1	509.9**
	[188.5]	[180.4]	[229.0]	[238.9]
q80	17.1	515.1**	-30.0	750.0**
	[253.6]	[232.6]	[293.7]	[305.0]
q90	-115.4	568.3	337.0	1,118.1**
	[334.3]	[353.7]	[432.9]	[507.1]
Observations	1,196	968	1,200	970
Trimming	10%	10%	10%	10%

The Quantile Treatment Effects indicate the impact of the treatment (receiving a voucher in the first 3 columns and using the package of the voucher for maize production in the last 3 columns) on the quantiles of the maize production. The treatments are instrumented by the result of the voucher lottery. The QTE are calculated using the estimator of Abadie, Angrist and Imbens (2002).

The standard errors in brackets have been obtained by bootstrap (500 repetitions)
*** p<0.01, ** p<0.05, * p<0.1
Trimming removes observations with highest absolute variation in yield between current and previous period
The control variables are maize production in the previous period, area cultivated in the previous period, and fertilizer used in the previous period.
Package used for maize is a dummy equal to one if the farmer replies that he used the package for maize production and the quantity of fertilizer used in the maize plots is strictly positive.

Table 7: Effect of the Agro-input Subsidy on Production Conditional on Experience (nb of years using fertilizer for maize in the past 9 years)

7A: ITT	**7A.1**	**7A.2**	**7A.4**	**7A.5**
Maize Production (kg)	**All farmers**		**With prior area <= 5ha**	
Won lottery	**214.44**	**-184.16**	**49.64**	**55.02**
	[341.82]	**[172.10]**	**[163.32]**	**[126.01]**
Won lottery * Experience	**273.33**	**78.58**	**100.95***	**106.15***
	[181.49]	**[65.38]**	**[54.46]**	**[58.34]**
Fertilizer experience (yrs)	-290.50	-14.54	-34.52	-45.59
	[221.58]	[60.08]	[40.51]	[44.76]
Production (kg) t-1	1.42**	0.39***	0.38***	0.56***
	[0.68]	[0.11]	[0.09]	[0.09]
Area (ha) t-1	17.36	150.23**	215.34***	103.90
	[129.04]	[71.52]	[75.11]	[76.90]
Observations	1,319	1,266	1,081	1,030
R-squared	0.51	0.29	0.19	0.30
Trimming	1%	5%	1%	5%
7B: IV - Impact of using voucher	**7B.1**	**7B.2**	**7B.4**	**7B.5**
Voucher used	**1,261.66**	**-897.38**	**295.80**	**325.22**
	[2,145.05]	**[935.91]**	**[748.72]**	**[643.25]**
Voucher used * Experience	**446.54**	**242.09**	**175.87**	**179.13**
	[393.36]	**[191.54]**	**[151.33]**	**[145.62]**
Fertilizer experience (yrs)	-366.41	-44.35	-66.76	-79.46
	[245.65]	[81.43]	[56.60]	[61.81]
Production (kg) t-1	1.42**	0.39***	0.37***	0.55***
	[0.66]	[0.09]	[0.08]	[0.09]
Area (ha) t-1	23.34	150.06***	224.81***	118.20*
	[121.44]	[57.34]	[67.66]	[68.38]
Observations	1,315	1,262	1,076	1,025
R-squared	0.51	0.27	0.20	0.30
Trimming	1%	5%	1%	5%
7C: IV Impact of Fertilizer Use	**7C.1**	**7C.2**	**7C.4**	**7C.5**
Fertilizer (kg)	**29.78**	**-13.88**	**2.81**	**3.52**
	[41.91]	**[17.34]**	**[9.18]**	**[7.79]**
Fertilizer (kg) * Experience	**-0.62**	**3.18**	**1.59**	**1.60**
	[6.52]	**[2.96]**	**[1.73]**	**[1.61]**
Fertilizer experience (yrs)	575.53	-451.02	-178.35	-170.35
	[1,145.77]	[483.14]	[135.20]	[131.51]
Production (kg) t-1	1.45**	0.34***	0.35***	0.52***
	[0.66]	[0.09]	[0.08]	[0.07]
Fertilizer (kg) t-1	-64.42	18.28	2.01	0.22
	[69.38]	[27.39]	[5.77]	[5.48]
Area (ha) t-1	111.79	123.75*	216.34***	119.30*
	[139.23]	[70.11]	[67.92]	[67.56]
Observations	1,311	1,258	1,072	1,021
R-squared	0.44	0.14	0.24	0.34
Trimming	1%	5%	1%	5%

Robust standard errors in brackets. Regressions include village fixed effects
*** p<0.01, ** p<0.05, * p<0.1
Trimming removes observations with highest absolute variation in yield between current and previous period
Regressions include village fixed effects
In table 7B, voucher used and voucher used*experience are instrumented by won lottery and won lottery*experience
In table 7C, fertilizer and fertilizer*experience are instrumented by won lottery and won lottery*experience

Table 8: Effect of the Agro-input Subsidy on Production Conditional on Irrigation (plot level regressions)

	8A.1	8A.2	8A.4	8A.5
8A: ITT	**Maize Production (kg)**			
	All farmers		**Hh with prior area <= 5ha**	
Won lottery	**275.5**	**-42.3**	**69.9**	**66.6**
	[249.2]	**[89.1]**	**[88.2]**	**[70.9]**
Won lottery * Irrigation t-1	**171.5**	**10.4**	**496.8**	**478.4**
	[851.0]	**[566.0]**	**[503.6]**	**[503.9]**
Irrigation t-1	457.2	417.9	84.4	56.0
	[615.8]	[479.8]	[388.8]	[403.5]
Production (kg) t-1	1.7**	0.4***	0.3***	0.4***
	[0.7]	[0.1]	[0.1]	[0.1]
Area (ha) t-1	-28.4	251.9***	275.6***	259.6***
	[193.0]	[66.7]	[74.8]	[67.7]
Observations	2,245	2,154	1,703	1,619
R-squared	0.60	0.37	0.26	0.32
Trimming	1%	5%	1%	5%
8B: IV - Impact of using voucher	**8B.1**	**8B.2**	**8B.4**	**8B.5**
Voucher used	**1,071.8**	**-164.4**	**240.9**	**229.3**
	[973.7]	**[347.2]**	**[302.4]**	**[242.1]**
Voucher used * Irrigation t-1	**-218.9**	**96.6**	**784.0**	**752.4**
	[1,533.6]	**[972.4]**	**[900.6]**	**[896.6]**
Irrigation t-1	543.2	397.8	22.7	1.2
	[744.0]	[553.0]	[464.8]	[482.9]
Production (kg) t-1	1.7**	0.4***	0.3***	0.4***
	[0.7]	[0.1]	[0.1]	[0.1]
Area (ha) t-1	-22.6	250.5***	280.5***	265.9***
	[190.7]	[66.7]	[74.0]	[67.7]
Observations	2,245	2,154	1,703	1,619
R-squared	0.60	0.37	0.27	0.32
Trimming	1%	5%	1%	5%
8C: IV Impact of Fertilizer Use	**8C.1**	**8C.2**	**8C.4**	**8C.5**
Fertilizer (kg)	**27.74**	**-4.76**	**4.77**	**6.63**
	[26.96]	**[10.95]**	**[7.80]**	**[7.39]**
Fertilizer (kg) * Irrigation t-1	**-19.54**	**-4.63**	**18.17**	**14.83**
	[40.77]	**[27.07]**	**[20.29]**	**[17.88]**
Irrigation t-1	2,217.99	488.99	-644.21	-372.99
	[3,194.54]	[1,835.67]	[959.90]	[853.83]
Production (kg) t-1	1.70**	0.35***	0.28***	0.40***
	[0.72]	[0.12]	[0.07]	[0.07]
Fertilizer (kg) t-1	-22.29	12.12	1.83	-4.47
	[33.70]	[16.85]	[5.56]	[4.22]
Area (ha) t-1	-66.24	258.37***	263.84***	250.77***
	[208.40]	[69.72]	[75.84]	[69.16]
Observations	2,241	2,150	1,699	1,615
R-squared	0.58	0.34	0.28	0.31
Trimming	1%	5%	1%	5%

The standard errors in brackets are clustered at the household level. Regressions include village fixed effects
*** p<0.01, ** p<0.05, * p<0.1
Trimming removes observations with highest absolute variation in yield between current and previous period
Regressions include village fixed effects
In table 8B, voucher used and voucher used*irrigation are instrumented by won lottery and won lottery*irrigation
In table 8C, fertilizer and fertilizer*irrigation are instrumented by won lottery and won lottery*irrigation

Table 9: Effect of the Agro-input Subsidy on Fertilizer Use Conditional on Experience and Irrigation

9A Fertilizer use and Experience	**9A1**	**9A.2**	**9A.3**	**9A.4**	**9A.5**	**9A.6**
	Package used for maize		**Fertilizer (kg)**			
ITT - OLS	**All**	**previous area <= 5**	**All**		**previous area <= 5**	
Won lottery	0.18***	0.19***	6.90	12.39***	14.55***	13.91***
	[0.03]	[0.03]	[4.99]	[2.51]	[3.04]	[2.76]
Won lottery * Experience	**0.05*** **	**0.05*** **	**8.85***	**3.18***	**4.43** **	**1.59**
	[0.01]	**[0.01]**	**[5.08]**	**[1.67]**	**[1.78]**	**[1.58]**
Fertilizer experience (yrs)	-0.00	-0.01**	-24.86**	-2.46	-2.39	0.68
	[0.01]	[0.01]	[11.55]	[2.10]	[2.60]	[1.07]
Fertilizer (kg) t-1	0.00*	0.00***	2.10***	0.80***	0.77***	0.58***
	[0.00]	[0.00]	[0.61]	[0.15]	[0.20]	[0.06]
Area (ha) t-1	-0.00	-0.01	-3.33*	0.33	0.29	-0.30
	[0.00]	[0.01]	[1.85]	[0.41]	[0.92]	[0.88]
Observations	1,413	1,154	1,407	1,392	1,148	1,140
R-squared	0.15	0.17	0.72	0.55	0.39	0.37
Trimming	0%	0%	0%	1%	0%	1%

9B Fertilizer use and Irrigation	**9B.1**	**9B.2**	**9B.3**	**9B.4**	**9B.5**	**9B.6**
	Package used for maize		**Fertilizer (kg)**			
ITT - OLS	**All**	**previous area <= 5**	**All**		**previous area <= 5**	
Won lottery	0.21***	0.22***	13.72***	14.32***	16.65***	15.07***
	[0.02]	[0.02]	[5.15]	[2.25]	[2.77]	[2.44]
Won lottery * Irrigation	**0.32** **	**0.26***	**-62.70**	**15.08**	**40.77**	**0.91**
	[0.13]	**[0.14]**	**[87.55]**	**[13.67]**	**[27.45]**	**[14.21]**
irrigprev	-0.13*	-0.13	60.81	-7.56	-29.33	-5.90
	[0.07]	[0.08]	[65.34]	[12.33]	[19.94]	[9.38]
Fertilizer (kg) t-1	0.00**	0.00***	1.98***	0.79***	0.78***	0.61***
	[0.00]	[0.00]	[0.59]	[0.13]	[0.17]	[0.05]
Area (ha) t-1	-0.00	-0.01*	-3.43*	0.30	0.10	-0.28
	[0.00]	[0.01]	[1.99]	[0.42]	[0.91]	[0.87]
Observations	1,414	1,155	1,408	1,393	1,149	1,141
R-squared	0.26	0.28	0.70	0.54	0.39	0.36
Trimming	0%	0%	0%	1%	0%	1%

Robust standard errors in brackets. Regressions include village fixed effects
*** p<0.01, ** p<0.05, * p<0.1
Regressions include village fixed effects
Package used for maize is a dummy equal to one if the farmer replies that he used the package for maize production and the quantity of fertilizer used in the maize plots is strictly positive

ANNEXES

Figure A2: Impact of the treatment on the distribution of theYield for the Compliers

Figure A2.1: Impact on PDF of the Yield

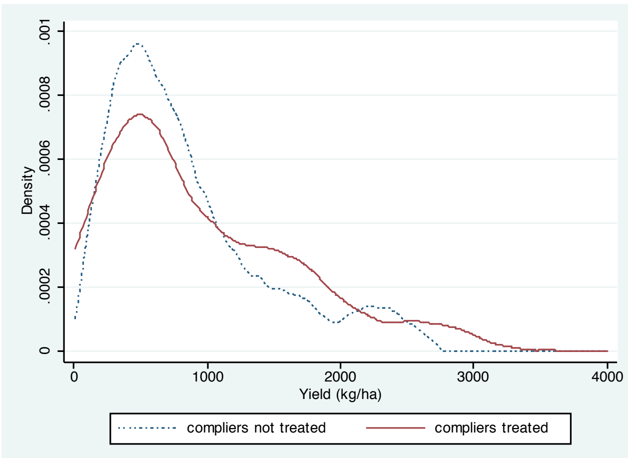


Figure A2.2: Impact on the CDF of the Yield

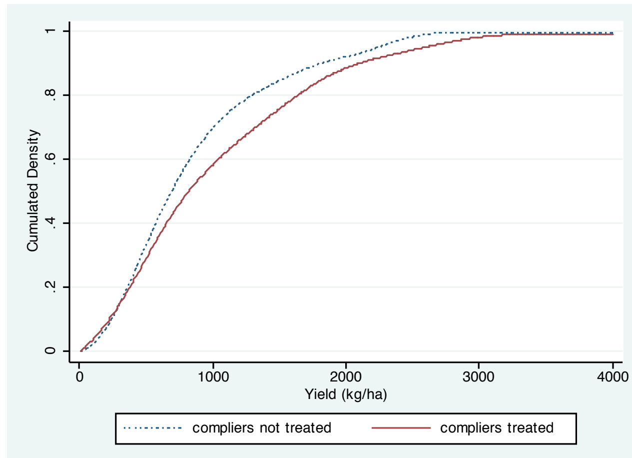


Figure A2.3: Impact on PDF of the Change in Yield

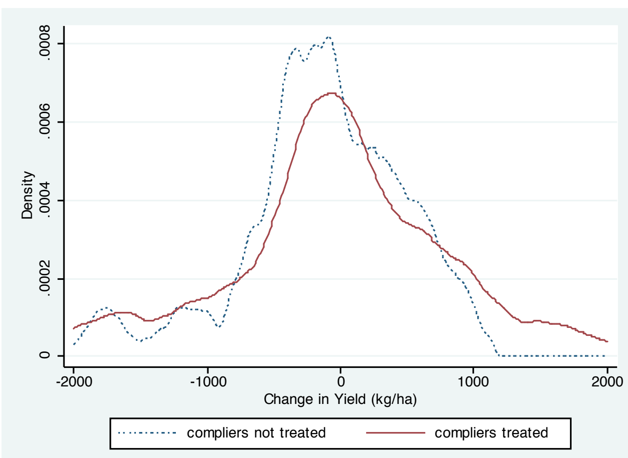


Figure A2.4: Impact on CDF of the Change in Yield

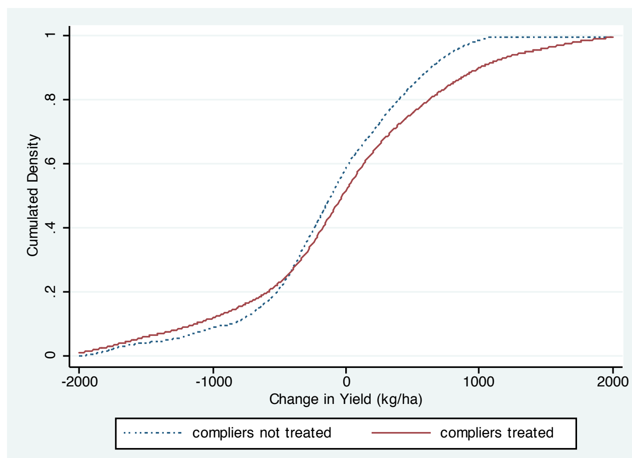
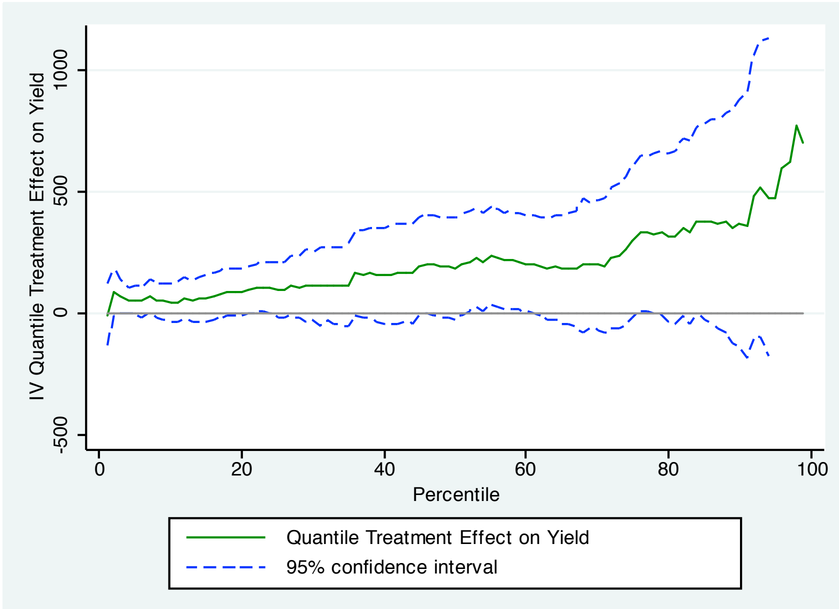
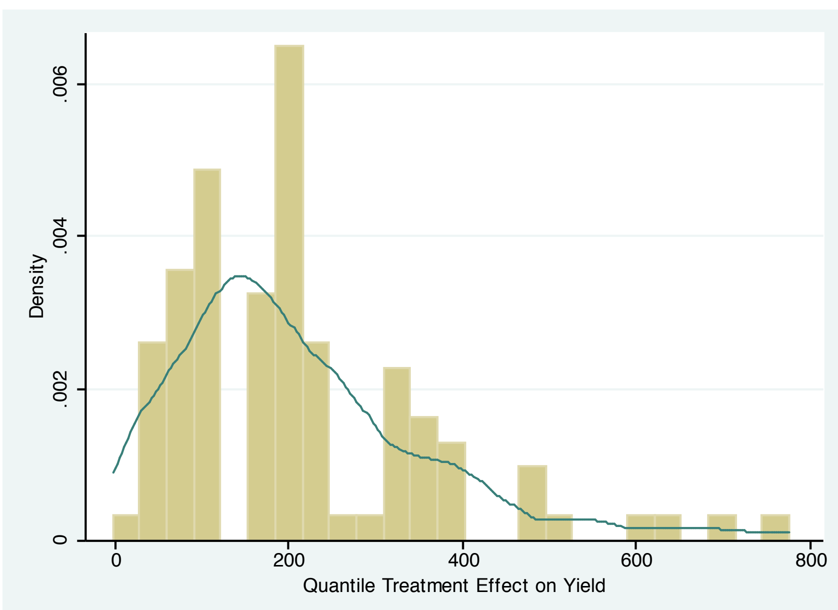


Figure A3: Instrumental Variable Quantile Treatment Effects on Yield of Compliers



Only includes households with maize area <= 5 hectares in previous period

Figure A4: Distribution of the Impact the Subsidy on Yield of Compliers



Compliers are defined as the households who obtained a voucher, redeemed it, and used the fertilizer for their maize production only if they were treated (i.e won the voucher lottery). The distribution of the outcome for the compliers who are treated versus those who are not, is revealed using the method described byImbens and Rubin [45]. The 10% of the data with highest absolute change in their yield (absolute change higher than 2,022 kg/ha) have been trimmed.

Table A2: impact of Voucher on Input Use per Hectare

Explained variable:	Fertilizer (kg/ha)		Improved seeds (kg/ha)	
A2A: ITT	**A2A.1**	**A2A.2**	**A2A.3**	**A2A.4**
Won lottery	**8.82****	**8.04****	**2.15****	**1.33****
	[3.95]	**[3.82]**	**[1.052]**	**[0.549]**
Fertilizer (kg/ha) t-1	0.57***	0.57***		
	[0.17]	[0.18]		
Improved seeds (kg/ha) t-1			0.71***	0.80***
			[0.070]	[0.045]
Area (ha) t-1	-0.53**	-0.49**	-0.22*	-0.11*
	[0.21]	[0.20]	[0.120]	[0.056]
Observations	1,407	1,393	1,410	1,396
R-squared	0.27	0.26	0.32	0.69
Trimming	0%	1%	0%	1%
A2B: IV - Impact of receiving voucher	**A2B.1**	**A2B.2**	**A2B.3**	**A2B.4**
Voucher received	**23.05*****	**22.95*****	**5.55****	**3.43*****
	[6.26]	**[6.28]**	**[2.37]**	**[1.14]**
Fertilizer (kg/ha) t-1	0.56***	0.52***		
	[0.17]	[0.18]		
Improved seeds (kg/ha) t-1			0.70***	0.79***
			[0.07]	[0.04]
Area (ha) t-1	-0.55***	-0.65***	-0.23**	-0.11**
	[0.21]	[0.21]	[0.11]	[0.05]
Observations	1,397	1,382	1,401	1,387
R-squared	0.30	0.28	0.32	0.69
Trimming	0%	1%	0%	1%
2C: IV - Impact of Using Voucher for Maize	**2B.1**	**2B.2**	**2B.3**	**2B.4**
Voucher used	**40.58*****	**40.96*****	**9.76****	**6.17*****
	[10.63]	**[10.81]**	**[4.12]**	**[2.03]**
Fertilizer (kg) t-1	0.54***	0.50***		
	[0.17]	[0.18]		
Improved seeds (kg) t-1			0.69***	0.79***
			[0.07]	[0.04]
Area (ha) t-1	-0.51**	-0.61***	-0.22**	-0.10**
	[0.20]	[0.20]	[0.10]	[0.05]
Observations	1,402	1,387	1,406	1,392
R-squared	0.35	0.34	0.32	0.68
Trimming	0%	1%	0%	1%

Robust standard errors in brackets
*** p<0.01, ** p<0.05, * p<0.1
Regressions include village fixed effects
explanatory variable between current and previous period
In table A2B, vouchers is instrumented by won lottery

Table A3: Impact on Maize Yield Household Level Regressions

	A3A.1	A3A.2
A3A: ITT VARIABLES	**Maize Yield (kg/ha)**	
Won lottery	**65.32**	**-2.30**
	[55.78]	**[41.11]**
yield (kg/ha) t-1	0.34***	0.50***
	[0.04]	[0.04]
Area (ha) t-1	-16.82	-22.56***
	[18.21]	[5.79]
Observations	1,320	1,267
R-squared	0.15	0.29
Trimming	1%	5%
A3B: IV - Impact of using voucher	**A3B.1**	**A3B.2**
Voucher used	**285.94**	**-10.02**
	[252.44]	**[184.99]**
yield (kg/ha) t-1	0.34***	0.50***
	[0.05]	[0.04]
Area (ha) t-1	-16.40	-22.57***
	[16.82]	[5.15]
Observations	1,316	1,263
R-squared	0.14	0.29
Trimming	1%	5%
A3C: IV Impact of Fertilizer Use	**A3C.1**	**A3C.2**
Fertilizer (kg/ha)	**5.65**	**-0.06**
	[5.29]	**[4.22]**
yield (kg/ha) t-1	0.32***	0.50***
	[0.05]	[0.04]
Fertilizer (kg/ha) t-1	-1.68	-0.12
	[3.48]	[2.78]
Area (ha) t-1	-14.44	-22.87***
	[17.20]	[5.34]
Observations	1,312	1,259
R-squared	0.16	0.29
Trimming	1%	5%

Robust standard errors in brackets. Regressions include village fixed effects
*** p<0.01, ** p<0.05, * p<0.1
Trimming removes observations with highest absolute variation in
yield between current and previous period
Regressions include village fixed effects
In table A3B, voucher used is instrumented by won lottery
In table A3C, fertilizer is instrumented by won lottery

Table A4: Impact on Maize Yield, Plot Level Regressions

	A4A.1	A4A.2
A4A: ITT VARIABLES	**Maize Yield (kg/ha)**	
Won lottery	**33.14**	**2.21**
	[58.17]	**[42.41]**
yield (kg/ha) t-1	0.35***	0.51***
	[0.04]	[0.04]
Area (ha) t-1	-32.14	-38.68***
	[35.15]	[9.50]
Observations	2,245	2,154
R-squared	0.21	0.35
Trimming	1%	5%
A4B: IV - Impact of using voucher	**A4B.1**	**A4B.2**
Voucher used	**126.70**	**8.45**
	[222.12]	**[162.14]**
yield (kg/ha) t-1	0.35***	0.51***
	[0.04]	[0.04]
Area (ha) t-1	-31.43	-38.64***
	[35.40]	[9.56]
Observations	2,245	2,154
R-squared	0.22	0.35
Trimming	1%	5%
A4C: IV Impact of Fertilizer Use	**A4C.1**	**A4C.2**
Fertilizer (kg/ha)	**2.25**	**0.30**
	[4.70]	**[4.31]**
yield (kg/ha) t-1	0.33***	0.51***
	[0.05]	[0.04]
Fertilizer (kg/ha) t-1	1.26	0.21
	[2.05]	[1.80]
Area (ha) t-1	-29.38	-38.84***
	[36.01]	[9.92]
Observations	2,241	2,150
R-squared	0.24	0.35
Trimming	1%	5%

The standard errors in brackets are clustered at the household level. Regressions include village fixed effects
*** p<0.01, ** p<0.05, * p<0.1
Trimming removes observations with highest absolute variation in yield between current and previous period
Regressions include village fixed effects
In table A4B, voucher used is instrumented by won lottery
In table A4C, fertilizer is instrumented by won lottery

Table A5: OLS Regressions on Returns to Fertilzer (plot level regressions)

OLS **Maize Yield (kg/ha)**	**A5A.1**	**A5A.2**
VARIABLES		
Fertilizer (kg/ha)	**3.43*****	**3.18*****
	[0.72]	**[0.81]**
Fertilizer (kg/ha) * Period2		**0.21**
		[1.42]
Period2 (dummy)		71.14
		[73.10]
OPV (dummy)	-24.01	-28.61
	[65.29]	[67.25]
Hybrid (dummy)	-7.34	-25.74
	[62.85]	[63.57]
Area (ha) t-1	-82.40***	-82.60***
	[12.99]	[12.96]
Observations	2,150	2,108
R-squared	0.14	0.14
Trimming	5%	5%
p-value of Hausman exogeneity test	0.4994	0.5061

OLS **Maize Yield (kg/ha)**	**A5B.1**	**A5B.2**
VARIABLES		
Fertilizer (kg/ha)	**3.03*****	**2.14*****
	[0.70]	**[0.79]**
Fertilizer (kg/ha) * Irrigation	**7.08***	
	[3.79]	
Fertilizer (kg/ha) * Experience		**0.69*****
		[0.20]
Irrigation	-70.72	
	[268.85]	
Fertilizer experience (yrs)		-57.16***
		[13.68]
opv	-18.47	-6.17
	[65.20]	[64.31]
hybrid	-9.71	11.16
	[62.86]	[60.82]
Area (ha) t-1	-82.18***	-82.10***
	[12.99]	[12.81]
Observations	2,150	2,149
R-squared	0.15	0.15
Trimming	5%	5%
p-value of Hausman exogeneity test	0.4482	0.8938

The standard errors in brackets are clustered at the household level
*** p<0.01, ** p<0.05, * p<0.1
Trimming removes observations with highest absolute variation in yield between current and previous period
Regressions include village fixed effects

Table A6: Instrumental Variable Quantile Treatment Effects

	A6.1	A6.2
Treatment:	**Received the voucher**	**Package used for maize**
Maize Yield (kg/ha)	**All**	**All**
Quantile		
q10	19.4	29.2
	[31.5]	[39.0]
q20	42.5	80.2*
	[37.6]	[45.8]
q30	68.2	107.5*
	[48.1]	[59.5]
q40	76.7	142.6*
	[59.8]	[81.6]
q50	105.3	168.0*
	[70.3]	[90.0]
q60	134.9**	194.0**
	[67.6]	[84.4]
q70	129.1	177.0
	[92.7]	[117.8]
q80	213.9*	297.4**
	[121.6]	[151.0]
q90	227.4	346.8*
	[179.6]	[209.7]
Observations	1,196	1,200
Trimming	10%	10%

The Quantile Treatment Effects indicate the impact of the treatment (receiving a voucher in the first 3 columns and using the package of the voucher for maize production in the last 3 columns) on the quantiles of the outcome of interest (maize yield or production). The treatments are instrumented by the result of the voucher lottery. The QTE are calculated using the estimator of Abadie, Angrist and Imbens (2002).

The standard errors in brackets have been obtained by bootstrap (500 repetitions)
*** p<0.01, ** p<0.05, * p<0.1
Trimming removes observations with highest absolute variation in yield between current and previous period
Package used for maize is a dummy equal to one if the farmer replies that he used the package for maize production and the quantity of fertilizer used in the maize plots is strictly positive.

Table A7: Effect of the Agro-input Subsidy on Yield Conditional on Experience (nb of years using fertilizer for maize in the past 9 years)

A7A: ITT Maize Yield (kg/ha)	**A7A.1**	**A7A.2**
Won lottery	**24.57**	**-25.75**
	[61.12]	**[43.74]**
Won lottery * Experience	**49.19****	**28.52**
	[18.63]	**[25.52]**
Fertilizer experience (yrs)	-23.01	-12.75
	[19.54]	[24.31]
yield (kg/ha) t-1	0.35***	0.50***
	[0.04]	[0.04]
Area (ha) t-1	-16.42	-22.36***
	[18.34]	[5.75]
Observations	1,319	1,266
R-squared	0.15	0.29
Trimming	1%	5%
A7B: IV - Impact of using voucher	**A7B.1**	**A7B.2**
Voucher(s) received	**154.50**	**-114.64**
	[316.56]	**[233.18]**
Voucher used * Experience	**86.99**	**68.49**
	[73.09]	**[59.75]**
Fertilizer experience (yrs)	-37.21	-22.42
	[24.87]	[24.17]
yield (kg/ha) t-1	0.34***	0.50***
	[0.05]	[0.04]
Area (ha) t-1	-16.18	-22.56***
	[16.87]	[5.13]
Observations	1,315	1,262
R-squared	0.15	0.30
Trimming	1%	5%
A7C: IV Impact of Fertilizer Use	**A7C.1**	**A7C.2**
Fertilizer (kg/ha)	**3.49**	**-1.77**
	[6.12]	**[4.67]**
Fertilizer (kg/ha) * Experience	**1.98**	**1.74**
	[1.35]	**[1.17]**
Fertilizer experience (yrs)	-111.19*	-77.26
	[66.54]	[56.08]
yield (kg/ha) t-1	0.32***	0.50***
	[0.05]	[0.04]
Fertilizer (kg/ha) t-1	-2.90	-1.75
	[3.25]	[2.71]
Area (ha) t-1	-12.74	-21.71***
	[16.99]	[5.20]
Observations	1,311	1,258
R-squared	0.15	0.30
Trimming	1%	5%

Robust standard errors in brackets. Regressions include village fixed effects
*** p<0.01, ** p<0.05, * p<0.1
Trimming removes observations with highest absolute variation in yield between current and previous period
Regressions include village fixed effects
In table A7B, voucher used and voucher used*experience are instrumented by won lottery and won lottery*experience
In table A7C, fertilizer and fertilizer*experience are instrumented by won lottery and won lottery*experience

Table A8: Effect of the Agro-input subsidy on Yield Conditional on Irrigation (plot level regressions)

A8A: ITT	**A8A.1**	**A8A.2**
	Maize Yield (kg/ha)	
Won lottery	**21.9**	**-9.8**
	[58.2]	**[42.4]**
Won lottery * irrigation t-1	**737.9***	**764.6****
	[383.0]	**[348.9]**
Irrigation t-1	2.9	-58.4
	[191.4]	[192.9]
yield (kg/ha) t-1	0.3***	0.5***
	[0.0]	[0.0]
Area (ha) t-1	-32.3	-38.9***
	[35.2]	[9.5]
Observations	2,245	2,154
R-squared	0.22	0.35
Trimming	1%	5%
A8B: IV - Impact of using voucher	**A8B.1**	**A8B.2**
Voucher used	**85.6**	**-37.1**
	[226.3]	**[165.1]**
Voucher used * Irrigation t-1	**1,175.2***	**1,279.4****
	[637.3]	**[597.9]**
Irrigation t-1	-90.5	-166.3
	[227.2]	[245.3]
yield (kg/ha) t-1	0.3***	0.5***
	[0.0]	[0.0]
Area (ha) t-1	-31.7	-39.2***
	[35.5]	[9.6]
Observations	2,245	2,154
R-squared	0.22	0.35
Trimming	1%	5%
A8C: IV Impact of Fertilizer Use	**A8C.1**	**A8C.2**
Fertilizer (kg/ha)	**1.85**	**-0.18**
	[4.75]	**[4.38]**
Fertilizer (kg/ha) * Irrigation t-1	**41.37**	**40.70**
	[58.44]	**[53.68]**
Irrigation t-1	-2,482.84	-2,346.39
	[4,002.77]	[3,651.24]
yield (kg/ha) t-1	0.32***	0.48***
	[0.05]	[0.05]
Fertilizer (kg/ha) t-1	-0.90	-2.19
	[4.67]	[4.72]
Area (ha) t-1	-36.77	-47.48***
	[39.30]	[17.16]
Observations	2,241	2,150
R-squared	0.09	0.14
Trimming	1%	5%

The standard errors in brackets are clustered at the household level. Regressions include village fixed effects
*** p<0.01, ** p<0.05, * p<0.1
Trimming removes observations with highest absolute variation in yield between current and previous period
Regressions include village fixed effects
In table A8B, voucher used and voucher used*irrigation are instrumented by won lottery and won lottery*irrigation
In table A8C, fertilizer and fertilizer*irrigation are instrumented by won lottery and won lottery*irrigation

Table A9: Effect of the Agro-input Subsidy on fertilizer/ha conditional on Experience and Irrigation

A9A Fertilizer use and Experience	**A9A.1**	**A9A.2**
	Fertilizer (kg/ha)	
ITT - OLS	**All**	
Won lottery	8.10**	7.24***
	[3.31]	[2.60]
Won lottery * Experience	**0.80**	**0.92**
	[2.15]	**[1.21]**
Fertilizer experience (yrs)	1.37	-0.48
	[2.15]	[1.15]
Fertilizer (kg/ha) t-1	0.56***	0.73***
	[0.18]	[0.08]
Area (ha) t-1	-0.58**	-0.37**
	[0.24]	[0.17]
Observations	1,406	1,393
R-squared	0.27	0.44
Trimming	0%	1%

A9B Fertilizer use and Irrigation	**A9B.1**	**A9B.2**
	Fertilizer (kg/ha)	
ITT - OLS	**All**	
Won lottery	9.36**	8.53***
	[3.90]	[2.59]
Won lottery * Irrigation	**-12.19**	**-16.20**
	[18.79]	**[15.49]**
irrigprev	21.31	18.05
	[14.83]	[12.81]
Fertilizer (kg/ha) t-1	0.57***	0.72***
	[0.17]	[0.07]
Area (ha) t-1	-0.54**	-0.38**
	[0.21]	[0.17]
Observations	1,407	1,394
R-squared	0.27	0.44
Trimming	0%	1%

Robust standard errors in brackets. Regressions include village fixed effects
*** p<0.01, ** p<0.05, * p<0.1
Regressions include village fixed effects

Can Matched Savings Stimulate Asset Accumulation?
Theory and Evidence from a Field Experiment in Mozambique

Introduction

In developed countries, the majority of individuals begin saving years before they apply for their first loan. They learn to be financially responsible for their future, including both predictable and unpredictable life events. Later, when they need to borrow money, they know the financial system, and the financial system know them. Why should it be different in the developing world? The belief that an individual can be too poor to save underlies a longstanding predominance of microcredit over savings. However, this assumption may be as unfounded as the belief that the poor were not creditworthy, the assumption that prevailed until the success of the Grameen Bank, starting in the late 70's. The poor certainly face a sharp tradeoff between present consumption and capital accumulation to improve their future well-being, but this trade-off is all the more salient when savings are costly and insecure. The last decade has seen a renewed interest for savings in the developing world (Dowla and Alamgir 30, Ledgerwood and White 51), with some recent evidence demonstrating the ability of the poor to save when given access to savings services [33, 68].

MS has emerged as a new instrument to encourage the poor to accumulate assets, yet its application has been primarily restrained to developed countries. MS, also known as Individual Development accounts (IDA), are a form of subsidy for capital accumulation. An IDA usually matches savings at a fixed rate (often between 50% and 400%) and is offered to the saver at the end of a given period or once a specific financial goal is achieved. These accounts are designed to help modest families achieve their goals and develop the habit of saving. The use of this instrument represents a major shift in social policy from consumption to assets and development (Sherraden 74). Drawing on explanations of the low savings of the poor from behavioral and institutional economics, 73 (p: 5,17) explain that "people tend to take the life path worn smooth by policies and to take greater notice of options highlighted by institutions [...] such choice takes less effort than to imagine all possible choices and then to weigh the probability of various consequences". In other words, by being offered the option of participating in the MS program, the population will be more likely to realize the importance of savings. In other words, by being offered the option of participating in the MS program, the population will be more likely to realize the importance of savings.

Examples of incentives for the non-poor to save in the US include tax deductions for interest paid on home mortgage, student loans, or on savings locked in a retirement account, but until the emergence of IDA, policies that encourage savings remained inaccessible to the poor of the US. Schreiner and Sherraden's institutional theory is embedded in the context of the US, yet it seems highly applicable to the poor of developing countries. In these contexts, poverty often finds its source in asset inequality, as evidenced by Birdsall and Londoño [14], and access to financial services is often the privilege of the wealthiest. A survey from Gallup in 18 Sub-Saharan African countries found that only 19% of the population have personal bank accounts. This rate decreases to 15% in rural areas, and of the poorest 40% of the entire population, only 11% have personal bank accounts[25]. Both the absence of financial institutions and the cost of access to information in rural areas prevent the population from access to formal savings. Meanwhile, private banks are reluctant to enter rural areas because of transaction costs and lack of evidence of the poor's interest in formal savings. Hence, Matched Savings Accounts may offer an ideal institutional instrument to familiarize the poor with both financial savings and the banking system in order to initiate the accumulation of assets necessary to improve their long term economic condition.

This paper presents a simple economic framework with simulations that illustrate the main mechanisms through which IDAs can reduce poverty in developing countries. We adopt a perspective in line with the asset-based approach of Carter and Barrett [20], where an individual can be persistently poor, potentially poor, or never-poor. The model in this paper highlights the potential of MS to first shift the boundaries between these groups, reducing the number of persistently poor and increasing the number of never-poor, and second, to then allow some individuals in the potentially poor group to transit from their low level equilibrium to their high level equilibrium. We provide evidence from a field experiment in rural Mozambique that combines subsidies for improved seeds and fertilizer with the encouragement to open savings accounts and the offer of Matched Savings. Our application of MS in rural Mozambique is slightly different from the one generally implemented in developed countries, where the use of the match is generally tied to the purchase of an asset (e.g., housing). Our training emphasizes the use of savings for the purchase of agro-inputs, but it is not imposed on the farmer. The rules of implementation are close to the guidelines of Schreiner [72] who recommends that MS in low income countries should target the poor through account design and by keeping matches low, it should be very simple, transparent, and should not attempt to monitor the use of matched withdrawals in order to keep administrative costs low.

The two primary assets encouraged by the program are financial knowledge and financial capital (i.e., the money held in the bank). Because communication costs are very high in rural areas, familiarizing farmers with the financial system is in itself a significant achievement. This paper focuses on the financial service intervention and its complementarity with the agro-input subsidy. In a separate paper, Carter et al. [19] evaluates the impact of the fertilizer and seed subsidy on production decisions and outcomes.

[25] "Few in Sub-Saharan Africa Have Money in a Bank" (May, 11th 2010) , Washington D.C., Gallup, Retrieved July 27, 2010 from the World Wide Web http://www.gallup.com/poll/127901/Few-Sub-Saharan-Africa-Money-Bank.aspx

The context

The project "Savings, Subsidies and Sustainable Food Security: A Field Experiment in Mozambique" was first piloted in 2009 and fully implemented in 2010. This program, implemented by the University of Michigan in cooperation with the International Fertilizer Development Center and Banco Oportunidade de Moçambique, offers MS to maize farmers in the Manica province of Mozambique. The province of Manica, with 43.6% of the population below the poverty line in 2003, is located in the west of Mozambique, next to the Zimbabwean border. The independence of Mozambique from Portugal in 1975 was followed by 15 years of civil war (1977-1992) which killed one million Mozambicans and displaced several million[26]. Since the civil war, political stability and sound economic reforms initiated a remarkable recovery, with an average annual growth rate of 8% between 1996 and 2006. However, Mozambique is only taking its first steps toward development; in the 2009 Human Development Report, Mozambique was ranked 172 out of 182 countries in the Human Development Index. Agricultural productivity is low, even compared to the rest of Sub-Saharan Africa, and requires modernization to reach agricultural self-sufficiency.

According to FAO data, Mozambique used 22,751 tons of fertilizer to feed a population of more than 21 million, a ratio of fertilizer use per inhabitant that is 3.7 times smaller than Malawi and 5.6 times smaller than Zambia.

While numerous interventions from government, donors, and NGOs have aimed to increase the use of agro-inputs in the region, they have struggled to achieve a sustainable change in agricultural practices rather than a temporary relief for beneficiaries. In Malawi, the reemergence of a food shortage in 2001-2002 during the scaling down of the Starter Pack Subsidies[27] raised concerns about the sustainability of the impact of the subsidy on maize production.

Oftentimes, farmers who have received assistance in the past fall back to their initial status and argue that they do not have the money to purchase fertilizer on their own. A potential cause is the complementarity between farming skills and financial management. Asset accumulation first requires a surplus generated from a production that is more than sufficient to satisfy the household's basic needs, but a productive farmer who consumes all his production from year to year is unable to accumulate assets. The cost and uncertainty related to savings at home or in the form of crop stocks increase the difficulty to re-invest the producer's profits from year to year. This motivated our implementation of an experiment that combines an agro-input subsidy with an intervention that promotes savings.

[26] US state department, Background Note on Mozambique, Retrieved July 22, 2010 from the World Wide Web http://www.state.gov/r/pa/ei/bgn/7035.htm

[27] Although localized floods contributed to the drop in maize production from 2.5 million tons in 99/00 to 1.7 million tons in 00/01 [75], the scaling down of subsidies from 2.8 million to 1.5 million beneficiaries played a substantial role [40].

A model of Persistent Poverty Depending on Ability and Patience

A Dynamic Poverty Trap Model

This section represents a farmer with a non concave production function and no access to credit, which generates a risk of poverty trap that is determined by the farmer's ability α and patience β. Typically, rain-fed farming can be represented by two phases per year. First, an inactive phase, from harvest to planting season, when one needs to save for future investments; second, the production phase, from the beginning of the rainy season to harvest. Therefore, the investment in inputs such as seeds and fertilizer first requires the producer to save the money during the approximate four-month inactive phase, which may constitute an obstacle to investment depending on the farmer's ability to save the money. The model below represents this framework from a dynamic perspective and examines the long term outcome conditional on the initial characteristics of the producer. This framework provides a benchmark that will, in the next subsection, be compared with the situation after the introduction of an MS intervention.

In the model presented below, during each period, the farmer goes through two phases. At the beginning of the first phase, the farmer decides how to allocate her wealth w_t between consumption c_t and savings s_t. At the end of the first phase, only a proportion k of the savings remain for the purchase of the input x_t. The second phase is the production, which is determined by $f(x_t)$ and will generate the wealth in the following period.

The intertemporal utility maximization of a farmer is as follows:

$$\max_{\{x_t\}} \sum_{t=0}^{\infty} \beta^t u(c_t) \quad s.t. \tag{0.7}$$

$$c_t + s_t = w_t \tag{0.8}$$

$$x_t = k\, s_t \tag{0.9}$$

$$w_{t+1} = f\,(x_t) \tag{0.10}$$

$$w_0 = \overline{w_0} \tag{0.11}$$

where β is the discount factor, and $u(c_t)$ is the utility, which is a function of consumption at period t, satisfying $u'(c) > 0$ and $u''(c) < 0$. In this model, the only way to carry money forward is to save it during the first phase, meaning that if a share $1-k$ is depleted; then in the second phase, this money can then be invested in agro-inputs in order to produce $f(x)$, which is a non-concave production function characterized by:

$f_1(x) = \alpha x^{\gamma}$

$f_2(x) = \alpha H x^{\gamma} - FC$

$f(x) = max\{f_1(x)\ ;\ f_2(x)\}$

$f(x)$ is the upper envelope of the low technology function $f_1(x)$ and the high technology function $f_2(x)$, which incurs a fixed cost FC but has a marginal productivity H times higher than the low technology. The parameters must satisfy $\alpha > 0$, $0 < \gamma < 1$, $FC > 0$, and $H > 1$. This type of model is similar to Buera [17] and Barrett et al. [8], where α represents the productivity of the farmer. Here, the input x_t increases production only at period t and is completely depleted at the end of the period. This is meant to represent an investment such as seeds and fertilizer, which needs to be renewed each year. However, the farmer must save enough money from one period to the next in order to be able to purchase the input. The need to save results from the alternation between unproductive phases and investment phases in rain-fed agriculture.

In practice, the existence of a non-concave production function is often difficult to assert. In the case of maize producers, a key question is whether a fixed cost is associated with the use of fertilizer. In principle, farmers can purchase any quantity from the agro-input seller, but in practice, farmers rarely purchase less than a 50 kg bag of fertilizer, which suggests the existence of a fixed cost that can be due to transportation or results from the initially low return due to the the learning by doing.

The variable k represents the proportion of savings that the farmer is able to keep between two subsequent periods. $1-k$ is the depletion associated with the mode of savings used in the absence of formal savings. When the alternative is holding a stock of grain, $1-k$ is the depreciation of the grain stock over time due to its deterioration. When the alternative is holding cash at home, $1-k$ represents the losses due to one of the following three reasons: 1) the money being lost or stolen, 2) the gifts and loans to family and friends, and 3) the money being spent due to self-control issues[28]. It is now a standard finding in behavioral economics that hyperbolic discounting and liquid assets generate impulsive consumption decisions [50]. For simplicity, I consider that the loss of wealth due to $1-k$ provides no utility even when it is due to impulsive consumption, an assumption similar to Banerjee and Mullainathan [7], who describe a part of income that is lost in the consumption of temptation goods. Although

[28] I assume that k is deterministic, yet given the stochastic nature of these three reasons, k could be a random variable. In this case, not only its average, but also its variance would affect the farmer's decision and payoff. It would also highlight the benefits of savings accounts through consumption smoothing [24]. This is an extension that may be explored in the future.

potentially a lucrative investment, the use of livestock is not considered a viable alternative to save between harvest and the time to purchase inputs, given that it is excessively illiquid for the investment ${x_t}$[29].

The problem is converted into the following Bellman equation:

$$max\left\{u(c_0)+\beta v_1(w_1)\right\} \tag{0.12}$$

Solving it gives the Euler equation:

$$u'(c_0)=\beta u'(c_1)k\,f'(x_0) \tag{0.13}$$

Given that at equilibrium, consumption is constant over time, plugging $c_0 = c_1$ *in equation 0.13 implies that an equilibrium must satisfy* $x^*(\alpha,\beta) = f'^{-1}(\frac{1}{\beta k})$. *Notice that* x^* *is increasing in* β *and* k, *which shows first that patient agents have their equilibria at a higher level of production, and second, that a low* k *discourages the accumulation of wealth. Each technology has a strictly decreasing marginal productivity and thus only one equilibrium. Hence, substituting the low and high production functions, there is a possible low equilibrium with input level* $x_l^*(\alpha,\beta) = (\beta k\alpha\gamma)^{\frac{1}{1-\gamma}}$ *and wealth* $w_l^*(\alpha,\beta) = (k\alpha)^{\frac{1}{1-\gamma}}(\beta\gamma)^{\frac{1}{1-\gamma}}$, *and a high equilibrium with input* $x_h^*(\alpha,\beta) = (\beta k\alpha H\gamma)^{\frac{1}{1-\gamma}}$ *and wealth* $w_h^*(\alpha,\beta) = (k\alpha H)^{\frac{1}{1-\gamma}}(\beta\gamma)^{\frac{1}{1-\gamma}} - kFC$. *Nonetheless, there will be two equilibria only under certain conditions, including that 1)* $f_1(x_l^*(\alpha,\beta)) > f_2(x_l^*(\alpha,\beta))$ *and* $f_2(x_h^*(\alpha,\beta)) > f_1(x_h^*(\alpha,\beta))$ *, meaning that both points must be located on the upper envelope of the production function, and that 2) consumption in the steady state is higher in the high equilibrium than in the low equilibrium. Hence, there are three possible cases:.*

- Situation 1 - Always poor: x_l^* *is the only equilibrium reached independently of the initial level of income* $\overline{w_0}$, *.*

- Situation 2 - Potentially in a poverty trap: The individual converges to a high equilibrium $x_h^*(\alpha,\beta)$ *if* $\overline{w_0}$ *is higher than a certain threshold, or otherwise to the low equilibrium* x_l^* *.*

- Situation 3 - Non-poor: $x_h^*(\alpha,\beta)$ *is the only equilibrium reached independently of* $\overline{w_0}$*..*

The farmer's productivity α *and her discount rate* β *are the two individual characteristics that determine which equilibrium is possible. To illustrate this, we ran simulations using a utility function and parameters that are presented in Appendix 1. We vary* α *and* β, *keeping all other parameters constant. Figure 1 indicates in which*

[29] Buying livestock after selling maize in order to re-sell it at time to purchase inputs is quite infrequent give the transaction costs

situation a farmer is, once the dynamic optimization problem is solved. Results are presented with respect to α and β, keeping all other parameters constant. For example, farmers in the lower left corner are always poor, meaning that once the dynamic optimization of the problem is solved, the only equilibrium of the farmer corresponds to the low level equilibrium. As expected, farmers who are impatient and less productive are always poor. Farmers who are patient and productive are never poor, meaning that even if they started with extremely low wealth, they are willing and able to invest and save until they reach their high equilibrium. Farmers with intermediate characteristics may fall on either side, depending on the amount of wealth that they begin with. If all farmers start with very low wealth, then all farmers in situation one and situation two are poor. However, policy implications are quite different for each situation. Those in situation 1 are persistently poor; they need a structural change in productivity and/or patience through trainings. Those in situation 2 need a transition from their low equilibrium to a higher one. This can be achieved through a "big push," such as a cash transfer. In the following section, I simulate the MS intervention and examine how it generates both a transitional and a structural change. .

A simulation of the Matched Savings Intervention

We reproduce the model of section 2, adding the following modifications:

- The farmer can choose to open a savings account in the first period, which causes the disutility of the administrative steps,

- Maintaining the account provides a small disutility to the farmer (mainly the transaction cost to regularly go to the bank), but it increases her capacity to keep the money during the first phase,

- If the farmer decides to open an account, then she receives a match of 50% of the amount saved at the end of the first period s_0,

- The farmer initially underestimates the benefits of the savings account[30].

The new inter-temporal utility function of the farmer is given by:

$$\max_{\{x_t, s_t\}} \sum_{t=0}^{\infty} \beta^t (u(c_t) - b_t d_k) - b_0 d_o \quad s.t. \tag{0.14}$$

$$c_t + s_t = w_t \tag{0.15}$$

[30]The farmer may overestimate the risk of saving in a bank because of a lack of trust towards the bank, or could underestimate the benefits of "putting the money away"

$$x_t = s_t\left(b_t k_b + (1-b_t)k\right) \;\; \forall t \geq 1 \tag{0.16}$$

$$x_1 = s_1\left(b_1 k_b(1+M) + (1-b_1)k\right) \tag{0.17}$$

$$w_{t+1} = \; f\left(x_t\right) \tag{0.18}$$

$$w_1 = \left[(1-s_0)k + s_0((1+M)k_s\right] f\left(x_0\right) \tag{0.19}$$

$$w_0 = \overline{w_0} \tag{0.20}$$

Where

$$b_t = \begin{cases} 1 & if \;\; farmer \; has \; a \; banking \; account \; open \; at \; time \; t \\ 0 & otherwise \end{cases}$$

and d_o is the disutility of opening a banking account (e.g., due to administrative constraints), and d_k is the disutility of the transaction cost associated with the use of the account. In equation 0.19, M is the fraction of the savings that is matched during the first period. If a farmer has a banking account, then instead of keeping the proportion k of her production from one period to the next, she is able to keep $k_b > k$, which follows Aryeetey [5], who shows that the returns of informal savings are on average lower than the ones in the financial sector. This is due to the security provided by the bank, but also by the fact that money becomes less liquid. Tobacman [81] shows that illiquid assets substantially increase the savings of the poorest, an effect that is even stronger in the case of quasi-hyperbolic utility compared to exponential utility. As in Laibson [50], the need for pre-commitment of consumption increases one's self-control and reduces the consumption of agents with hyperbolic time preferences.

Farmers who had little previous exposure to banks do not know the real value of k_s; instead, they have a prior belief with an average value of k_b^0 satisfying $k \leq k_b^0 < k_b$. For this reason, even though some farmers may have already had the possibility of opening a savings account, their mistrust of the banking system, combined with an irreversible cost in utility to open the savings account, dissuades most of them from opening one. However, if the benefits of the MS exceed the cost of opening the account, then farmers will always open an account, even if they expect to close it in the following period. I assume that once the account is open, then the farmers observe k_b without any noise and can make the decision to keep the account open based on the real benefits of having a banking account. This simple scheme highlights the role of the MS as a learning subsidy for farmers who are unfamiliar with financial institutions. It also underlines the importance of transaction costs, which are a key challenge to reach low-income farmers. However, for the simulation, we assume that the transaction costs are low enough that, once the benefits of having an account are known, they outweigh the transaction costs. We also assume no trust issue from the farmers side that the match will be paid by the bank[31].

We now simulate the results of the dynamic optimization, assuming that all farmers open a savings account and receive the MS. We assume that before the MS intervention, all farmers in situation 1 and 2 are at their low-level equilibrium, and farmers in situation 3 are in their high-level equilibrium. We assume that the intervention targets only poor farmers (who are in situation 1 and 2). Keeping the same parameters as in Figure 1, except that k is now equal to 1 instead of 0.8 because of the savings account, Figure 2 presents the result when varying α and β.

Figure 2 still shows the persistently poor farmers in the lower left corner and structurally non-poor farmers in the upper right corner, yet this time the farmers in situation 2 are separated into:

- Situation 2.1: farmers who stay at their lower level equilibrium despite receiving the MS

- Situation 2.2: farmers who will transit to the high level equilibrium thanks to the money transfer and temporary incentive to save provided by the MS

Hence, we can see two channels through which MS durably reduces poverty. First, access to a savings account has made permanent changes, reducing the proportion of farmers who are structurally poor and increasing the ones that are never poor. In other words, the level of productivity and patience required to become non-poor has decreased because k has increased. According to the model, MS gives access to savings because it provides an incentive to learn about its benefits through one's own experience. We term this effect the "learning subsidy effect". Second, the MS propels some farmers in situation 2 from their low equilibrium to their high equilibrium. This is due to both the cash transfer and the condition attached to it, which provides additional incentives to save. We term this effect the "conditional cash transfer effect".

Based on the same simulation, Figure 3 illustrates the amounts that are transferred to the farmers as a function of α and β. Note that by assumption, the non-poor receive no transfer at all, which further assumes that the MFI would be able to target the poor, but not to observe patience and productivity among them. Under this assumption, Figure 3 shows that farmers who are the most patient and have the highest productivity are the ones that receive the highest MS payoff. Several factors explain this result. First, the farmers with greater ability and

[31] *In the Mozambique field experiment, the MS intervention was made available for 2 years, allowing the more reluctant farmers to gain trust through observation in the first year..*

patience have higher wealth at their low equilibrium. Second, farmers with greater ability are able to produce more, and the ones with greater patience are more willing to save. Third, the farmers who are aware that the subsidy gives them the opportunity to transit toward a higher equilibrium and who value these long term benefits more have an additional motivation to save. All these elements combined explain the "filtering effect" of the MS. While Micro-credit institutions undergo sizable costs to identify clients with a productive project as well as the potential and willingness to make the effort to increase their living condition, MS naturally attracts the farmers with the highest potential to transit out of poverty. According to the simulation, the average transfer is 0.254 among the farmers who remained poor after the MS intervention, compared to 0.476 among those who overcome poverty thanks to the MS. The size of the difference is of little interest given that the simulation is not calibrated, but the numbers indicate that MS is efficient in the sense that more money is transferred to farmers who are on a path out of poverty, and less to the ones that will stay in poverty. Note that in this simulation, all farmers who receive the MS decide to open an account; in fact, if a minimum gain in utility was necessary to open the account, then the farmers with very low α and β would not open it and thus not receive any MS, which would add to the filtering effect of the MS (graphically, it would flatten the lower left corner in Figure 3).

Intervention and Research Design

The Intervention

Our project in rural Mozambique combines agro-input voucher subsidies with savings training and MS. A separate paper evaluates the impact of the agro-subsidy program on the maize production of the beneficiaries [19]; the current paper focuses on the impact of the financial treatment on savings and asset accumulation, though it also examines whether this impact is affected by the allocation of voucher subsidy treatment (VT). The two implementing organizations are Banco Oportunidade de Mocambique (BOM) and International Fertilizer Development Center (IFDC). BOM has multiple features that make microfinance very accessible to the poor. First, the use of digital identification techniques, both photographic and fingerprint, allow illiterate clients to easily open and use a savings account. Second, there is no charge for opening or maintaining a savings account. Finally, the branches are located in small towns, and two mobile banks drive from the branches to rural communities each week to serve the clients located in more remote areas. Given that there is a fixed cost to provide financial services in remote areas, it is important for the bank to reach a critical mass in each location, which increases the relevance of financial education and MS.

The financial services were randomized at the locality level. In order to limit the risk of spillover, localities were defined as units of population such that information circulates easily within localities, but less between localities. In most cases, localities correspond to villages, but some large villages have been divided into smaller localities, one for each neighborhood, and in some rare cases, small neighboring villages have been pooled into one locality. The sample includes a total of 94 localities, with an average of 17 households sampled per locality in the baseline survey; it targeted what the extension defined as “progressive” maize farmers. For the randomization of the financial service, 32 groups of three localities (pooled by geographical proximity). Within each group of three, each locality was randomly attributed to the control group, the ST (Savings Treatment) and the MST (Matched Savings Treatment), with the same probability of falling into each treatment group. Furthermore, within each village, one half of the households were randomly selected to receive a voucher that offers a subsidized package of 12.5 kg of improved maize seeds (either OPV or hybrid) and 100kg of fertilizer (50 kg of urea and 50 kg of NPK 12-24-12) for a subsidy that amounts to 73% of the market price of the package.

The subsidized agro-input package was made available in December 2010, and its harvest was expected around May to June 2012. A baseline survey was implemented prior to harvest, in April 2011. The week following the survey, farmers in each locality of the ST or MST treatment group were invited to the first financial education session and were encouraged to open savings accounts. Beneficiaries of the MST also received an explanation of how the MS is calculated. The training sessions, jointly given by BOM and IFDC, covered the benefits of using fertilizer and improved seeds and the importance of savings in order to be able to afford agro-inputs and other investments. Participants were introduced to Banco Oportunidade and were told how to open and use a savings account.

In the first session, participants were asked to form groups of five beneficiaries and select one representative per group. Representatives were offered a t-shirt with the logo of Banco Oportunidade and were given the responsibility of maintaining the connection between the bank and the members of their group. Two follow-up sessions, organized between May and July 2011, gave the BOM and IFDC personnel the opportunity to ask the representatives about the progress of their groups towards opening savings accounts and to address any questions or concerns of the participants. Representatives were also given more financial education, including the use of a comic strip and a board game. At the end of each follow-up session, participants were are asked to communicate what they had learned to the rest of their group members. All meetings were organized in the communities, and the representatives were usually offered a meal or a snack during the training. The initial information sessions, to which all participants were invited, and the two follow-ups, which the representatives attended, define the savings intervention.

The MST intervention included all the components of the ST plus a 50% match on the minimum amount that was saved between August 1st and October 31st 2011, with a maximum match of MZN 1500 per individual (approximately USD 56). The purpose of the matched savings was to familiarize the maize farmers with the banking system and encourage them to develop a habit of saving between harvest and the time to purchase agro-inputs.

The amount was deposited in the beneficiaries' accounts at Banco Oportunidade during the first week of November. The dates were chosen to fit the farmer's calendar. A majority of farmers sell most of their maize production before August first and purchase their agro-inputs in November. Although the information sessions emphasized savings to purchase the agro-inputs needed for maize production, once the amount was deposited in the accounts, the beneficiaries owned the money and had the freedom to decide how to use it. In the MST groups, the MS was explained during the sessions and a flyer was given to the representatives, in order to summarize the rules of the MS and increase the credibility of the program.

To evaluate the impact of the intervention, we use the data from the baseline survey, carried out in April 2011, and from the first follow-up survey, implemented in August 2011, slightly after the main maize harvest. August was also the first of the three months during which the beneficiaries of the MS were required to save in order to receive it. The surveys included modules on consumption, savings, and some assets (though they do not include most assets related to small non-agricultural businesses). We also use the monthly minimum balance of all clients of Banco Oportunidade in our sample, shared by Banco Oportunidade, which provides a check of self-reported savings without measurement error and risk of under-reporting. Before analyzing the results, Table 1 shows basic statistics of the beneficiaries and confirms that the intervention is orthogonal to the basic characteristics of the beneficiaries. The average consumption per capita is only MZN 60 (USD 2.2) per month, of which about 80% is used for food consumption. Fifty-five percent of the households have a consumption per capita and per day that is below the equivalent of USD 2. The project includes quite remote areas, with on average only 11% of households having access to electricity; however, among the heads of household, 84% are male and 76% are literate (compared to 66% male heads of household and a 45% literacy rate in rural Manica[32]), and 20% of the households held a savings account before the intervention, which is above the average in rural Africa. The population is relatively poor, but slightly less than the rest of the population in the region, given that the agro-input subsidy program intentionally targeted progressive small-scale farmers.

Research Design

The empirical study addresses four questions. First, how successful were the ST and MST interventions at encouraging the beneficiaries to open a savings account and save money in Banco Oportunidade? Second, does the increase in savings at Banco Oportunidade reflect an increase in total savings, or is it the result of a reduction of savings in other banks, informal savings, or non monetary forms of savings such as crops or livestock? If the

[32]The Manica data used for comparison is from the 2007 "Terceiro Recenseamento Geral da População e Habitação", provided by Mozambique's National Institute of Statistics, accessible online at http://www.ine.gov.mz/home_page/censo2007

household is increasing its asset accumulation, we would expect to observe a reduction in consumption. Third, as the optimal asset portfolio depends on the levels of return, risk, and liquidity of each form of asset, to what extent does the appearance of a new way of savings and the expectation of an increase in financial assets for the ST and MST groups affect the asset portfolio of the beneficiaries? Finally, the financial interventions (ST or MST) and the Voucher Treatment (VT) have been combined because of their expected complementarities. An increase in the maize production in the VT group would increase the beneficiaries' ability and willingness to open and save in order to carry forward the benefits of the subsidy. Therefore, do the answers to the previous questions differ depending on whether the household was assigned to receive the vouchers?

To address these questions, we use a simple regression specification that allows us to compare different outcomes of interest for the control, the ST, and the MST :

$$Y_{ilg} = a_0 + a_1 ST_{lg} + a_2 MST_{lg} + X^{'}_{ilg} a_3 + \theta_g + \epsilon_{ilg} \tag{0.21}$$

where Y_{ilg} is the outcome of interest (a form of savings, consumption, or assets) of household i in locality l in the group of localities g. As a reminder, we organized localities in 32 groups of three adjacent localities. Among each group, one locality was assigned to the ST, one to MST, and one was kept as a control group. ST_{lg} is an indicator equal to one if the locality l was assigned to the Savings Treatment and zero otherwise. Likewise, MST_l is equal to 1 when the locality l was assigned to the Matched Savings Treatment. X_{ilg} is a vector of control variables, generally limited to the lag of the outcome variable, if available. ϵ_{ilg} is a mean zero error term of individual i in locality l and group g. Following Moulton [63], the standard errors are clustered at the locality level since it is the level of assignment of the lottery. a_1 and a_2 provide consistent estimates of the Intention To Treat (ITT) effect of ST and MST on Y_{ilg} . We also test whether $a_1 = a_2$ in order to assess whether the impact of the ST on Y_{ilg} is significantly different from that of the MST.

Given that not all households allocated to the ST or MST groups opened a savings account, one could consider instrumenting the act of opening an account by the assignment to the treatment groups in order to obtain the Average Treatment Effect. However in the treatment groups, a larger proportion of beneficiaries attended the trainings, which may have affected their behavior, even though they did not open an account afterwards. Therefore, since the assumption that the instrument affects only the outcome of interest through the treatment would be violated, we do not use instrumental variables and consider only the ITT effect.

The Impact of the Financial Interventions on Formal Savings, Consumption and Asset Accumulation

The impact on Savings

Table 2 analyzes the impact of the ST and MST on formal and informal savings. Table 2A presents the OLS regressions, where, for all but non-binary variables, the upper 1% of the outcome variable has been replaced by the 99th percentile in order to limit the influence of outliers. Table 2B shows OLS on the log of the outcome, and 2C presents quantile regressions at the median, meaning they are both less sensitive to outliers and provide additional perspectives on the impact of the program. The ST increased the probability of the household owning a savings account by 14 percentage points and increased their formal savings by a non significant MZN 259. By contrast, the MST increased the proportion of households with savings accounts by 20 percentage points and increased formal savings by MZN 988, which is significantly different from zero and significantly higher than the impact of the ST. We also find that the amount of informal savings[33] (regression 2A.5) has dropped by an amount of the same order of magnitude as the increase in formal savings, and the last column of Table 2 shows no significant change in total savings among the beneficiaries of the two treatments (if anything, the MST has reduced the median total savings of its beneficiaries). Therefore, the MST generated an increase in formal savings that is 3.8 times higher with the MST than the ST. We can also note that the increase in formal savings (in BOM and other banks together) generated by the two treatments is substantially higher than the increase in BOM (2.7 times higher in the MST). Hence, the increase is not driven by a transfer from other savings accounts to a BOM account, but on the contrary, it seems that some farmers understood the message that formal savings are important, but preferred placing their money in a different bank. Some participants stated that they chose other banks because BOM is relatively new, is not as well known as other banks in the country and because of a lack of confidence in the mobile banks. This indicates a positive externality for the other banks of the trainings that encourage placing savings in other banks when a large part of the potential to save is untapped due to important informal savings.

Table 3 investigates the levels of consumption and asset holding. The outcome variable of the first column is the sum of food consumption and monthly consumption (converted into consumption per day and per capita). We isolate these components of consumption from the yearly expenditures because they are likely to be affected in the short run. The results show a 3-4% reduction of the “food and monthly consumption” caused by the MST and ST, which is not significant. The second column uses the total value of durables [34]. Interestingly, both interventions have significantly reduced the value of these durable goods. Hence, it appears that households were able to curb

[33]Informal savings is given by the reply to the question “How much money do you keep outside of the banking system?”

[34]Consumption items include car, motorbike, bike, radio, television, fridge, freezer, ironing machine, bed, table, mobile phone, clock, and solar panel.

their expenditures on the purchase of durable goods (or may have sold them) more than they were able to reduce their food expenditures.

The Impact on Consumption and Assets

We now turn to the analysis of the value of assets of the household and find a significant reduction in the stock of crops for both ST and MST. If savings in the form of crops is costly because of its deterioration over time, then it should be expected that the availability of a more or less costly form of savings causes a reduction in the stock of crop. The effect of the ST and the MST on the livestock of the beneficiaries is not significantly different from zero, but appears to be positive with the MST and negative with the ST. We do not find a significant impact on total savings and assets; however, this may be due to a lack of power. With a standard error of more than 2,000 MZN in the impact of the ST and MST on total assets (regression 3A.6), even an increase in total asset of 3,000 MZN among all beneficiaries would not be statistically significant (MZN 3,000 is the maximum amount for which a 50% match is offered and is worth about USD 111). In the case of the MST, it appears that the reduction in the durable goods has been reallocated to assets and savings. Even though not significant, the magnitude of the transfer is relatively large.

Figures 4.1 to 4.5 display the cumulative density function of different outcomes of interest for the control, ST, and MST groups and display the distribution of the outcome among the beneficiaries. Figure 4.1 shows that even with the MST, about 60% of the population is unable to have a savings account. Therefore, a better understanding of the constraints that prevent the farmers from benefitting from this high payoff is needed. Nonetheless, among those who opened an account, MST is particularly effective in increasing savings among the "small savers" who save between 0 and 3,000 MZN. This is not surprising given that the MS rewarded 50% of the amount saved for up to MZN 3,000. The fact that even beyond MZN 3,000, the distribution of savings in the MST group still dominates the distribution of the two other groups indicates that the financial remuneration is not the only motivation for saving, and that once the sunk cost of opening an account has been overcome, many households find it advantageous to save beyond the amount for which a financial reward is offered[35]. Figure 4.2 shows a reduction in informal savings (i.e., savings located in the home or buried) that spreads relatively well between the 30th and 90th percentile. Therefore, the decision to transfer savings into formal banking was not confined to households with the highest amount of cash available. Comparing Figure 4.1 and Figure 4.2, we see that even for the two treatment groups, the amount of informal savings is generally higher than the formal savings, indicating an important margin of progress

[35] Further analysis can explore the different motivations for savings by using the discontinuity of the savings at the threshold beyond which no match is offered.

for the financial sector. Figure 4.3 and Figure 4.4 show that, while the reduction of consumption items in the MST was relatively well spread among the population, the reduction of food consumption appears stronger between the 20th and 80th percentiles (although not significant). Figure 4.5 shows a slight shift to the right of the cumulative distribution of assets, above the 60th percentile for the ST group and above the 35th percentile for the MST group. Some of these findings are compatible with the idea that the households who are able to foresee a transition out of poverty due to the intervention have more incentive to accumulate assets. In line with the findings of Zimmerman and Carter [85], the increase in financial assets reduces the household's absolute risk aversion, which allows poor households to increase their investment in productive assets. The following survey results will provide additional perspectives on these dynamic changes.

Effect of the Voucher Treatment

We test whether the changes in savings, consumption, and assets are affected by whether or not the household was assigned to receive an agro-input subsidy. For this, Table 4 and Table 5 reproduce the regressions of Table 2 and Table 3, with three explanatory variables added: a dummy for the assignment to the Voucher Treatment alone, multiplied by the ST and multiplied by the MST:

$$Y_{ilg} = b_0 + b_1 ST_{lg} + b_2 MST_{lg} + b_3 VT_{ilg} + b_4 VT_{ilg} * ST_{lg} + b_5 VT_{ilg} * MST_{lg} + X'_{ilg} b_3 + \theta_g + \epsilon_{ilg} \tag{0.22}$$

where VT_{ilg} is a dummy equal to one if household i was assigned to the Voucher Treatment. When Y_{ilg} is a form of asset, b_3 gives the impact of being assigned to receive the voucher on the accumulation of asset Y_{ilg} in the absence of the financial service intervention. b_4 and b_5 being significantly positive would be interpreted as a complementarity of the voucher program with the ST and MST, respectively, at encouraging the accumulation of asset Y_{ilg}. Table 4 shows no discernible evidence that the VT affected the amount of monetary savings nor that it enhanced the impact of ST and MST on savings. The results in Table 5 suggest that the VT significantly increased both the reduction of durable goods as well as crop stock induced by the MST. These results are in line with the objective of the combination of the two interventions, as durable good expenditures and crop stock were hypothesized to shift toward financial savings and eventually more productive investments. However, the VT did not increase the impact of MST on livestock, and since the survey did not collect data on all forms of investment, we are unable to assess whether the crop stock and durable good expenditures have been redirected toward other long term investments.

The Filtering Effect

The filtering effect obtained in section predicts that, for a given level of asset and wealth, the amount of savings, and thus the match should be increasing in the patience and ability of the beneficiary. In this preliminary investigation, we test whether more patient individuals tend to save more as a reaction to the MS intervention and thus receive a higher match from the bank. The ability is not included because of the difficulties to measure it, but it will be incorporated in future work. Omitting the ability from the regression is equivalent to integrating out α in the model; it does not affect the prediction that the match should be increasing in β if α and β are orthogonal, but it does affect it if the two parameters are correlated. The measure of patience that we use is the planning horizon of the respondent, which is the reply to the question "How far ahead do you plan your future expenditures?"[36]. Table 6 analyzes the effect of horizon on the probability of opening an account at BOM, savings at BOM, and the Matched received. It controls for the initial value of assets and savings, as well as the maize production, since the filtering effect is expected to hold for a given level of wealth. Additional controls include the level of education and prior account or savings at BOM. Regressions 6.1 and 6.3 confirm that both the probability of having an account at BOM and the amount saved at BOM are increasing in the time horizon of the beneficiary. Interestingly, regressions 6.2 and 6.4 show that this effect is almost twice higher in the MST group than in the control group (although the coefficients are not statistically different). A change in the horizon from the 25th percentile to the 75th percentile increases the probability of owning an account by 2.7 percentage points for the control group and 5.1 percentage points in the MST group. This evidence confirms that the MST generate an incentive to save that is strongest among the most patient households. However regressions 6.5 and 6.6 show a non significant impact of the time horizon of the beneficiary on the amount of the match received, which may be due to a reduction of the sample size when restrained to the MST group. In the future, this research needs to establish a theoretical framework from which will be derived clear predictions about who is expected to open an account, to save up to the maximum amount that is matched, and to save beyond this amount, before testing these predictions.

Conclusions

The first part of this paper uses dynamic programming to predict the long term changes in poverty dynamics that can be triggered by MS, and the second part is an empirical investigation of the impact of ST and MST on savings, consumption, and asset accumulation during its first year of implementation. The model is based on a framework of rational, credit-constrained farmers, where a non concave production function creates two possible equilibria which depend on the degree of ability and patience of the farmer. Without savings accounts, farmers a part of the savings is lost between harvest and the time to invest in agro-inputs. The farmers initially underestimate the benefits of the savings account because of a lack of information regarding financial institutions. In this context, this paper

[36]The planning horizon measure, inspired by Ameriks et al. [3], is explored in detail in the third essay of this dissertation. It appears to be correlated with many economic outcomes of the respondent.

highlights three major channels that give Matched Savings the potential to be a powerful tool to stimulate financial development and create a path away from persistent poverty:

- The learning subsidy effect: the MS allows the farmer to experiment and learn about the benefits of holding a savings account, while, at the same time, gives them the opportunity to change their savings habits.

- The conditional cash transfer effect: comprised of both the impact of the transfer and the impact of the condition, the MS allows the beneficiary to transit from low to high equilibrium through an increase in their assets.

- The filtering effect: the poor farmers with high ability and patience who are able to transit out of poverty due to the transfer receive the highest proportion of the MS; this self-selection increases the efficiency of the MS without any increase in the cost of screening.

This model relies on the fact that the MS will encourage the use of formal savings among its beneficiaries and result in an increase in k, the capacity to retain wealth from one period to the next. This hypothesis is tested using a field experiment in Mozambique, in which we randomly assigned farmers a ST (financial education and encouragement to open a savings account) or a MST (which added MS to the previous intervention). We find that in the first year of implementation, the proportion of participants with savings accounts increased by 13 percentage points among those with an ST and 20 percentage points among those with the MST. Hence, the MST doubled the proportion of participants with a savings account (from 20% to 40%), but failed to convince the remaining 6 out of 10 participants to open a savings account. Even so, the MST generated 2.7 times more formal savings than the ST, an increase which is particularly important among small new savers. Hence, the MS shows some potential for changing savings behavior, although the long term impact remains uncertain and will be the subject of further evaluations using survey data . The increase in total formal savings generated by the ST and MST is higher than the increase in our partner bank, BOM, showing a positive externality due to the financial training rather than a displacement of savings from one bank to another. The majority of the increase in formal savings came from a reduction in informal savings.

The interventions generated a change in the way the beneficiaries save rather than an increase in the total amount of savings, which is perhaps unsurprising given that the follow-up survey was implemented only four months after the beneficiaries of the MST and ST received financial training and encouragement to save. A change in total savings may appear in the long run if formal savings actually help the beneficiaries better manage their expenditures. The data shows a reduction in consumption that is more evident in durables (e.g., motorbike, television, furniture) than in food and monthly expenditures. The reduction of food consumption in order to accumulate assets may not be an option for the very poor given the demonstrated impact of nutrition on health and productivity [76, 26, 11].

Reallocation of assets from crop stocks to livestock and other assets was observed. The MST increased the total value of assets and savings of the beneficiaries by an economically sizable value, though it is econometrically not significant. The ST and MST were combined with an agro-input voucher subsidy treatment in order to test the complementarity between the two interventions. However, the VT did not increase formal savings nor did it significantly boost the benefits of the ST or MST. We find some evidence that the combination of VT and MST contributes to a sharp reduction of durable goods.

Whether the increase in formal savings generates improvement in the well-being of the beneficiaries remains a fundamental question. The microeconomic theory emphasizes the effect of the reduced liquidity and psychological commitment, which allow the individual to reduce consumption, reduce risk exposure, and increase asset accumulation. Furthermore the macroeconomic theory emphasizes the role of financial deepening in economic growth because it increases the ability to channel capital where it is needed [60, 49]. Yet the net benefits of financial deepening in a poor rural setting, with high transaction costs in order to save relatively small amounts remains to be demonstrated. Are formal savings superior to holding grain stocks, given that the latter is less sensitive to cyclical food price variations? The next rounds will provide further evidence on this issue.

This work provides both encouraging evidence for the potential of savings accounts and MS to encourage asset accumulation as well as limitations. Further investigations will examine why some farmers did not open a savings account despite the important potential payoff of the MS, with a particular focus on issues of mistrust and high transaction costs. The theoretical model predicts self-selection of the beneficiaries into the MS, which can be tested using the data on MS payoffs and baseline characteristics. The observed changes in formal savings and consumption indicate a change in poverty dynamics for the beneficiaries of the MS who opened an account. Whether the change in asset accumulation generated by the MS is sustainable or not is a fundamental question which will be addressed using the survey data. This research provides new evidence that will inform the debate on the impact of savings account in the developing world and provide policy makers with new tools to change poverty dynamics through micro-savings and a stimulation of asset accumulation among the poor.

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Figure 1: Income category based on productiviy and patience

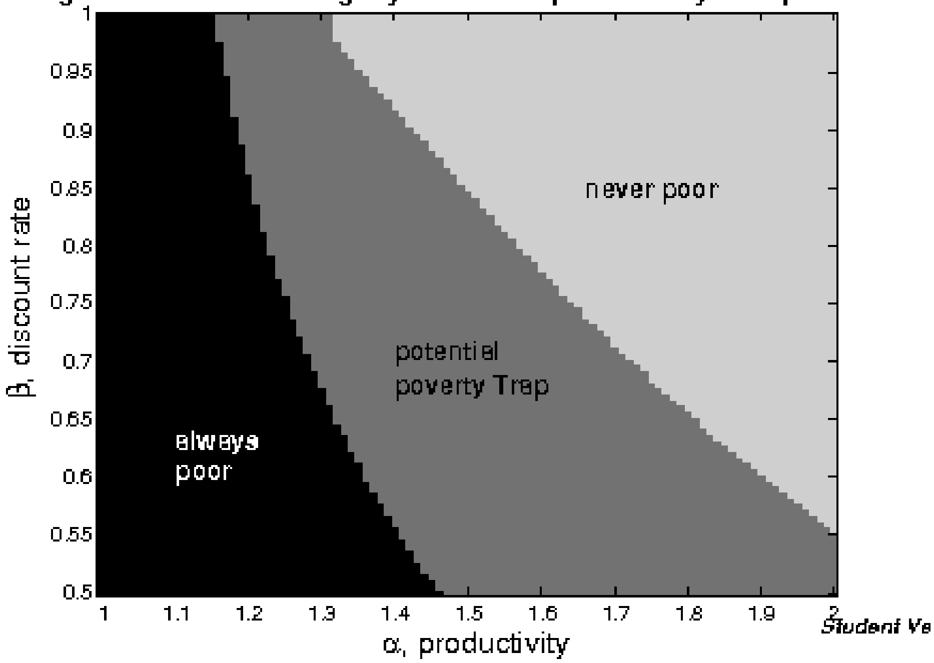

Figure 2: Income category after Matched Savings intervention

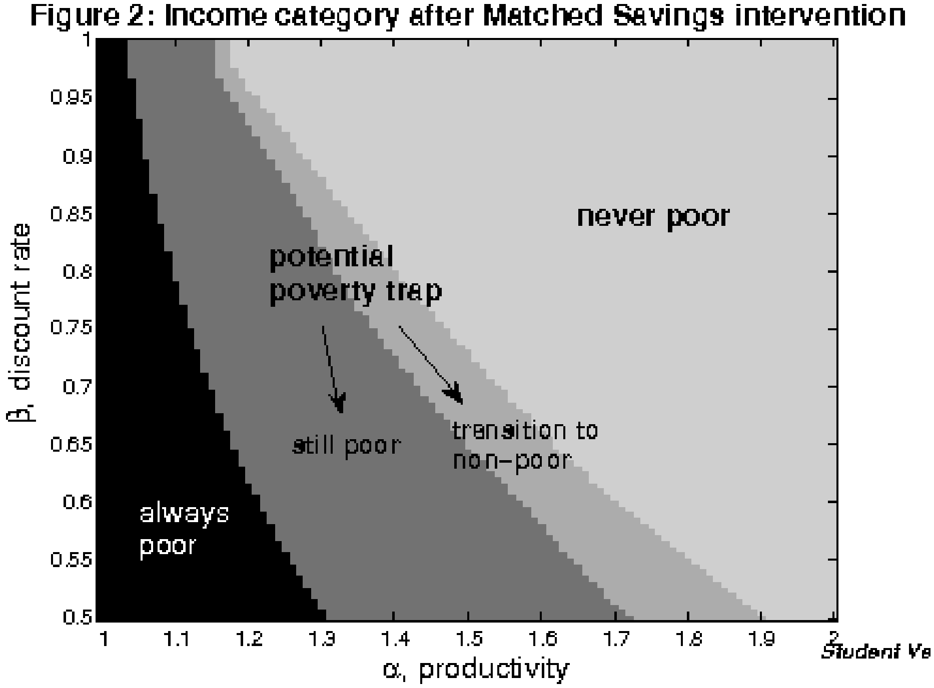

Figure 3: Amounts transfered through Matched Savings

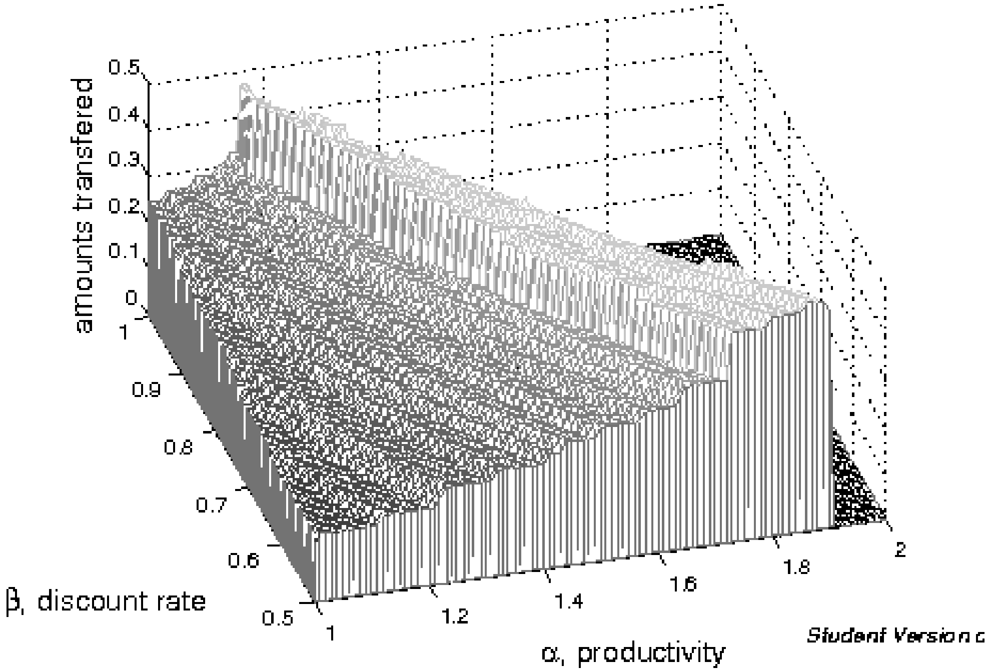

Figure 4.1: Distribution of Formal Savings by Treatment Group

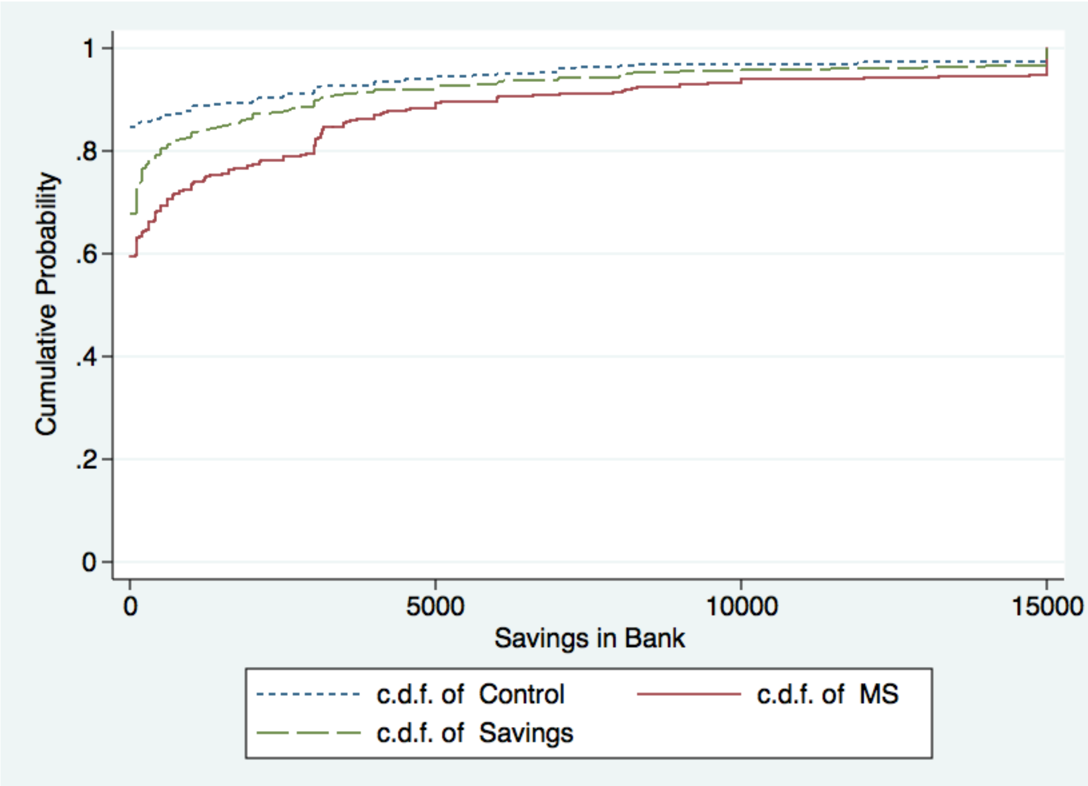

Figure 4.2: Distribution of Savings out of Banking System by Treatment Group

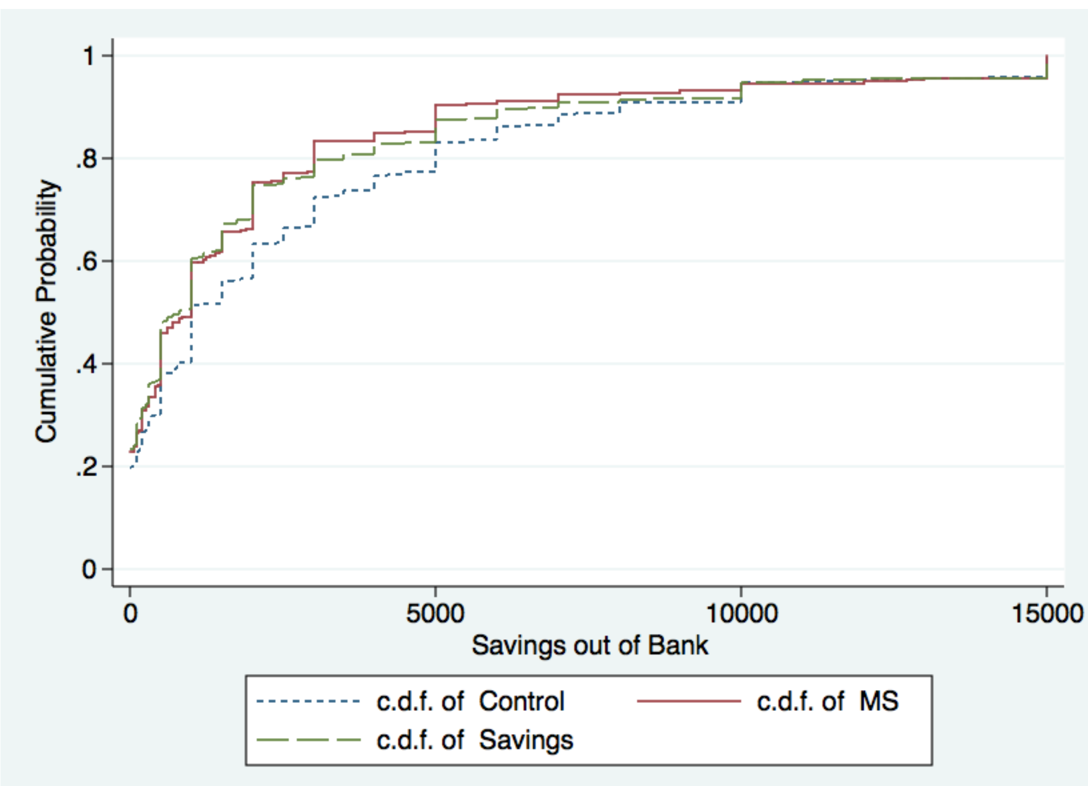

Figure 4.3: Distribution of Food and Monthly Consumption by Treatment Group

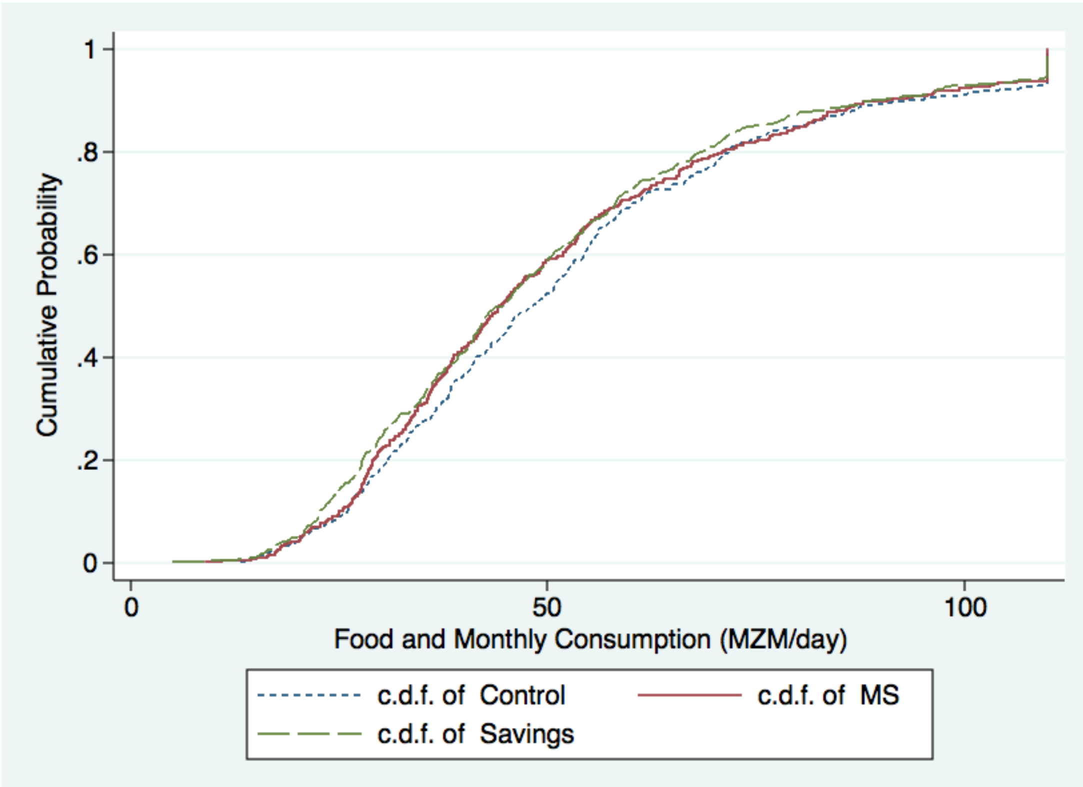

Figure 4.4: Distribution of Value of Consumption Items by Treatment Group

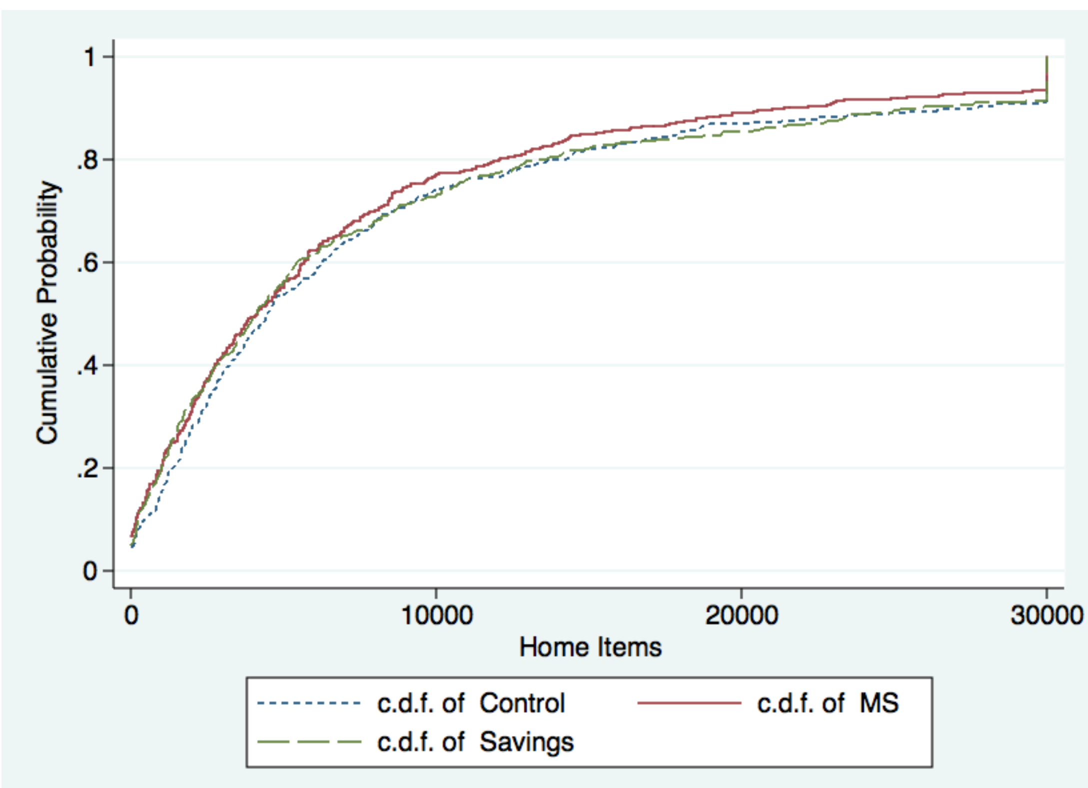

Figure 4.5: Distribution of Value of Savings and Productive Assets by Treatment Group

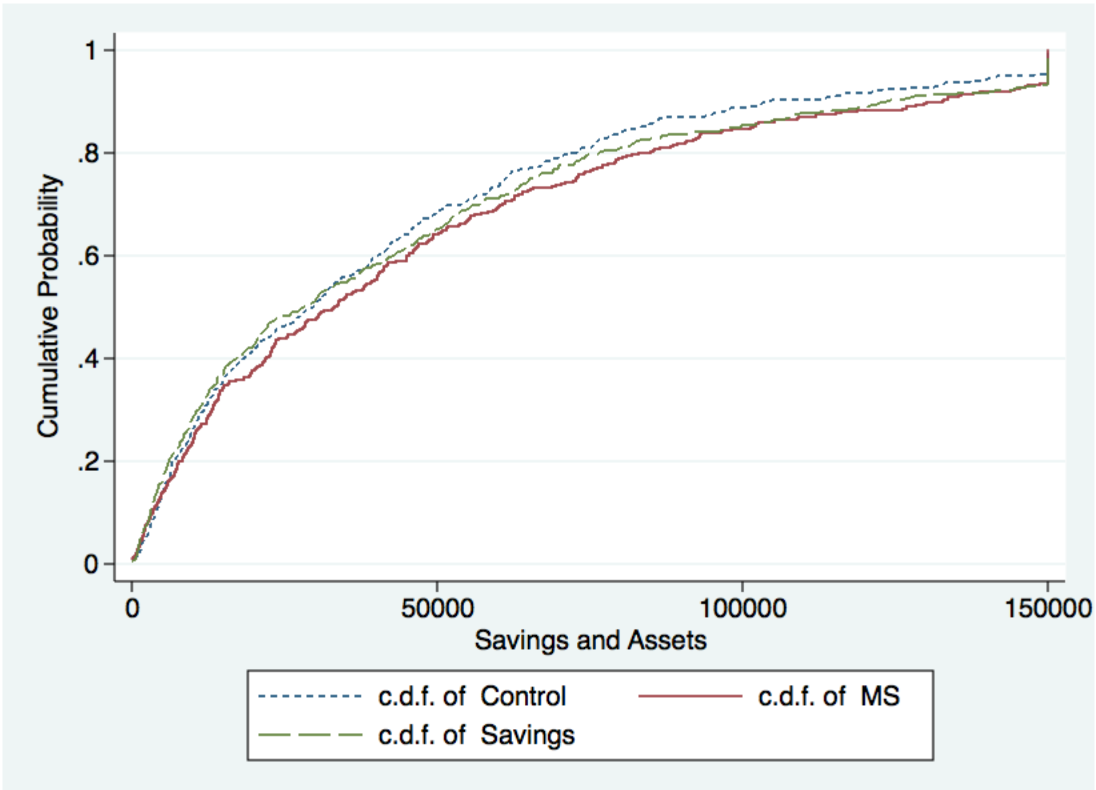

Table 1 Basic Statistics and Verification of Randomization

	Control		Savings		MS		All treatment groups	p-value of Wald test
	No voucher	Voucher	No voucher	Voucher	No voucher	Voucher		
Hh size	7.45	7.82	7.63	7.87	7.67	7.46	**7.65**	0.62
	[2.86]	[3.60]	[3.34]	[3.86]	[3.38]	[3.26]	**[3.41]**	
Hh head educ (yrs)	4.78	4.71	4.78	4.83	4.67	4.42	**4.70**	0.92
	[3.35]	[3.00]	[3.43]	[3.42]	[3.14]	[3.24]	**[3.27]**	
Hh head male (%)	0.85	0.85	0.86	0.82	0.85	0.82	**0.84**	0.76
	[0.36]	[0.36]	[0.35]	[0.38]	[0.35]	[0.38]	**[0.36]**	
Hh head age	45.89	46.34	46.53	46.18	46.43	45.97	**46.22**	0.98
	[14.06]	[13.74]	[14.18]	[13.90]	[13.68]	[13.94]	**[13.90]**	
Hh head literacy (%)	0.79	0.77	0.74	0.77	0.76	0.73	**0.76**	0.64
	[0.41]	[0.42]	[0.44]	[0.42]	[0.43]	[0.45]	**[0.43]**	
Electricity (%)	0.10	0.11	0.13	0.15	0.10	0.08	**0.11**	0.77
	[0.31]	[0.31]	[0.34]	[0.35]	[0.30]	[0.27]	**[0.32]**	
Total area owned (ha)	9.18	7.91	17.13	9.87	9.32	7.62	**10.28**	0.49
	[20.04]	[9.43]	[126.81]	[26.57]	[18.14]	[10.48]	**[55.69]**	
Maize area (ha)	3	3	3.70	3.76	3.78	3.47	**3.57**	0.89
	[3.09]	[3.93]	[3.95]	[4.72]	[3.74]	[3.20]	**[3.84]**	
Maize fertilizer (kg)	29.06	23.28	22.21	26.00	28.55	19.10	**24.77**	0.76
	[83.83]	[59.12]	[95.44]	[66.77]	[167.25]	[64.90]	**[95.68]**	
Maize Production (kg)$_1$	2,776	2,730	3,039	3,011	3,107	2,595	**2,885**	0.5
	[3034]	[3300]	[3728]	[3648]	[3366]	[3159]	**[3395]**	
Savings account (%)	0.13	0.18	0.22	0.2	0.23	0.22	**0.2**	0.12
	[0.34]	[0.39]	[0.41]	[0.40]	[0.42]	[0.41]	**[0.40]**	
Formal Savings (MZN)1	1,487	1,363	1,495	1,574	2,959	1,654	**1,740**	0.60
	[7743]	[6308]	[7009]	[7227]	[10923]	[6446]	**[7742]**	
Informal Savings (MZN)1	3,060	4,083	2,833	2,698	3,286	2,604	**3,073**	0.66
	[6929]	[9930]	[6783]	[6080]	[7130]	[6679]	**[7303]**	
Livestock (MZN)1	31,522	35,152	37,380	37,449	38,606	35,877	**36,014**	0.77
	[41945]	[48445]	[49337]	[50625]	[50008]	[47649]	**[48106]**	
Crop Stock (MZN)1	29,973	33,636	36,024	36,115	37,040	34,657	**34,594**	0.65
	[41048]	[48047]	[48332]	[50382]	[49846]	[47101]	**[47578]**	
Home items (MZN)1	892	1,065	820	811	971	740	**880**	0.30
	[2034]	[2465]	[2200]	[2010]	[2222]	[1863]	**[2136]**	
Food consumption (MZN/day/person)1	47.85	49.10	44.87	47.00	48.10	51.14	**47.90**	0.24
	[25.10]	[29.22]	[24.11]	[28.58]	[26.86]	[31.70]	**[27.66]**	
Monthly expenditures (MZN/day/person)1	8.66	9.25	8.17	7.47	9.31	7.39	**8.35**	0.32
	[11.09]	[12.87]	[9.46]	[8.96]	[12.11]	[9.13]	**[10.65]**	
Yearly expenditures (MZN/day/person)1	3.85	3.81	3.40	3.01	4.13	3.59	**3.61**	0.49
	[5.33]	[5.06]	[5.08]	[3.95]	[6.08]	[4.54]	**[5.03]**	
Total consumption (MZN/day/person)1	60.71	62.66	56.51	57.74	61.32	62.49	**60.07**	0.44
	[34.23]	[38.98]	[31.95]	[35.82]	[35.90]	[37.37]	**[35.70]**	
Number of observations	269	249	278	303	248	246	**1,593**	

Standard deviations in brackets
All statistics are from baseline survey, prior to the assignment to saving and MS treatments

1: the top 1% of the values have been replaced by the 99th percentile, to limit the influence of extreme values.

Table 2: Impact of Savings and Matched Savings Treatments on Household Savings

2A: OLS	**Account at BOM**	**Account**	**Balance at BOM**	**Formal Savings**	**Informal Savings**	**Total savings**
Impact on savings	**2A.1**	**2A.2**	**2A.3**	**2A.4**	**2A.5**	**2A.6**
Savings Treatment	0.14***	0.13***	38	259	-479	-193
	[0.03]	[0.03]	[40]	[303]	[342]	[462]
MS Treatment	0.22***	0.20***	362***	988***	-1,017***	223
	[0.04]	[0.04]	[65]	[328]	[355]	[513]
Observations	1,436	1,435	1,436	1,435	1,350	1,435
R-squared	0.14	0.31	0.09	0.25	0.23	0.28
p-value: savings =MS	0.05	0.03	0.00	0.03	0.15	0.49
2B: OLS Log regression	**2B.1**	**2B.2**	**2B.3**	**2B.4**	**2B.5**	**2B.6**
Savings Treatment	-	-	0.72***	0.78***	-0.49**	-0.02
			[0.20]	[0.26]	[0.22]	[0.16]
MS Treatment			1.51***	1.49***	-0.55**	0.16
			[0.26]	[0.31]	[0.23]	[0.17]
Observations			1,436	1,435	1,350	1,435
R-squared			0.14	0.31	0.08	0.11
p-value: savings =MS			0.004	0.01	0.81	0.29
2C Quantile regression at median	**2C.1**	**2C.2**	**2C.3**	**2C.4**	**2C.5**	**2C.6**
Savings Treatment	-	-	-	-	-367***	-303**
					[104]	[127]
MS Treatment					-310***	3
					[109]	[134]
Observations					1,350	1,435
p-value: savings =MS					0.59	0.02

*** p<0.01, ** p<0.05, * p<0.1

In table 2A and 2B the standard errors in brackets are clustered at the locality level.Regressions include fixed effects for each group of 3 localities at which the randomization was stratified. In regressions 2A.3 to 2A.6, outcome values above 99th percentile have been replaced by the 99th percentile. Columns 2, 4, 5 and 6 control for the lag of the outcome variable.

Total Savings = Savings in Bank + Savings out of Bank

Table 3: Impact of Savings and Matched Savings Treatments on Household Consumption and Assets

3A: OLS	**Food & monthly cons/day**	**Home Items**	**Livestock**	**Crop Stock**	**Assets and Savings**
Impact on savings	**3A.1**	**3A.2**	**3A.3**	**3A.4**	**3A.5**
Savings Treatment	-1.65	-2,066*	-1,087	-471	-594
	[1.79]	[1,068]	[1,217]	[472]	[2,170]
MS Treatment	-1.07	-1,336	625	-380	1,221
	[1.48]	[1,398]	[1,404]	[561]	[2,203]
Observations	1,406	1,435	1,435	1,435	1,435
R-squared	0.33	0.52	0.75	0.15	0.69
p-value: savings =MS	0.72	0.60	0.19	0.86	0.38
3B: OLS Log regression	**3B.1**	**3B.2**	**3B.3**	**3B.4**	**3B.5**
Savings Treatment	-0.04	-0.26**	-0.13	-0.48**	-0.04
	[0.03]	[0.11]	[0.11]	[0.21]	[0.06]
MS Treatment	-0.03	-0.25**	-0.03	-0.40**	-0.08
	[0.02]	[0.12]	[0.13]	[0.20]	[0.08]
Observations	1,406	1,435	1,435	1,435	1,435
R-squared	0.33	0.39	0.47	0.10	0.41
p-value: savings =MS	0.61	0.95	0.43	0.69	0.52
3C Quantile regression at median	**3C.1**	**3C.2**	**3C.3**	**3C.4**	**3C.5**
Savings Treatment	-1.09	-663***	-90	-669**	-997
	[1.64]	[239]	[260]	[331]	[1,053]
MS Treatment	-1.39	-524**	138	-612*	-109
	[1.73]	[253]	[274]	[350]	[1,109]
Observations	1,406	1,435	1,435	1,435	1,435
p-value: savings =MS	0.86	0.57	0.39	0.87	0.41

*** p<0.01, ** p<0.05, * p<0.1

In table 3A and 3B the standard errors in brackets are clustered at the locality level.Regressions include fixed effects for each group of 3 localities at which the randomization was stratified. In table 3A, outcome values above 99th percentile have been replaced by the 99th percentile. All regressions control for the lag of the outcome variable.

Assets and Savings = Total Savings + Livestock + Crop + Jewelry + Sewing Machine

Table 4: Impact of Savings and Matched Savings Treatments on Household Savings, , Conditional on Winning the Agro-input Subsidy

4A: OLS **Impact on savings**	**Account at BOM** **4A.1**	**Account** **4A.2**	**Balance at BOM** **4A.3**	**Formal Savings** **4A.4**	**Informal Savings** **4A.5**	**Total savings** **4A.6**
Savings Treatment	0.13***	0.13***	-5	189	-290	-321
	[0.04]	[0.04]	[46]	[488]	[663]	[918]
MS Treatment	0.21***	0.21***	308***	1,106**	-782	473
	[0.04]	[0.05]	[80]	[524]	[566]	[927]
Voucher	-0.00	-0.02	-58	68	473	84
	[0.02]	[0.03]	[42]	[509]	[735]	[1,017]
Voucher * Savings	0.02	-0.00	86	132	-394	241
	[0.04]	[0.05]	[55]	[743]	[955]	[1,349]
Voucher * MS	0.03	-0.01	109	-234	-481	-496
	[0.04]	[0.05]	[89]	[744]	[833]	[1,363]
Observations	1,436	1,435	1,436	1,435	1,350	1,435
R-squared	0.14	0.31	0.09	0.25	0.23	0.28
4B: OLS **Log regression**	**4B.1**	**4B.2**	**4B.3**	**4B.4**	**4B.5**	**4B.6**
Savings Treatment	-	-	0.64***	0.79**	-0.28	0.13
			[0.22]	[0.34]	[0.29]	[0.21]
MS Treatment			1.38***	1.58***	-0.60*	0.25
			[0.29]	[0.40]	[0.32]	[0.27]
Voucher			-0.07	-0.05	0.12	0.13
			[0.13]	[0.27]	[0.30]	[0.26]
Voucher * Savings			0.15	-0.02	-0.41	-0.29
			[0.21]	[0.39]	[0.40]	[0.36]
Voucher * MS			0.27	-0.18	0.10	-0.18
			[0.29]	[0.41]	[0.44]	[0.45]
Observations			1,436	1,435	1,350	1,435
R-squared			0.14	0.31	0.08	0.11

*** p<0.01, ** p<0.05, * p<0.1

Standard errors in brackets are clustered at the locality level.Regressions include fixed effects for each group of 3 localities at which the randomization was stratified. In regressions 4A.3 to 4A.6, outcome values above 99th percentile have been replaced by the 99th percentile. Columns 2, 4, 5 and 6 control for the lag of the outcome variable.

Total Savings = Savings in Bank + Savings out of Bank

Table 5: Impact of Savings and Matched Savings Treatments on Household Consumption and Assets, Conditional on Winning the Agro-input Subsidy

5A: OLS **Impact on savings**	**Food & monthly cons/day** **5A.1**	**Home Items** **5A.2**	**Livestock** **5A.3**	**Crop Stock** **5A.4**	**Assets and Savings** **5A.5**
Savings Treatment	-3.26	-2,613**	-2,060	-782	-2,895
	[2.34]	[1,315]	[2,117]	[808]	[3,466]
MS Treatment	-1.17	684	2,140	549	2,636
	[2.71]	[1,674]	[2,688]	[873]	[3,860]
Voucher	-1.94	319	1,567	-308	534
	[2.32]	[989]	[2,184]	[760]	[3,618]
Voucher * Savings	3.23	1,038	1,785	616	4,406
	[3.21]	[1,669]	[2,871]	[1,050]	[4,536]
Voucher * MS	0.28	-4,010**	-3,027	-1,834	-2,788
	[4.22]	[1,750]	[3,970]	[1,145]	[5,495]
Observations	1,406	1,435	1,435	1,435	1,435
R-squared	0.33	0.52	0.75	0.15	0.69
5B: OLS **Log regression**	**5B.1**	**5B.2**	**5B.3**	**5B.4**	**5B.5**
Savings Treatment	-0.07**	-0.29*	-0.33*	-0.60**	-0.07
	[0.04]	[0.15]	[0.17]	[0.30]	[0.11]
MS Treatment	-0.03	-0.06	-0.24	-0.20	-0.22*
	[0.04]	[0.17]	[0.17]	[0.29]	[0.13]
Voucher	-0.03	0.04	-0.25	0.02	-0.09
	[0.04]	[0.15]	[0.18]	[0.23]	[0.14]
Voucher * Savings	0.07	0.05	0.39	0.24	0.07
	[0.05]	[0.21]	[0.25]	[0.35]	[0.19]
Voucher * MS	0.00	-0.38*	0.42*	-0.40	0.28
	[0.06]	[0.23]	[0.24]	[0.41]	[0.19]
Observations	1,406	1,435	1,435	1,435	1,435
R-squared	0.33	0.39	0.47	0.10	0.41

*** p<0.01, ** p<0.05, * p<0.1

Standard errors in brackets are clustered at the locality level.Regressions include fixed effects for each group of 3 localities at which the randomization was stratified. In table 5A, outcome values above 99th percentile have been replaced by the 99th percentile. All regressions control for the lag of the outcome variable.

Assets and Savings = Total Savings + Livestock + Crop + Jewelry + Sewing Machine

Table 6: Preliminary Test of Filter Effect based on the Planning Horizon of Beneficiaries

VARIABLES	**6.1 Account at BOM**	**6.2 Account at BOM**	**6.3 Log Savings at BOM**	**6.4 Log Savings at BOM**	**6.5 Match (MZN)**	**6.6 Log Match (MZN)**
Log horizon (t-1)	**0.010***		**0.062***		**3.03**	**0.016**
	[0.005]		**[0.032]**		**[13.285]**	**[0.068]**
Log horizon (t-1) * Control		**0.011***		**0.078***		
		[0.006]		**[0.041]**		
Log horizon (t-1) * Savings		**0.001**		**0.006**		
		[0.009]		**[0.050]**		
Log horizon (t-1) * MS		**0.021***		**0.123**		
		[0.012]		**[0.081]**		
Savings treatment	0.122***	0.166***	0.645***	0.965***		
	[0.033]	[0.059]	[0.196]	[0.366]		
MS treatment	0.211***	0.165**	1.441***	1.244**		
	[0.038]	[0.069]	[0.248]	[0.487]		
Voucher	0.003	0.005	0.016	0.025	27.441	0.094
	[0.018]	[0.019]	[0.116]	[0.118]	[32.235]	[0.228]
Education of hh head (yrs)	-0.002	-0.003	-0.012	-0.013	-0.547	-0.013
	[0.003]	[0.003]	[0.021]	[0.021]	[6.808]	[0.048]
Log assets and savings (t-1)	0.016***	0.016***	0.122***	0.121***	42.630***	0.175**
	[0.004]	[0.004]	[0.029]	[0.029]	[14.856]	[0.077]
Log maize production	0.013	0.013	0.089	0.089	19.957	0.159
	[0.009]	[0.009]	[0.060]	[0.061]	[20.462]	[0.117]
Account at BOM (t-1)	0.126**	0.123**				
	[0.051]	[0.052]				
Log savings at BOM (t-1)			0.049	0.049	3.938	0.037
			[0.050]	[0.051]	[22.438]	[0.116]
Constant	-0.251***	-0.255***	-1.838***	-1.894***	-431.607**	-1.790*
	[0.069]	[0.073]	[0.479]	[0.499]	[179.492]	[0.890]
Observations	1,270	1,270	1,270	1,270	384	384
R-squared	0.153	0.155	0.151	0.152	0.191	0.218

The standard errors in brackets are clustered at the locality level.
*** p<0.01, ** p<0.05, * p<0.1

Appendix 1: Parameters of the simulation

The utility function satisfies Constant Relative Risk Aversion:

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

Parameters of the numerical simulation:

Expression	Explanation of the variable	Values
γ	Output elasticity	0.5
H	Multiplicator of the high technology production function	4
FC	Fixed cost of the high technology	4
σ	$\frac{1}{\sigma}$ = Elasticity of intertemporal substitution	1.5
β	Individual discount rate	{0.5, 0.505, ... , 0.995, 1}
α	Individual productivity	{1. 1.01, ... , 1.99, 2}
k	Wealth kept between two periods without savings account	0.8
k_b	Wealth kept between two periods with savings account	1
M	Share of wealth matched in the first period of MS intervention	50%
w_t	State variable is discretized to compute dynamic programming	{0.13, 0.19, ... , 30.74, 30.8}

Closing the Eyes on a Gloomy Future: Psychological Causes and Economic Consequences

> "*My third maxim was to endeavor always to conquer myself rather than fortune, and change my desires rather than the order of the world*"

Rene Descartes, Discours de la Méthode (1637), III, p. 595 596, Translated by John Veitch 1901

Endogenous time discounting, cognitive dissonance and anticipatory utility

Since Rae (1834:109) stated that what he called the "effective desire of capital accumulation" is the psychological factor that most affects the growth of countries, numerous studies have confirmed the positive correlation between patience (or time discounting) and income. Subsequently, the pioneering work of Strotz [78] and Pollak [67] led to a burgeoning literature on inconsistent time preference and its consequence on long term well-being (e.g. 50, 66 and 7), which inspired interventions such as commitment savings (Ashraf et al. 6, Brune et al. 16) qualified by Loewenstein et al. [56] as "light paternalism". Yet without a deeper understanding of the causes of the reluctance or difficulties for the poor to save, as observed by Duflo and Banerjee [31], interventions may address the symptom rather than the source of the issue, which limits their chances of generating a life change in the economic path of the beneficiaries. Becker and Mulligan [9] are among the rare publications investigating the possibility of the endogenous determination of the time preference, with a model where the individual can invest in a "forward looking capital" in order to build patience, they find that the discount factor is increasing in the initial wealth of the individual.

Another body of the literature looks at aspirations and fatalism (Macours and Vakis 57, Bernard et al. 13,Ray 70,Appadurai 4). Macours and Vakis [57] find that the exogenous participation of community leaders in an asset transfers program increased the recipients' aspirations as well as their investment in human and physical capital. In an experiment in Nicaragua, according to a beneficiary's own words, "Before the program, I just thought about working in order to eat from day to day. Now I think about working in order to move forward through my business". Bernard et al. [13] find evidence of fatalistic beliefs among rural households, meaning that they believe that they have little control over their future. In both cases, aspirations are highly interrelated with the time horizon of the individual and the authors find that aspirations are endogenously determined and matter for long term economic outcomes.

This paper investigates theoretically and empirically the endogenous determination of an individual's time horizon. The time horizon is defined as the extent to which the individual identifies with future selves at any given point in time. The individual will feel some utility from anticipation and plan his expenditures only for periods that are within his time horizon. I also present a version of the model where the time horizon fades away progressively. In this case, the horizon function indicates the extent to which an individual relates to his future self, which is a decreasing function of the time span between the present and a given future period. The horizon function closely relates to the recent psychology literature, which indicates decision making involving future selves is similar to the one involving other individuals [46], and that the *psychological remoteness* determines the level of altruism [82]. As the time span increases between now and a perceived future, the *psychological remoteness* toward this future self increases which reduces the altruism toward this future self, affecting both the planning of consumption and the utility from anticipation. The utility from anticipation worsens the condition of the poor, who faces a dilemma caused by his gloomy prospects and his desire to have a better future. The dilemma causes a cognitive dissonance, which can be lessened by a reduction of the time horizon, which in turn makes the poor more vulnerable in the long turn, generating a behavioral poverty trap.

The predictions of the model are tested over 1,546 rural households in the Manica province of Mozambique. I find that randomly selected recipients of either an agro-input subsidy or a matched savings intervention, reacted to the intervention by increasing their planning horizon by two to three months (an increase of 30 to 50% of the initial time horizon). As predicted, I also find that this effect is economically and statistically more significant for the small farmers than for the large ones. The results highlight that besides its direct economic impact, the interventions also had a substantial behavioral impact. I argue for a more careful look at the behavioral impact of interventions, which can have a multiplier effect and a potentially high influence on long term poverty.

Cognitive dissonance and endogenous time discounting

Since Festinger [35], cognitive dissonance has been one of the most influential theories in social psychology. It was introduced into economics by Hirschman [43] and was first modeled by Akerlof and Dickens [2]. Cognitive dissonance is the feeling of uncomfortable tension which comes from holding conflicting thoughts in the mind at the same time. As a consequence, the individual mind alters his beliefs or preferences in a way that reduces this dissonance. Bramel [15], relates cognitive dissonance with ego-defensive processes, showing that in some situations, an individual can attribute undesirable characteristics to other people in order to preserve his self-esteem. In a well known illustration of this mechanism, two years later Glass [39] found that students who where asked to give electric shocks to victims tend to attribute undesirable characteristics to the victims in order to preserve their self-esteem.

Leibow [52]'s classic ethnographic book is revisited by Montgomery [62] to analyze the cognitive dissonance of the street-corner man. The contradiction between the social values that dictate that a man must financially support his family and inability of the street-corner man to do so, generates a cognitive dissonance, that causes major distress. In Montgomery's model of endogenous altruism, a man receives a positive utility from supporting the members of his family, but a negative utility from the cognitive dissonance, both proportional to his attachment to his family. Hence, through an unconscious process, the street-corner man detaches himself from his family to limit this cognitive dissonance.

Reproducing the reasoning of Montgomery [62] in an intertemporal perspective, the poor face three conflicting thoughts:

1- I am a good and successful person

2- I want to reach decent living conditions in the future[37]

3- I am unable to ensure myself (and my family) a decent future

The three thoughts are conflicting because the inability to reach one's objective is a failure, which questions the first thought. Hence the ego-defensive process of the individual needs to alter either the second or the third statement. A first set of less conflicting thoughts consists in replacing the third statement by:

3- I will work hard to ensure myself (and my family) a decent future

However, when the prospective are very gloomy and the third statement is not achievable or comes at a dissuasive utility cost, then an alternative scenario is to replace the second statement by:

2- I live my life day after day without worrying about the future

Hence the poor can either face anxiety and low self-esteem, or close their eyes on the future, which harms their long term economic development. The quotes from Narayan and Ebrary [65] in the introduction indicate that, at least in some cases, the poor opt for the latest option. This paper provides a model of endogenous time horizon that formalizes this change in attitude toward the future.

Anxiety and the anticipation of poverty

This paper argues that the anxiety from future poverty can be such that individuals may prefer being shortsighted in order to avoid the anxiety even though they are aware of the negative economic consequences of shortsightedness. Narayan and Ebrary [65] asked 20,000 poor people across the developing world about their perception of poverty and found that anxiety represents a large part of the burden, in particular in Africa where, according to the authors,

[37]Notice that the individual's perception of a decent living condition is crucial. Montgomery [62] considers a social norm, this paper provides more discussion on the decency norm in subsection .

the sources of anxiety “are closely related to basic agriculture and survival that depend on the vagaries of nature, rains, droughts”. The book includes many quotes that describe the anxiety of the poor, among which the following ones:

> *Mental health problems—stress, anxiety, depression, lack of self-esteem and suicide—are among the more commonly identified effects of poverty and ill-being by discussion groups. In some African communities, people often describe a mental condition associated with poverty as “madness.”*
>
> *As if land shortage is not bad enough we live a life of tension worrying about the rain: will it rain or not? There is nothing about which we say, “this is for tomorrow.” We live hour to hour. —A woman, Kajima, Ethiopia*
>
> *“These agonizing decisions take their toll. People cope by focusing on one day at a time, becoming indifferent, apathetic or hovering near losing their mind.” A member of the research team in Ghana*
>
> *In Malawi, ukavu means a state of constant deprivation. It is explained that households described in this group lack peace of mind because they are always worried about how to make ends meet. In most ukavu households, couples quarrel and fight a lot because they desire good lifestyles (umoyo uwemi), but they lack the means. “It is not surprising that most men from these households are drunkards because they drink to forget home problems.”*

These quotes mark a distress caused by the inability to reach better economic prospects. The toll of anxiety is omnipresent, yet the most striking feature of these testimonies is the apparently irrational reaction to poverty by living day to day rather than making all possible efforts to plan a long-term exit strategy. The paradox was stressed by Duflo and Banerjee [31] stating that *“one senses a reluctance of poor people to commit themselves psychologically to a project of making more money. Perhaps at some level this avoidance is emotionally wise: thinking about the economic problems of life must make it harder to avoid confronting the sheer inadequacy of the standard of living faced by the extremely poor*”. To the best of my knowledge, this paper is the first attempt to understand and evaluate the cause and consequences of the psychological mechanisms through which gloomy prospects discourage a poor individual from being forward looking.

The idea that future disutility is a source of distress is closely related to utility (or disutility) from anticipation, a concept that goes as far back as Bentham [12]. It was first applied in intertemporal choice by Jevons [48] and his son Jevons [47], and has been formalized by Loewenstein [54][38]. While Jevons [47] assumes that individuals always

[38] For more historical background, Loewenstein and Elster [55] provide an excellent review of the history of the economics of intertemporal choices.

maximize their present utility, which incorporates utility from the anticipation of pleasure or pain, Loewenstein analyzes an agent that maximizes his intertemporal utility, given that the utility at each period incorporates the anticipation of future consumption. Loewenstein's model explains why subjects are willing to pay a substantially higher amount to avoid an electric shock that is delayed than an immediate electric shock.

With an exogenous preference for the present, the inclusion of anticipated utility makes individuals more willing to save. However, if one has the possibility to alter his focus toward the future, then he may close his eyes on the future to avoid the permanent distress of gloomy prospects. Whether the anticipation of future poverty can be such that individuals prefer a more acute, but myopic poverty is an empirical question that is investigated in section () of this paper.

Caplin and Leahy [18] show how anticipatory utility can provide an explanation for many time inconsistencies by analyzing a model that incorporates the anxiety caused by uncertainty into the utility function. They claim that the cost of uncertainty about the future includes not only the loss caused by risk aversion, but also the psychological effect of this uncertainty. They provide an example of its impact on portfolio management, yet one can imagine that the anxiety is likely to be higher when facing a risk of starvation depending on the rainfall.

Getting into the brain

The recent progress in neuroscience brings many insights that help understand and model the human decision making process. Van Veen et al. [83] provide new evidence that support the existence of a cognitive dissonance activity in the brain. The authors asked the participants to claim that the uncomfortable scanner environment was a pleasant experience. They found that cognitive dissonance engages certain regions of the brain, and that the extent to which the regions in question are activated predicts well the participants' change in attitude toward their experience in the scanner. The study directly observes how a contradiction generates a tension in the brain, resulting in a change in preferences in a way that reduces the dissonance.

Neuroscientists also paid a particular interest to time preferences. McClure et al. [59] recorded the neuro-images of subjects who were being asked to select from options that may or may not include immediate gratification. The researchers distinguish a "delta part" of the brain, which includes regions that are related to cognitive functions, from a "beta part" of the brain, which has consistently been implicated in impulsive behavior such as drug addiction. The delta part is activated similarly for all decisions, but the beta part is significantly more active in decisions that involve an immediate gratification. Individuals with more activation of the "delta part" are also more likely to opt for the delayed gratification. Besides this, Jamison and Wegener [46] compare the neural activity during a decision between immediate and delayed gratification to the one during a decision between oneself and others and conclude that "the decision making process involving a tradeoff between our current and future selves is substantially the same as the decision making process involving a tradeoff between ourselves and other individuals". Hence since Glass [39] found that students asked to give electric shocks to victims increased their unfriendliness towards them, the same phenomena may occur between present and future selves. When the pressing needs of the present push a poor individual to "punish" future selves by saving very little money for them, relating less closely to the future selves allows him to reduce the cognitive dissonance.

Besides indicating that the attitude toward future selves is likely to be affected by the individual's economic conditions, these findings from neuroscience corroborate both economic models with a distinction between present and future selves (e.g Laibson [50] and O'Donoghue and Rabin [66]), but also models that incorporate two selves with different preferences at any single point in time. For example Thaler and Shefrin [80] model a farsighted principal who controls the myopic agent through the alteration of his incentives and limitation of his opportunities. More recently Fudenberg and Levine [38] show that this dual self model gives a unified explanation for several time inconsistencies. This paper also presents a dual self model that separates the economic decision from the endogenous determination of time discounting.

A model of cognitive dissonance and endogenous time horizon

This section presents a model where the cognitive dissonance appears in two different ways. First, a utility (or disutility) from the anticipation of consumption is incorporated. Hence when the future consumption is expected to be below a decent living condition, then its anticipation generates the cognitive dissonance which reduces the utility of the individual. Second, the model has two selves. The "outer self" makes the consumption decision, taking his time preference as exogenous. The "inner self" determines the outer self's time time horizon. Although mostly subconscious, the determination of the time horizon is very rational since the inner self maximizes the intertemporal utility of the "whole self" without being biased towards any period. The time horizon is the extent to which the individual identifies with future selves at any given point in time. When a period is out of the individual's time horizon, the individual does not identify with himself at that period, hence he does not plan and save for this future self nor does he feel any utility from anticipation from consumption at periods beyond his time horizon. A long term planning horizon requires the individual to face the potential distress caused by his gloomy economic prospects, which increases the cognitive dissonance. Consequently, even though the inner self is farsighted, she may opt for a low patience in order to reduce the permanent burden of the cognitive dissonance[39]. As shown in this section,

[39]In order to distinguish them, I use the feminine for the inner-self and the masculine for the outer-self.

the process of cognitive dissonance reduction has the side effect of reducing patience and can thus be the cause of a vicious cycle between poverty and myopia. This section first clarifies the introduction of the cognitive dissonance which is negative when consumption falls below a decency norm, and then provides an illustrative example that provides an intuitive grasp of the theoretical model, before getting to the formal model and its conclusions.

Cognitive dissonance and the decency norm

The model incorporates a utility from anticipation, which, like Loewenstein [54] is proportional to the actualized utility to be derived from future consumption. The cognitive dissonance is a source of disutility when a decent living condition will not be achieved in the future. Let z be the "decent" level of consumption, which can be interpreted as a local poverty line. Below z the lack of basic food, shelter, clothes and other needs creates anxiety as a result of anticipation. Above z, resources are used for other goods and services of which the anticipation a savoring[40]. Also let $\bar{u} = u(z)$ with $u(c)$ an increasing and concave utility function derived from immediate consumption. When $c = z$, the utility from anticipation should be null. The utility from anticipation of consumption at period t is proportional to $u(c_2) - \bar{u}$. Hence for a poor individual, the loss in utility from anticipation caused by the cognitive dissonance is proportional to the loss in utility caused by the poverty gap in period t. By normalizing $u(z) = 0$[41] the utility from anticipation is proportional to $u(c_t)$, it is negative when the individual will be poor at time t and positive when he will be above the poverty line. Anchoring the utility function matters in models that give the possibility to experience or not a utility (e.g. Becker and Posner 10), because adding a constant increases the willingness to experience this period.

An Illustrative Example

This illustrative tale provides an intuitive grasp of the theoretical model. Miguel receives a meagre salary of $300 on day one and needs to manage this amount over a period of 30 days, with no other source of income during the month. Miguel equally values every day of the month (no time discounting), has a decreasing marginal utility, and has no utility from anticipation. In a first scenario, Miguel has a planning horizon of 30 days (the entire duration of the game). Hence in the first period, he plans to consume $10 per day, a plan that he manages to follow until the 30th day. In a second scenario, Miguel is myopic and does not project himself farther than 10 days ahead, hence he always makes his consumption plan for the following 10 days. In the first period, Miguel thinks that he has $300 to consume over 10 days and decides that he will consume $30 per day, which he does in day one. However, when Miguel reaches day 2, he realizes that he has $270 to be spent in the following 10 days (his horizon is still

[40]Savoring commonly refers to a positive utility derived from the anticipation of consumption
[41]Hence for a log utility function $z = 1$

10 days, but shifted forward by one day). Hence Miguel's new plan is to consume $27 per day from day 2 to day 12. Once again, in period 3, Miguel will need to adjust his consumption plan, because he is left with $243 for 10 days of consumption, and will thus consume $24.3 on day 3. Only when Miguel reaches period 21 will he be able to establish a consumption plan that he will follow until the end of the month, since he will not be "surprised" by the constant extension of the time horizon.

If Miguel could, at no cost, choose his planning horizon in a way that maximizes his actualized utility, he would opt for the 30 day time horizon given that it allows him to smooth his consumption much better than with a 10 day time horizon. Hence when the determination of the time horizon is free and costless, and in the absence of utility from anticipation, the individual will always opt for the highest possible time horizon.

Now let us introduce the utility from anticipation, and assume that it is negative for any day with a planned daily consumption that falls below the $20 poverty line. In this case, though consumption choices would be different from the scenarios previously described, one can see how it raises a tradeoff in the determination of Miguel's optimal time horizon. With a 30 days time horizon, Miguel will unavoidably face a distress that is caused by his inability to be above the poverty line during the 30 days. By contrast, with a 10 day period, the distress is reduced (at least during the initial phase), first because Miguel does not worry about any consumption beyond his 10 day horizon, and second because the illusion that he can consume all his wealth over 10 days makes him over-estimate his consumption during this period and thus reduces his anxiety related to the consumption within his time horizon. Hence for the poor, this creates a tradeoff between the reduction of psychological distress and a better consumption smoothing. Thus in this situation, the time horizon that maximizes Miguel's intertemporal utility would be lower than 30 days. The following section formalizes this endogenous determination of the time horizon by an "inner self", with a succession of consumption decisions at each period made by a potentially myopic "outer self".

The decision process

The game describes an agent's consumption decision from period 0 to T. It incorporates utility from anticipation and limited endogenous time horizon.

The succession of actions in this game is as follows:

<u>Step 1:</u> The inner self determines the horizon boundary H which is the maximum time horizon. The time horizon of each outer self i is constrained by the most binding element between the horizon bounder H and the end of the game T: $h_i = min(H, T - i)$. When $h_i < T$, the outer self i is myopic, and the consumption plan is consistently updated.

Step 2: The outer self i (starting with $i = 0$) makes the consumption plan $\{c_t^i\}$ that maximizes his (myopic) intertemporal utility function, which incorporates the utility from consumption and its anticipation between period i and $i + h_i$. Only the immediate consumption c_i^i actually occurs in the consumption plan of the outer self i. The rest of the consumption plan of the outer self i, $\{c_t^i\}$ only affects the utility from anticipation at time i.

Step 3: The wealth increases (or decreases) by the difference between the returns from assets and the consumption c_i^i , and continuously, the following outer self repeats step 2) until $i = T$.

The model is solved by backward induction, meaning that the inner self chooses H (step 1) knowing the response function of the outer selves (step 2 and 3). Hence the following subsection first describes the decision process of the outer selves before describing the decision of the inner self.

The Succession of Outer Selves (step 2 and 3)

The outer self i acts as a typical consumer, maximizing his intertemporal utility function, although it adds two additional features. First the utility from anticipation is incorporated and second, the outer self i is myopic when $h_i < T - i$. The outer self i, identifies with his future selves up to the time $i + h_i$ and considers the future selves after time $i + h_i$ to be another person that he is indifferent to [42]. This implies 1) that for the outer self i, only the consumption between i and h_i generates a utility from anticipation, 2) that the outer self i makes a consumption plan, given w_i and $\dot{w}_t = rw_t - c_t$ as if he will only live until time $i + h_i$ hence such that $w_{i+h_i} \geq 0$, and 3) that the consumption plan is consistently updated as time passes and the time horizon $[i, i + h_i]$ shifts forward.

For the outer self i with time horizon h_i, his utility at any given time t is composed of the utility from the instantaneous consumption c_t and anticipation of future consumption c_τ up to time $i + h_i$.

$$v_t^i\,(h_i, \{c_t\}) = e^{-\rho(t-i)}[u(c_t) + \gamma \int_t^{i+h_i} e^{-\rho(\tau-t)}u(c_\tau)d\tau] \tag{0.23}$$

Where v_t^i is the valuation for the outer self i of his utility at time t, which incorporates both $u(c_t)$ the utility derived from c_t the consumption at time t, and from the anticipation of consumption between time t and $i + h_i$ (after t, but within the time horizon of the outer self i). γ is an exogenous parameter that indicates the weight on utility from anticipation and ρ is the time discount factor[43]

[42] A more progressive drop in the identification with future selves is discussed later

[43] Two forms of actualisation appear in the utility from anticipation. $e^{-\rho(\tau-t)}$ indicates the extent to which anticipation of c_τ at time t decreases with the distance between t and τ, because a consumption that is farther away, generates a less intense utility from anticipation. $e^{-\rho(t-i)}$ is simply the actualization at time i of the utility from consumption or its anticipation at time t. Unlike Loewenstein [54], the same time discount rate ρ applies to both forms of discount.

The outer self i maximizes a utility function that incorporates the utility from anticipation:

$$\begin{aligned} \max_{\{c_t\}} U_i\left(\{c_t\}, h_i\right) = \textstyle\int_i^{i+h_i} v_t^i dt = \int_i^{i+h_i} e^{-\rho(t-i)} \left[u(c_t) + \gamma \int_t^{i+h_i} e^{-\rho(\tau - t)} u(c_\tau) d\tau\right] dt \\ s.t.\ w_i = \bar{w_i} \\ \dot{w}_t = r w_t - c_t \\ w_h \geq 0 \end{aligned} \tag{0.24}$$

A continuum of outer selves i solve the maximization problem of equation 0.24 at time i. Let $\left\{c_t^i(h_i, w_i)\right\}$ be the consumption at time t planned by the outer self i that solves the intertemporal maximization problem of equation 0.24, and let $v_t^i(h_i, w_i) = v_t^i\left(h_i, \left\{c_t^i(h_i, w_i)\right\}\right)$. Because the time horizon shifts forward with time, different outer selves (at different points in time i) can have different consumption plans given their horizon h_i and wealth w_i. Each outer self i is only able to decide $\left\{c_i^i(h_i, w_i)\right\}$, the immediate consumption at time i, and the rest of his consumption plan $(\left\{c_t^i(h_i, w_i)\right\}$ for $i < t \leq i + h)$ will generally not occur (unless the consumption plan is unchanged by the following outer selves), yet it matters because it determines the utility from anticipation of future consumption at time i, which enters in $v_i^i(h_i, w_i)$. Hence it is not the actual flow of consumption (the successive c_i^i for $0 \leq i \leq T$) that affects the utility from anticipation, but the anticipated consumption at each point i given time horizon h_i. Hence a poor agent has less anxiety from anticipation if he is myopic because the consumption beyond $i + h_i$ does not generate any utility from anticipation, but also because he naively believes that he will be able to consume all his wealth between i and $i + h_i$ and thus underestimate his poverty during this period.

At any given time i, the utility from consumption $c_i^i(h_i, w_i)$ and from the anticipation of the consumption plan $\left\{c_t^i(h_i, w_i)\right\}$ provide the instantaneous utility:

$$v_i^i(h_i, w_i) = u\left(c_i^i\right) + \gamma \int_i^{i+h_i} e^{-\rho(\tau - i)} u\left(c_\tau^i\right) d\tau \tag{0.25}$$

Continuously, the wealth changes following $\dot{w}_i = r w_i - c_i^i$ and the following agent repeats the same steps, solving again equation 0.24 from which the new consumption and instantaneous utility are obtained. The same process is repeated until $i = T$. Hence once all the outer selves have played, the agent (the whole self) receives the actualized utility:

$$U(H, w_0) = \int_0^T e^{-\rho(i)} v_i^i(h_i, w_i) di \tag{0.26}$$

After substituting equation 0.25:

$$U(H, w_0) = \int_0^T e^{-\rho(i)} \left[u\left(c_i^i\right) + \gamma \int_i^{i+h_i} e^{-\rho(\tau - i)} u\left(c_\tau^i\right) d\tau \right] di \tag{0.27}$$

with c_i^i and c_τ^i so that they solve the maximization problem of each outer self i, described in equation 0.24.

The Inner Self (step 1)

Aware of c_t^i, the response function of the outer selves and of $U(H, w_0)$, the inner self selects the horizon boundary $H \in (0, T]$, which maximizes the agent's intertemporal utility given by equation (0.27) :

$$\max_H U(H, w_0) = \int_0^T e^{-\rho(i)} \left[u\left(c_i^i\right) + \gamma \int_i^{i+h_i} e^{-\rho(\tau - i)} u\left(c_\tau^i\right) d\tau \right] di \tag{0.28}$$

such that $\left\{c_t^i\right\}$ solve the maximization problem of each outer self i, described in equation 0.24 and $h_i = min(H, T - i)$. H represents the maximum time horizon of any outer self i, who has a time horizon equal to the most limiting factor between the horizon boundary H and the end of the remaining time before the end of the game $T - i$. Let $H(w_0) \in (0, T]$ be the solution that maximizes equation 0.28. Notice that the inner self is far sighted in the sense that her objective function is the actualized utility of the whole self during the entire game.

Results

Propositions:

The propositions all assume a log utility function and their proofs are in the appendix.

Proposition 1: $\exists\, \hat{w_0}$ *such that* $H(w_0) < T \ \forall \ w_0 < \hat{w_0}$ *and* $H(w_0) = T \ \forall \ w_0 \geq \hat{w_0}$.

In words, there exists a level of wealth $\hat{w_0}$ such that when the initial wealth falls below $\hat{w_0}$, then the inner self decides to be myopic in the sense that she selects a time horizon H lower than the duration of the game T.

Proposition 2: *For any* $w_0 < \hat{w_0}$ *then* $\frac{dH(w_0)}{dw_0} > 0$

This proposition states that, for any individual with a level of initial wealth below $\hat{w_0}$, the time horizon of the individual is increasing in the initial wealth of the individual.

Proposition 3: *If* $w_0 < \hat{w_0}$ *then* $\frac{\partial \frac{\dot{w}_i}{w_i}}{\partial w_0} > 0$ *when* $i < T - H(w_0)$

Proposition 3 highlights the divergence in the accumulation of assets. Individuals who are initially richer (starting with a higher w_0) will accumulate assets at a pace that is higher than individuals who are initially poorer. This is true as long as $i < T - H(w_0)$; since the duration of the game is finite and the model includes no bequest motive, all individuals will start exhausting their wealth when reaching the end of the game in order to end with $w_T = 0$. Still individuals who are richer initially accumulate and thus generate more wealth during the course of their life.

A generalization of the horizon function

So far I have used a degenerate horizon function: $h(\theta, H) = \begin{cases} 1\, if\, \theta \leq H \\ 0\, if\, \theta > H \end{cases}$. Where $h(\theta, H)$ represents the extent to which the outer-self at any time i identifies with himself at time $t = i + \theta$ The effective time discounting of the outer self at time i is thus given by $\int_i^T e^{-\rho\theta} h(\theta, H) c_t d_t$. Although the degenerate function offers an intuitive grasp of the time horizon, in practice it is likely that the time horizon of an individual drops more gradually. In the appendix, I generalize the same results to any function $h(\theta, H)$ that satisfies $\frac{dh(\theta,H)}{d\theta} \leq 0 \,\forall\, H \in (0, T]$ and $\frac{dh(\theta,H)}{dH} \geq 0 \,\forall\, \theta \in [i, T]$ and $\frac{dh(\theta,H)}{dH} > 0$ for at least some $\theta \in [i, T]$.

The effective time discounting at any given time can thus be divided into two elements. $e^{-\rho\theta}$ is the objective time discount, consistent over time, and $h(\theta, H)$ indicates how much individual i cares about his future self $i + \theta$ which is driven by the extent to which one identifies with his future self. Given that it is unusual for someone to prefer a decreasing consumption path over his life, $h(\theta, H)$ is expected to be the main source of effective time discounting.

Empirical analysis

Context and data

This model predicts that among a relatively poor population, an increase in the initial or expected wealth of an individual should increase his patience. To test this prediction, I use the data from the project "Savings, subsidies, and sustainable food security: A food experiment in Mozambique". This project includes the distribution of randomly assigned vouchers that give rights to a 70% subsidy for a seed and fertilizer package for a half hectare of maize production. The distribution occurred in November-December 2010 and was followed by a survey of 1,593 households in April-May 2011 and 1,436 in the follow-up survey implemented in July-August 2011. The survey includes the question "How much time ahead do you plan your future expenditures?". I name the reply to this question the "horizon" variable. The question is inspired by Ameriks et al. [3], who measured individuals' propensity to plan and find that it has a strong impact on actual savings. Their questions, initially designed to capture the propensity to plan of highly educated Americans, was adapted to rural farmers in Mozambique. I use the horizon variable rather than typical time discounting questions (e.g "Do you prefer receiving x today or x a month from now?") because the latter comprises not only time discounting but also the cost of remembering the debt and the trust that the money will be given a month later which may be accentuated by the low levels of income and education. Additionally, the answer is affected by the change in marginal utility between the time of the survey and one month after the survey. This is particularly problematic in the case of our project, given that farmers who received an agro-input subsidy do expect a larger harvest and thus a lower marginal utility about one month after the survey and would appear to be less patient. Hence, the replies to the typical time discounting questions would not only be noisy, but also biased against people who won the voucher lottery. Because the horizon variable is a new variable (to the extent of my knowledge), I first examine its correlation with other economic variables. Table 1a suggests that individuals who have a savings account, who have already received a formal credit, who used fertilizer for maize production during the previous campaign, or who are more optimistic about their future, all tend to have a higher time horizon than others. Although the causality is unknown, this suggests that the time horizon does have a relationship with key economic decisions.

The impact of receiving an agro-input subsidy on time horizon

The survey occurred before the harvest of 2011, corresponding to the campaign in which the fertilizer was subsidized for those who received a voucher. Hence the farmers who received a voucher experienced an exogenous increase in their economic prospect. The model thus predicts that these farmers should become more forward looking (as measured by the horizon variable).

The following regression provides an unbiased estimate of the intention to treat effect:

$$H_i = \beta_0 + \beta_1 T_i + \epsilon_i \tag{0.29}$$

where H_i is the horizon of individual i, and T_i indicates whether individual i has been randomly selected to be in the treatment group, i.e. to receive a voucher for agro-input subsidy. However, winning the lottery did not always translate to receiving the voucher because the result of the voucher lottery was not perfectly implemented and because farmers who were unable to complete the subsidy declined the voucher. An unbiased estimator of the impact of receiving the voucher on the time horizon can be obtained by an instrumental variable approach, where the first stage regressions is:

$$V_i = \alpha_0 + \alpha_1 T_i + v_i \tag{0.30}$$

where V_i indicates whether the individual i received a voucher according to his own reply to the survey.

$$H_i = \beta_0 + \beta_1 \hat{V}_i + \epsilon_i \tag{0.31}$$

with $\hat{V}_i = \alpha_0 + \alpha_1 T_i$

Table 3 shows the first stage of the IV regressions, which confirms that winning the lottery significantly increased the probability of receiving a voucher. Table 2 presents the regressions 0.29 and 0.31. I find that on average, winning the lottery increased an individual's time horizon by more than a month, from 198 days to 235 days, and increased it by about 13% on average. The effect is significant, and is only somewhat robust to the use of log of horizon instead of horizon. The third column indicates that once controlled for exogeneity bias, receiving a voucher increases the recipient's time horizon by more than three months. The results show that the time horizon of an individual is endogenous, and that it changed rapidly and substantially after receiving an agro-input subsidy.

Differential impact by income groups

The model predicts that the cognitive dissonance process affects relatively poor individuals, hence receiving the voucher should only increase the time horizon of individuals who were below a certain income threshold. The survey includes the maize production of the agricultural campaign preceding the treatment (2009-2010). Since maize is the major crop produced in the region, I use this data to separate the farmers into two groups, depending on whether they harvested more or less than two tons[44] of maize in 2010. In Table 3, I find that receiving a voucher significantly increases the time horizon of the small maize producer by 113 days, while it increases it by 62 days for a large maize producer, and the latter effect is not significantly different from zero.

Impact of the Matched Savings intervention

A second intervention has been implemented starting in April 2011, following the baseline survey. One third of the sample was encouraged to open savings accounts through easier access and financial education, and another third was offered a matched savings on top of the same encouragement to save. The Matched Savings offers a bonus of 50% of the savings left in the account between harvest and the time to purchase fertilizer (from August 1st to October 31st) . The financial intervention aims at helping farmers develop a habit of savings in order to carry forward the benefits of the agro-input subsidy from year to year. Table 6 compares the savings group to the matched savings group, allowing us to isolate the impact on the planning horizon of a subsidy that encourages savings. It excludes the control group since a financial training, which may have influenced the beneficiaries' time horizon, has been provided to both savings and matched savings groups but not to the control group. Table 5 shows that being selected to receive the matched savings increased the time horizon of the small maize producer by 29% on average, but it did not have any significant impact on the large maize producer, which provides further evidence

[44]While the threshold is arbitrary, generally a household that produces more than two tons of maize is above self sufficiency

that confirm the predictions from proposition one and two.

Interpretation and Competing Explanations

The agro-input subsidy of a value equivalent to USD 65 increased the time horizon of small maize producers by more than a half, and the Matched Savings with an average transfer of USD 34 increased the time horizon of the small producers by 29% on average. These interventions were designed to leverage the amounts transferred, by requiring contributions from the farmers, and orienting it toward productive and forward looking activities. It is unlikely that a simple cash transfer of the same amount would have the same impact on the beneficiaries' planning horizon. Yet the results show that two different interventions which improve the economic prospects of the poor led to a substantial increase in his time horizon. Future research should address whether the change of attitude towards the future is permanent or temporary and how the planning horizon translates into economic decisions such as consumption, savings and investment. Although drawn from a very different context (a relatively highly educated population in the US), the results of 3 indicate that planning is essential for savings and capital accumulation.

This section explores the competing explanations to the empirical evidence of this paper. Are there other channels through which the randomized interventions can have affected the planning horizon of the beneficiaries? One can think that the beneficiary may have been waiting for the future resource coming from harvest or the Matched Savings. Although not in complete contradiction with the argument that the improvement in economic prospects increases peoples planning horizon, it would cast doubts on the occurrence of a cognitive dissonance and behavioral change described in the theoretical model. The first survey (used to analyze of the impact of the voucher) was implemented two to three months before harvest, and the second survey (used to analyze the impact of the Matched Savings) preceded the payment of Matched Savings by three months. If farmers were simply waiting for the harvest or the Matched Savings payment, then it would result in a concentration of planning horizons around the three month period. Figure 1a and 1b show the distribution of the planning horizon for the treated group and group of control in the two interventions. It shows no particular concentration of planning horizon around the three month period for the treated group, but rather an increase in time horizon well spread among the different initial levels of planning horizon. Hence the results are not driven by individuals waiting for their payment.

It is sometimes argued that one can be "too poor to save". Despite its absence of theoretical foundations, this recurring argument is intuitively appealing and thus deserves some discussion. Does the scarcity of money explain the shortsightedness of the poor? In fact these elements are included in the theoretical model presented in this paper. In the model, for a poor, the cost of being forward looking is the disutility generated by the distress of projecting oneself into a gloomy future. It is easy to show that in this version of the model, when this cost is replaced by a fixed cost of extending the time horizon, then the optimal time horizon is independent of the individual's income[45]. The reason is that, on one side more wealth increases the benefits of planning by having more money to allocate properly across time, but on the other side, wealth reduces the marginal utility of consumption, and thus the marginal cost of a misallocation across time. With a log utility function, the two effects exactly compensate each other. In fact, which effect prevails depends on the relative risk aversion. With a relative risk aversion below one, wealth increases the optimal planning, but with a relative risk aversion higher than one, then the poor individual will have a higher planning horizon and a higher savings rates than the rich. Intuitively no matter how little money a household has, it still needs planning and saving as much as wealthier households (in relative proportions) because poverty sharpens the cost of neglecting the future. Hence without the reluctance to project oneself into a gloomy future (analytically represented by inclusion of the utility from anticipation), poverty in itself does not explain a reduction of the planning horizon. Furthermore the theoretical model of this paper provides a better explanation for the observation that the increase in the time horizon resulting from an increase in economic prospects even before the current wealth of the beneficiary is affected.

A more substantially grounded criticism is that the consumption basket of the poor includes a higher proportion of visceral goods, for which it is more difficult to behave rationally. Banerjee and Mullainathan [7] separate regular goods from temptation goods (such as fatty or sugar ones) which are assumed to provide an immediate gratification, but are not valued by the long run self, and act as a temptation tax. They find that if this temptation tax rate is higher among the poor, then poor individuals may react to the prospect of future income growth by saving more, generating a behavioral poverty trap similar to the one of this paper, for different reasons. Yet the implications of their model on an individual's time horizon are not straightforward. In the absence of utility from anticipation, the tax may reduce savings, but not necessarily the optimal time horizon. Without a combination of the two models, which goes beyond the scope of this paper, it is not clear how the temptation goods would provide an alternative explanation for the empirical findings of this paper. However, it is not excluded that the two factors reinforce each other in the creation of a behavioral poverty trap.

Conclusion and policy implications

Effective development interventions require structural changes that will outlive the interventions. Poverty dynamics show that patience is a fundamental factor for an individual to be willing to make the investments and sacrifices required to transit toward a higher equilibrium. Changing financial practices is key to allowing the poor to make

[45] results available upon request

long-term plans and conceive exit strategies. This paper looks at the psychological causes behind myopic economic behaviors. It offers new ways to approach the issue, with empirical evidence of the endogeneity of the individual's planning horizon, and shows how it can result in a behavioral poverty trap that can occur even in the absence of non-convex production technologies. Using a field experiment among Mozambican maize producers, I find that benefitting from an agro-input subsidy or a savings subsidy increased significantly the planning time horizon of the small maize producers, but had no significant impact on large producers, as predicted by the theoretical model.

An economic intervention can affect the asset accumulation both through its direct economic impact, but also through a behavioral impact, which embraces all changes in preference, aspirations or attitudes that will in turn affect the economic decisions. Depending on the intervention, the behavioral impact may be positive (e.g. increase in patience or aspirations), or negative (e.g increase in passivity or moral hazard). Improving the design of future projects requires a deep understanding of both the economic and behavioral impact of the interventions. While most of the literature has evaluated the economic impact, little is known about the behavioral effects. This paper shows that it is possible for typical impact evaluations to include an evaluation of changes in behavioral components that are expected to be affected by the treatments. It contributes to a better knowledge of the mechanisms that affect economic aspirations, which aims at encouraging the design of projects that enhance this effect. The type of intervention that deserve further intention include Individual Development Accounts, which offer a match at a fixed rate on savings towards the acquisition of assets. This approach stimulates long term investment both directly and indirectly because it generates "less fear and more hope" (73)

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Figure 1a

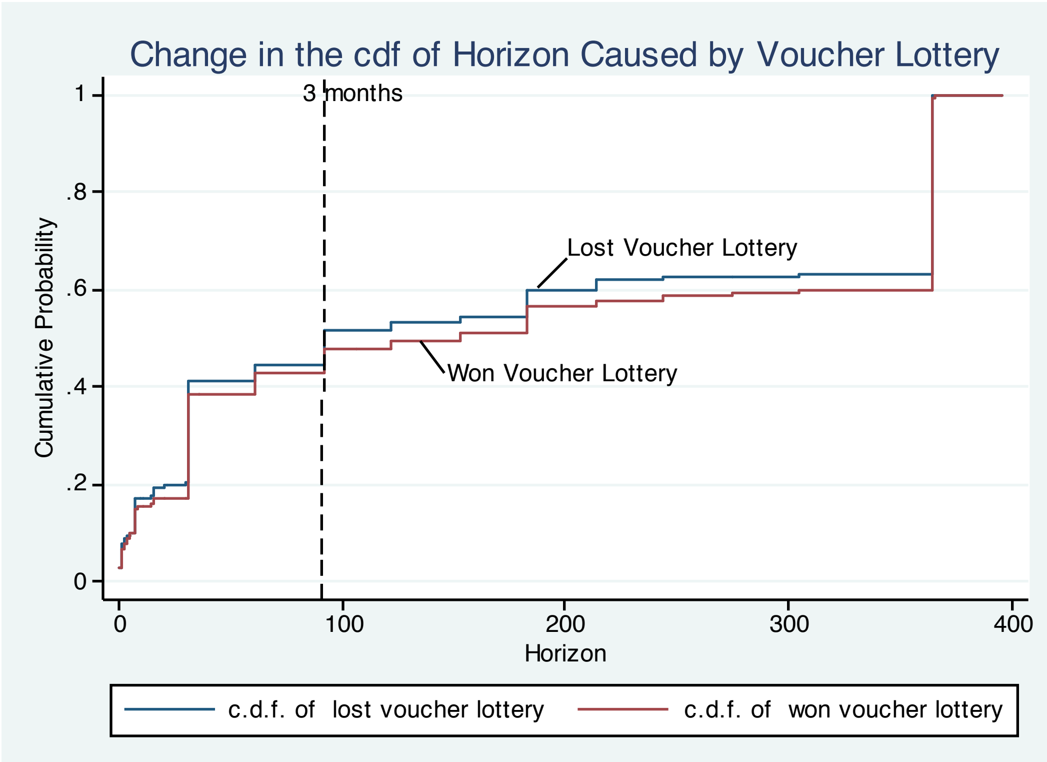

Figure 1b

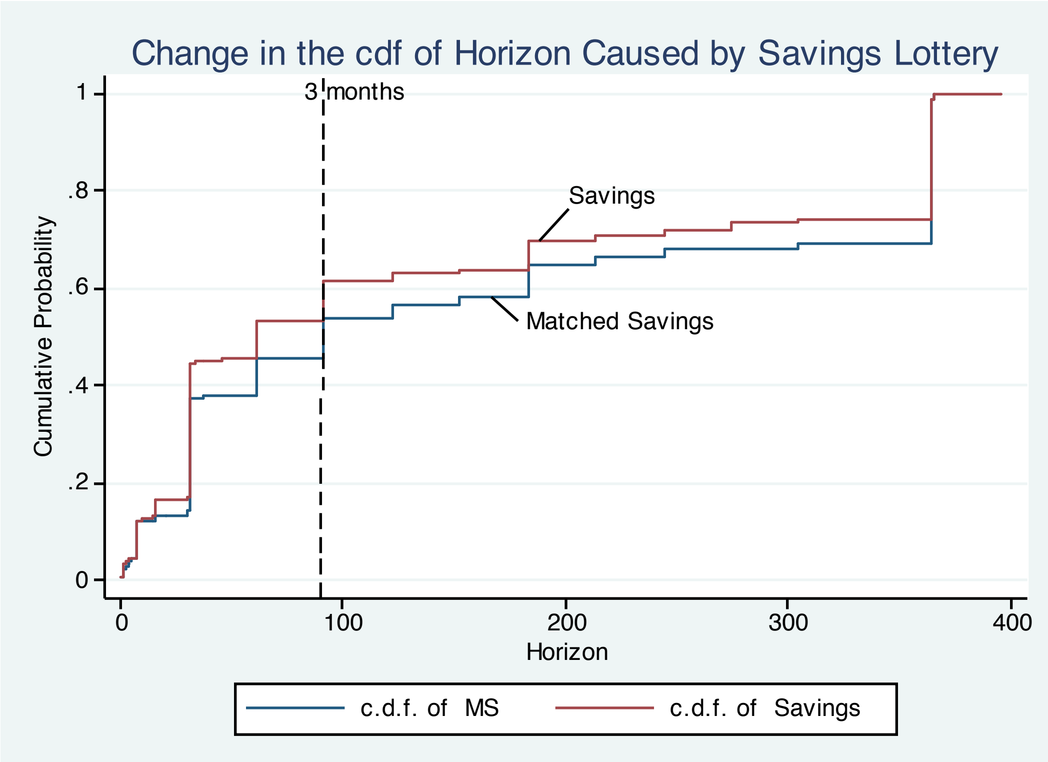
Change in the cdf of Horizon Caused by Savings Lottery
Cumulative Probability
Horizon
3 months
Savings
Matched Savings
0
.2
.4
.6
.8
1
0
100
200
300
400
c.d.f. of MS
c.d.f. of Savings

Table 1a: Basic Statistics

	Mean	SD	Min	10th pctile	Median	90th pctile	Max
Total land size (ha)	9.0	18.2	0	1.56	5	15	400
hh size	7.7	3.4	1	4	7	12	27
hh head educ (yrs)	4.6	3.2	0	0	4	9	13
urea (kg/ha)	6.2	20.7	0	0	0	20	300
npk (kg/ha)	5.5	18.2	0	0	0	16.7	185.2
maize prod (kg)	2362	4669	0	360	1250	4980	126120
Yield (kg/ha)	847	849	0	180	583	1869	5934
Area maize (ha)	3.59	3.8	0.21	0.72	583	7	50
Horizon (days)	217.34	299.9	0	7	152.5	365	5840

Table 1b: Horizon mean and median conditional on economic variables:

		#	Horizon median	Horizon mean	p-val equality of means
Has a savings account	No	1237	122	207	0.009***
	Yes	304	365	256	
Used Fertilizer in 2009-2010 campaign	No	1251	152	215	0.294
	Yes	284	183	235	
Cultivated more than 2ha of maize in 2009-2010 campaign	No	709	122	206	0.127
	Yes	814	183	229	
Has already received a credit from a formal bank	No	1355	152	207	0.022**
	Yes	188	244	211	
Believes that the hh's economic situation will be better in 5 years	No	163	61	159	0.008***
	Yes	1368	183	225	

Table 2: Impact of the voucher subsidy program on time horizon

	ITT - OLS		ATE - IV	
	Horizon	Log horizon	Horizon	Log horizon
Won lottery	37.46**	0.13		
	[0.019]	[0.143]		
Voucher(s) received			97.51**	0.34
			[0.020]	[0.141]
Constant	198.51***	4.36***	365.00***	5.90***
	[0.000]	[0.000]	[0.000]	[0.000]
Observations	1,546	1,546	1,546	1,546
R-squared	0.085	0.077	0.072	0.086

Regressions include village fixed effects
Robust pval in brackets, *** p<0.01, ** p<0.05, * p<0.1

Table 3: Impact of the voucher subsidy program on time horizon by income groups

	Small maize producer (< 2 tons)				Large maize producer (>= 2 tons)			
	ITT - OLS		ATE - IV		ITT - OLS		ATE - IV	
	Horizon	Log horizon	Horizon	Log horizon	Horizon	Log horizon	Horizon	Log horizon
Won lottery	46.25***	0.22**			22.58	0.07		
	[0.005]	[0.047]			[0.523]	[0.697]		
Voucher(s) received			113.95***	0.54**			62.59	0.18
			[0.007]	[0.046]			[0.522]	[0.697]
Constant	174.76***	4.23***	-220.91***	1.00*	247.02***	4.58***	-55.59	1.90***
	[0.000]	[0.000]	[0.009]	[0.066]	[0.000]	[0.000]	[0.569]	[0.000]
Observations	993	993	993	993	503	503	503	503
R-squared	0.080	0.090	0.037	0.097	0.189	0.206	0.197	0.212

Regressions include village fixed effects
Robust pval in brackets, *** p<0.01, ** p<0.05, * p<0.1

Table 4: First stage for IV regressions (receiving a voucher is the explained variable)

	All	Small maize producers	Large maize producers
Won lottery	0.38***	0.41***	0.36***
	[0.000]	[0.000]	[0.000]
Constant	0.12***	0.08***	0.20***
	[0.000]	[0.000]	[0.000]
Observations	1,546	993	503
R-squared	0.215	0.227	0.300

Regressions include village fixed effects
Robust pval in brackets, *** p<0.01, ** p<0.05, * p<0.1

Table 5: Impact of the matched savings on time horizon (compared to treatment group with same encouragement to save but no matched savings)

	All		Small maize producers		Large maize producers	
	Horizon	Loghorizon	Horizon	Loghorizon	Horizon	Loghorizon
Matched Savings	22.27	0.12	55.47*	0.29**	-27.61	-0.07
	[0.243]	[0.179]	[0.093]	[0.012]	[0.253]	[0.649]
Constant	161.39***	4.29***	137.90***	4.17***	199.83***	4.45***
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
Observations	961	961	605	605	320	320
R-squared	0.045	0.047	0.079	0.064	0.165	0.168

Standard errors are clustered at the locality level (level of randomization)
Regressions include fixed effects at the stratification (groups of 3 localities by proximity)
pval in brackets, *** p<0.01, ** p<0.05, * p<0.1

Appendix

Assuming a log utility function, I solve the model, before providing a proof of the propositions.

The outer self's maximization

I solve the outer self's problem to obtain $\left\{c_t^i(h_i, w_i)\right\}$:

The following equation is equivalent to equation 0.24 (under the same constraints):

$$\max_{\{c_t\}} U_i\left(\{c_t\}, h_i\right) = \int_i^{i+h_i} \underbrace{e^{-\rho(t-i)}u(c_t)}_{Utility\ from\ consumption} + \underbrace{\gamma \int_i^t e^{-\rho(\tau-i)}e^{-\rho(t-\tau)}d\tau u(c_t)}_{Utility\ from\ anticipation}\ dt \tag{0.32}$$

Equation 0.24 is the sum of the utility (from instantaneous consumption and anticipation) at every point in time between i and h_i while equation 0.32 is the sum of the utility (from instantaneous consumption and anticipation) derived from every consumption c_t between i and h_i, which is equivalent.

Since $\gamma \int_i^t e^{-\rho(t-i)}u(c_t)dt = \gamma(t-i)e^{-\rho(t-i)}u(c_t)$; I simplify equation 0.32 to obtain:

$$\max_{\{c_t\}} U_i\left(\{c_t\}, h_i\right) = \int_i^{i+h_i} e^{-\rho(t-i)}(1+\gamma(t-i))u(c_t)dt \tag{0.33}$$

The marginal utility of increasing consumption at any time t, is given by the derivative with respect to c_t: $e^{-\rho(t-i)}(1+\gamma(t-i))u'(c_t)$

Given the interest rate r, the cost of consuming one unit at time t is: e^{rt}

At the optimum the marginal utility derived from one monetary unit dedicated to consumption must be the same for every period:

$$\frac{e^{-\rho(s-i)}(1+\gamma(s-i))u'(c_s)}{e^{r(s-i)}} = \frac{e^{-\rho(t-i)}(1+\gamma(t-i))u'(c_t)}{e^{r(t-i)}}\ \forall\ s,t \in [i, i+h_i] \tag{0.34}$$

I use a log utility function and simplify to obtain:

$$\frac{e^{(r-\rho)(s-i)}(1+\gamma(s-i))}{c_s} = \frac{e^{(r-\rho)(t-i)}(1+\gamma(t-i))}{c_t}\ \forall\ s,t \in [i, i+h_i] \tag{0.35}$$

I introduce the budget constraint: $\int_i^{i+h_i} e^{r(t-i)} c_t dt = w_i$, and obtain:

$$c_t^i(h_i, w_i) = w_i \frac{e^{(r-\rho)(t-i)}(1+\gamma(t-i))}{\int_i^{i+h_i} e^{-\rho(s-i)}(1+\gamma(s-i))ds} \tag{0.36}$$

Hence the utility from anticipation at time i from horizon h_i and consumption plan $\{c_t^i\}$ is given by:

$$UA_i\left(\{c_t^i\}, h_i\right) = \gamma \frac{\int_i^{i+h_i} e^{-\rho(t-i)}(t-i)u(c_t^i(h_i, w_i))dt}{\int_i^{i+h_i} e^{-\rho(s-i)}(1+\gamma(s-i))ds} \tag{0.37}$$

With $\{c_t^i(h_i, w_i)\}$ defined in equation 0.36

When $i \leq T-H$, the immediate consumption that will actually happen at time i is thus:

$$c_i^i(h_i, w_i) = \frac{w_i}{\int_i^{i+h_i} e^{-\rho(s-i)}(1+\gamma(s-i))ds} \ \forall i \leq T-H \tag{0.38}$$

From $\dot{w}_t = rw_t - c_t$, we obtain :

$$\frac{\dot{c_i^i}}{c_i^i} = \frac{\dot{w}_i}{w_i} = r - \frac{1}{\int_i^{i+h_i} e^{-\rho(s-i)}(1+\gamma(s-i))ds} \ \forall i \leq T-H \tag{0.39}$$

After solving for the integral and defining w_i with relation to w_0 I obtain:

$$w_i(w_0, H) = w_0 \ e^{i(r - \frac{\rho^2}{\gamma+\rho-e^{-H\rho}(\gamma+\rho+H\rho)})} \ \forall i \leq T-H \tag{0.40}$$

I substitute equation 0.40 into equations 0.36 and 0.38 to obtain the following ones:

$$c_t^i(h_i, w_i) = w_0 \ e^{i(r - \frac{\rho^2}{\gamma+\rho-e^{-H\rho}(\gamma+\rho+H\rho)})} \ \frac{e^{(r-\rho)(t-i)}(1+\gamma(t-i))}{\int_i^{i+h_i} e^{-\rho(s-i)}(1+\gamma(s-i))ds} \ \forall 0 \leq i \leq t \leq T-H \tag{0.41}$$

When $H \geq T-i$, $c_t^t(h_t, w_t) = c_t^i(h_i, w_i)$ for $t > i$ which means that the consumption plan of the outer self are consistent and defined by equation 0.36 once $i = T-H$ is reached.

$$c_t^i(h_i, w_i) = w_{T-H} \frac{e^{(r-\rho)(t-T+H)}(1+\gamma(t-T+H))}{\int_i^{i+h_i} e^{-\rho(s-T+H)}(1+\gamma(s-T+H))ds} \ \forall T-H \leq i \leq t \leq T \tag{0.42}$$

After plugging $w_i(w_0, H)$ from equation 0.40:

$$c_t^i(h_i, w_i) = w_0 \ e^{(T-H)(r - \frac{\rho^2}{\gamma+\rho-e^{-H\rho}(\gamma+\rho+H\rho)})} \ \frac{e^{(r-\rho)(t-T+H)}(1+\gamma(t-T+H))}{\int_i^{i+h_i} e^{-\rho(s-T+H)}(1+\gamma(s-T+H))ds} \ \forall T-H \leq i \leq t \leq T \tag{0.43}$$

The inner self's maximization

I take the derivative of $U(H, w_0)$ with respect to H to obtain the first order condition:

$$\frac{dU(H,w_0)}{dH} = \int_0^T e^{-\rho i} u'\left(c_i^i\right) \frac{dc_i^i}{dH} + \gamma \int_i^{i+h_i} e^{-\rho \tau} u'\left(c_\tau^i\right) \frac{dc_\tau^i}{dH} d\tau di + \gamma \int_0^{T-H} e^{-\rho H} u(c_{i+H}^i) di = 0 \tag{0.44}$$

Equations 0.41 and 0.43 show that c_t^i is proportional to w_0 $\forall\, 0 \leq i \leq t \leq T$, which is not surprising given the use of a log utility function. It implies that $u'\left(c_t^i\right) \frac{dc_t^i}{dH}$ is independent from w_0. Hence in equation 0.44, only the third element is a function of w_0, which I derive to find that:

$$\frac{d^2U(H(w_0),w_0)}{dH\,\partial w_0} = \gamma \int_0^{T-H} e^{-\rho H} u'(c_{i+H}^i) \frac{\partial c_{i+H}^i}{dw_0} di > 0 \tag{0.45}$$

Proof of propositions 1 and 2:

The solution $H(w_0)$ to the inner self's problem is either an interior solution, satisfying $H(w_0) < T$ and the first and second order conditions $\frac{dU(H,w_0)}{dH} = 0$ and $\frac{d^2U(H,w_0)}{dH^2} < 0$; or it is a corner solution satisfying $H(w_0) = T$ and $\frac{dU(T,w_0)}{dH} > 0$[46].

In the case of an interior solution, an implicit differentiation of $\frac{dU(H,w_0)}{dH} = 0$ give us:

$$\frac{d^2U(H,w_0)}{dH^2}\frac{dH(w_0)}{dw_0} + \frac{\partial \frac{dU(H,w_0)}{dH}}{\partial w_0} = 0 \tag{0.46}$$

Hence:

$$\frac{dH(w_0)}{dw_0} = -\frac{\frac{d^2U(H(w_0),w_0)}{dH\,\partial w_0}}{\frac{d^2U(H,w_0)}{dH^2}} > 0 \tag{0.47}$$

Since $\frac{d^2U(H,w_0)}{dH\,dw_0} > 0$, $\exists$ a unique $\hat{w_0}$ such that $\frac{dU(T,\hat{w_0})}{dH} = 0$. When $w_0 > \hat{w_0}$ then $\frac{dU(T,\hat{w_0})}{dH} > 0$ and $H(w_0) = T$ is the solution. When $\frac{dU(T,\hat{w_0})}{dH} < 0$, then since

From equation 0.45, we know that $\frac{dU(H=T,w_0)}{dH}$ is strictly increasing in w_0. Hence there exists only one $\hat{w_0}$ such that $\frac{dU(H=T,w_0)}{dH} = 0$. When $w_0 > \hat{w_0}$ then $\frac{dU(T,\hat{w_0})}{dH} > 0$ and $H(w_0) = T$ is the solution. When $w_{0<}\hat{w_0}$, then equation 0.47 tells us that $H(w_0) < H(\hat{w_0}) = T$ and that $H(w_0)$ is an increasing function. I have proved proposition 1 and 2.

[46] These are sufficient conditions for a local maximum and necessary conditions for a global maximum

Proof of propositions 3:

According to equation 0.39 then: $\frac{\dot{w}_i}{w_i} = r - \frac{1}{\int_i^{i+h_i} e^{-\rho(s-i)}(1+\gamma(s-i))ds}$ $\forall i \leq T-H$

When $i \leq T-H$, then $\int_i^{i+h_i} e^{-\rho(s-i)}(1+\gamma(s-i))ds$ is an increasing function of H (since $h_i = min(H, T-i)$, hence $\frac{\dot{w}_i}{w_i}$ is also strictly increasing in H.

Proof of propositions with a general smooth horizon function:

The maximization problem of the inner self becomes the following:

$$\max_H U(H, w_0) = \int_0^T e^{-\rho(i)} \left[u\left(c_i^i\right) + \gamma \int_i^T h(\tau - i, H)\, e^{-\rho(\tau - i)} u\left(c_\tau^i\right) d\tau \right] \tag{0.48}$$

The new first order condition with respect to H is as follows:

$$\frac{dU(H, w_0)}{dH} = \int_0^T e^{-\rho i} u'\left(c_i^i\right) \frac{dc_i^i}{dH} + \gamma \int_i^T h(\tau - i, H)\, e^{-\rho\tau} u'\left(c_\tau^i\right) \frac{dc_\tau^i}{dH} d\tau di + \gamma \int_0^T \int_i^T e^{-\rho(\tau-i)} h(\tau - i, H)\, u\left(c_\tau^i\right) d\tau\, di\ = 0 \tag{0.49}$$

For the same reason as in the previous case, c_τ^i and c_τ^i are proportional to income and thus only the third element of equation 0.49 remains to be derived to obtain the derivative of the first order condition with respect to w_0.

$$\frac{d^2U(H(w_0), w_0)}{dH\, \partial w_0} = \gamma \int_0^T \int_i^T \frac{dh(\tau - i, H)}{dH} e^{-\rho(\tau - i)} h(\tau - i, H)\, u\left(c_\tau^i\right) d\tau\, di\ > 0 \tag{0.50}$$

The remaining part of the proof of the propositions is unchanged.