Upgrade or Migrate: The Consequences of Fertilizer Subsidies on Household Labor Allocation

Binta Zahra Diop*

May 23, 2024

Abstract

Rural development programs often focus on increasing agricultural investment, but farmers can also benefit from investing in outmigration. I explore how input subsidies (ISPs) allow farmers to adjust their choices across both agricultural investments and outmigration. First, I use the staggered rollout of a large-scale Zambian ISP to estimate a difference-in-differences. I find that the ISP resulted in significant increases in both rates of fertilizer use (upgrades, +79%) and outmigration (+12%). Outmigration increases because farmers are funding expensive migration in two ways: (i) by selling the ISP vouchers in resale markets in the short run (+11%) and (ii) through the income effect of their increased in-farm productivity in the medium run (+14%). Second, I estimate a choice model and find that resale markets are key to efficiently re-allocate fertilizer among farmers within villages. Furthermore, the current program has three times higher upgrade rates than a revenue-neutral cash transfer program, but outmigration rates are similar. Hence, the ISP incorporating resale markets can be a better suited policy to achieve the dual objectives of enhanced food production and poverty alleviation.

Keywords: Internal migration, Input Subsidies, Agricultural Productivity, Sorting

JEL Codes: R23, O33, Q12

---

*Stanford University, bzdiop@stanford.edu

I am grateful to D. Gollin, M. J. Williams, I. Ruiz, J. Labonne, A. Teytelboym, C. McIntosh, H. Low, M. Morten, R. Hanna, G. Ulyssea, G. Schinaia, V. Pouliquen, Y. Zylberberg, V. Khandelwal, N. Moneke, S. Hou, L. Milsom, C. Pougué-Biyong, H. Zillessen, S. Mukherjee, J. Pougué-Biyong, S. Altmann, P. Hadunka, and N. Ridpath, C. Woodruff, C. Udry, M. Ngom, I. Rasooly, V. Wiedemann, S. Quinn, T. S. Jayne, A. B. Diop, Aysatou Ndiaye, L. Falcao Bergquist, M. Kasy, R. Meango, C. Imbert, A. Ouss, T. Qhotsokoane, J. Gignoux, R. Lajaaj, and conference participants at the NBER SI, STEG annual conference, NEUDC, PacDev, MWIEDC, EEA, ICDE, UEA, IFS, ES Africa meeting, AMIE and invited seminars participants.

Introduction

In the Global South, rural areas are home to 80% of households living in extreme poverty.[1] Most of these households rely on farming as their primary source of income and lack the resources to migrate to areas with better economic prospects, or to upgrade their agricultural technology (Gollin et al., 2014; Lagakos et al., 2023; Burke et al., 2019).[2] Efforts to reduce poverty place a strong emphasis on enhancing agricultural productivity rather than encouraging migration. African states—and indeed many governments in all parts of the world—invest in rural areas by subsidizing inputs such as fertilizer, pesticides, and seeds, or by offering cash transfers. Although widespread, these input subsidy programs (ISPs) are controversial among economists, as they could lead to an overuse of subsidized inputs or hinder productive outmigration, trapping individuals in rural areas. Despite an annual global investment of $540 billion into ISPs worldwide,[3] our understanding of their indirect impact on farmers' migration remains limited.

This paper uses a large-scale Zambian ISP to understand the effects of antipoverty programs on two of farmers' most productive investments: agricultural upgrading, proxied by the adoption of fertilizer, and migration. The Zambian ISP is a cash only program that provides smallholder farmers who are part of cooperatives with a limited number of vouchers at a 50% rebate to purchase fertilizer inputs.[4] In the early 2000s, the Zambian ISP represented 45% of the country's discretionary antipoverty spending and about 20% of its agricultural budget. Designed as an industrial policy, the ISP aims to alleviate poverty in rural areas and increase food production in the country. Yet, the ISP could have far-reaching effects due to its implications for farmers' income. In particular, this income effect could influence farmers' migration decisions if it outweighs the higher opportunity cost of outmigration for ISP recipients. I explore the effects of the ISP on upgrading and migration in two parts.

In the first part of the paper, I use a representative panel of Zambian smallholder farmers between 2000 and 2008 to estimate a difference-in-differences

[1] From Castañeda et al. (2018), using 89 countries from the Global South.

[2] See Harasty et al. (2015); Ghatak (2015); Balboni et al. (2022) for poverty traps.

[3] See Food and Agriculture Organization of the United Nations (2021) for world estimates.

[4] 8% of Zambia's smallholder farmers received the ISP in 2003/2004 vs. 85% today. Programs similar to the Zambian ISP are currently in place in a dozen African countries making this analysis of relevance well beyond Zambia's borders (Jayne et al., 2018).

and test whether the ISP altered upgrading and migration decisions in ISP-villages. To estimate the difference-in-differences, I exploit variations in the roll-out of the policy over time and across space.

I find that the Zambian ISP had large direct impacts on agricultural productivity and indirect impacts on migration into and from the areas that received the ISP. In particular, the introduction of the subsidy increased the share of households using fertilizer in treated areas by 79% over the first four years of the ISP. These increases in agricultural technology inputs led to a 15% increase in yields. Surprisingly, the subsidy also increased the share of households divesting from agriculture, with an additional 4 percentage points (12%) of households sending members to migrate over those years. I find suggestive evidence of increased inmigration into areas that received the subsidy, as indicated by an increased probability of hosting members in the household as a proxy for inmigration.

The effects of the ISP result from various decisions that households make regarding their labor allocation choices over time. In the short run, ISP recipients can (i) sell some (or all) of their vouchers to fund expenses such as migration, which aligns with the behavior of 45% of households in the sample, and (ii) farmers who did not receive the ISP can still purchase ISP-branded fertilizer through resale markets. Indeed, 3 to 5% of households that did not receive the subsidy in treated areas report using ISP-branded fertilizer—likely a lower bound of resale buyers as these resales are prohibited—suggesting that some farmers employ a mixed strategy by selling part of their vouchers. For households that invest all their vouchers in agriculture (i.e., choice i), earnings can increase in the medium run as they become more productive, thereby financing migration in later periods. Notably, 51% of households that received the subsidy and upgraded their technology without any migrants in 2004 had out-migrants by 2008, indicating a medium term effect of investing in agricultural technology upgrades.

The direct effects of the ISP on agricultural upgrading and its indirect effects on migration are consistent with four mechanisms, which I validate empirically. First, there is strong evidence of the existence of resale markets for vouchers enabling ISP recipients to cash out their vouchers and migrate in the short run. Alternatively, farmers who choose to double down in agriculture, can purchase more fertilizer in these resale markets. Second, migration occurs both in the short and medium term, implying that the ISP alleviates credit constraints for some farmers, leading to short term migration, and boosts productivity for other farmers who can fund migration in the medium term after reaping the returns of their increased productivity. Specifically, 11% of households send outmigrants in the short run (short run extensive outmigration), consistent with a relaxation of the credit constraint, while 14% do within four years of the introduction of the subsidy (long run extensive outmigration), consistent with structural change (Lewis et al., 1954; Gollin, 2014; Mazur and Tetenyi, 2022). The third mechanism shows that farmers who receive the vouchers, and not their neighbors in treated areas, are the ones who migrate at higher rates. Unlike cash transfer programs that inflate prices and price-out non-recipients (Cunha et al., 2019), this ISP with resale lowered fertilizer prices for ISP recipients and reduced the direct cost of upgrading for farmers in treated villages via resale markets. A suggestive fourth mechanism is through specialization into upgrading and migration occurring both within and across households, with the comparatively more productive farmers staying (and hosting inmigrants), and the farmers with the highest returns to migration outmigrating.

In the second part of the paper, I generalize the results from the natural experiment using a choice model that I estimate and compare with alternative policy counterfactuals. The model is static and incorporates key mechanisms highlighted in the first part of the paper. Specifically, I introduce resale markets that allow farmers to sell subsidized fertilizer to other farmers at a market price (World Bank, 2021; Mason and Jayne, 2013). These resale markets are often formally prohibited, but governments typically lack the ability to enforce the prohibition. I endogenize the fertilizer resale price and account for the quantity of fertilizer made available through the ISP. Additionally, incorporate a binding credit constraint that prevents farmers from borrowing against their migration income. Despite being static, the model captures outmigration occurring through increased productivity in the medium run, or as a result of the relaxation of their credit constraint occurring immediately. This proposition mimics my reduced-form findings, which are consistent with farmers migrating either as they become more productive over time or by monetizing their ISP vouchers in resale markets to relax their credit constraint. These implications of the model arise from the fact that farmers cannot borrow against future migration income but can use their agricultural surplus to fund migration. In this model, farmers with a binding credit constraint can use resale markets to generate enough liquidity to fund migration. In contrast, farmers who are most credit constrained may be better off funding their migration by first investing in improving the agricultural technology (by upgrading) and using the realized surplus in the medium run to migrate.

I use maximum likelihood estimation to compare the effects of the current subsidy program with resale markets to three revenue-neutral counterfactual policies and find that, due to documented frictions, the ISP with resale may be a preferred policy to increase both food production and income. The first counterfactual policy enforces the prohibition of resale markets, leading to fewer households sending outmigrants (-4.71%) and substantially lower propensity to upgrade (-64.54%) due to the inability to sell a portion of the vouchers. The second counterfactual policy provides cash to the 8% of households originally targeted by the subsidy, resulting in lower upgrade rates (-70.87%) and lower outmigration rates (-5.32%). The third counterfactual policy is an untargeted cash transfer given to all farmers in treated areas, which decreases extensive outmigration by -5.32% but has a large negative impact on upgrades (-79.87%) compared to the current ISP.

Assessing the overall welfare implications of these policies in an environment with market failures and externalities is complex. A back-of-the-envelope calculation suggests that the median and mean farming revenues are similar for the current ISP and the targeted cash transfer program. Migration rates are statistically the same across counterfactual policies, but the current ISP with resale yields higher in-farm production. This result highlights the trade-off a planner faces between choosing the ISP with resale markets to increase available food for all Zambians and a cash transfer program that leads to a small shift in income for treated villages.

In the model, the ISP with resale markets offers advantages over alternative counterfactuals through four channels. First, the increased availability of fertilizer due to the ISP leads to a reduction in fertilizer prices for all farmers in the treated villages, which is an advantage over the cash transfer counterfactuals.footnoteIn fact, Cunha et al. (2019) show an increase in prices as a result of a cash transfer. Second, like cash transfers, the existence of resale markets for vouchers provides liquidity to ISP recipients, relaxing their credit constraints and allowing them to make optimal choices. Third, the ability to split vouchers among multiple farmers within a village creates a snowball effect through resale markets, providing an advantage over the ISP without resale. Finally, the ISP's impacts extend to the medium run, as the increased availability of fertilizer increases farm productivity for upgraders, resulting in an income effect that further influences households' migration decisions.footnoteIn the model, I only consider agriculture and migration as options for farmers; however, in reality, cash could be invested in productive activities such as business creation, which I do not capture in this estimation.

This paper contributes to three strands of literature. First, I contribute to a large literature that explores drivers of migration and show that even when targeting agricultural upgrades, ISPs can have large impacts on migration. I show that migration occurs as farmers use the ISP to fund migration in two ways: in the short run through fertilizer resale markets or in the medium run by generating surplus from using the subsidized inputs on their farms. Previous studies tested the presence of either productivity-induced or liquidity-induced migration, making it difficult to distinguish between short term credit drivers of migration (Bazzi, 2017; Angelucci, 2015; Gazeaud et al., 2023; Cai, 2020) and long term improvements in technology that fund migration (Bustos et al., 2016; Gollin et al., 2014; Ngai and Pissarides, 2007; Lewis et al., 1954). I quantify the relevance of these two channels first with the natural experiment, decomposing short term and medium term migration, and then by shutting down different channels in the structural estimation of counterfactuals. I show that although structural change is important in explaining migration, credit constraints are nevertheless binding for many farmers.

Second, I contribute to the literature on anti-poverty programs in poor countries. Particularly, I build on a literature on rural markets and model explicitly well-documented market frictions in these areas. I consider a set of market frictions—fixed costs—that lead the ISP to affect migration and upgrade margins at higher rates than previously found (Jayne et al., 2018; Schmitz et al., 1997; Carter et al., 2021). The structural estimates indicate that unconditional cash transfers may not be as efficient in achieving specific policy objectives such as increasing in agricultural productivity because they do not address the costs associated with upgrading. In contrast, the ISP with resale markets can efficiently reallocate transfers by sorting beneficiaries based on their constraints. In the early stages of Zambia's ISP, the large transfer of fertilizer was documented as being too large for smaller landholders, leading to a snowball effect where one transfer could benefit multiple farmers when recipients sold a portion of their transfer. Despite previously documented inefficiencies of the ISP (Jayne and Rashid, 2013; Xu et al., 2009), I show that only the ISP with resale markets leads to efficiency gains and to combined increases in both upgrading and migration at levels higher than cash transfer programs.

Finally, I add important insights to a booming literature in public economics documenting the importance of adjustment markets that mitigate undesirable aspects of policies. In this paper, I document how an industrial, place-based policy, which in partial equilibrium could lead unproductive farmers to remain trapped in agriculture, can result in more migration out of these areas. This phenomenon occurs when resale markets allow farmers to turn an ISP into cash to fund expensive migration. Essentially, farmers convert a voucher program (the ISP) into a convex combination of a cash transfer program for those who cash out on resale markets and an in-kind transfer to those who do not. This finding is in line with work by Banerjee et al. (2023) and Aker (2017), who show that when cash transfer or in-kind transfer programs are not designed to meet recipients' needs, they use rotating savings and credit associations (ROSCAs) and tradable goods to obtain the amount of cash and goods they need. I further find that resale market mechanisms enable farmers with comparatively higher returns in non-agricultural activities to sell their subsidized vouchers to those with comparatively higher returns in fertilizer-intensive agriculture, thereby generating income to fund their migration. Resellers use private information unavailable to the central planner to sell their vouchers. Previous studies show that these resale markets are important and emerge in settings where beneficiary types are unobservable to the planner and when efficiency improvements are possible by reallocating transfers (Giné et al., 2022; Ravallion, 2021; Gadenne et al., 2021). In the baseline scenario, the ISP can be interpreted as a small cash transfer to prospective migrants and a substantial in-kind transfer to those with a comparative advantage in upgrading in the short run.

The remainder of the paper proceeds as follows: Section 2 presents the Zambian context, the data, and the empirical strategy for the natural experiment. In Section 3, I present the direct effects of the ISP on upgrading and the indirect effects on migration using the natural experiment. Section 4 discusses potential mechanisms that generate these results. Section 5 generalizes these findings with a selection model. In Section 6, I estimate the choice model, compare the current ISP with resale markets to other antipoverty policies, discuss optimal policies, and conclude.

2 Context, data, and natural experiment

In this section, I describe the relevant institutional details of the Zambian agricultural system, the data I use in the paper, and the estimation strategy for the natural experiment.

2.1 Data, productivity dispersion and outside options

Data

I use a panel of households in rural Zambia from the Zambian Central Statistical Office and the Zambia Food Security Research Project at Michigan State University. This panel comprises four waves: the 1999/2000 agricultural season's Post-Harvest Survey (PHS), which serves as the baseline for this study. The survey is representative of rural households in Zambia. To this baseline survey, I add the linked first supplemental survey to the 1999/2000 PHS conducted in the 2000/2001 agricultural season, the Second Supplemental Survey to the 1999/2000 PHS conducted in the 2003/2004 agricultural season, and the Third Supplemental Survey conducted in the 2007/2008 agricultural season. The PHS is a nationwide representative survey of small and medium landholders with three levels of sampling (Xu et al., 2009). Appendix A.2 details the variable construction and the sampling frame.

Typically, there is only one standard enumeration area (SEA) in a village, except for seven villages with two SEAs each (out of 273). In what follows, I refer to these SEAs as villages.

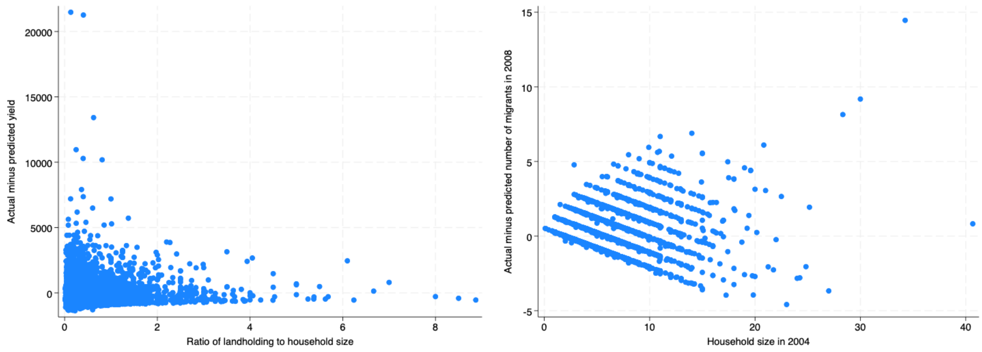
Productivity dispersion at baseline and outside options

In the early 2000s, smallholder farmers in Zambia made up 72% of all farmers in the country (Ritchie and Roser, 2020). These smallholder farmers represent the majority of households living in extreme poverty. Despite all being involved in agriculture, their productivities vary vastly within the sector. The left panel of

Figure 1 plots the difference between the linear projection of yields from Equation 1 (which regresses yields on landholdings and labor inputs) and the actual yields against the ratio of landholding to household size. If individuals with similar household sizes and landholdings are equally productive, their yields should be similar and the difference between their predicted and realized yields (y-axis of the left panel of Figure 1) should not be large. Instead, we observe substantial variations on the y-axis, and those variations exists across all ratios of landholding to household size (x-axis).

$$Yields_{2000,i} = \alpha + \beta_1 land_{2000,i} + \beta_2 HHsize_{2000,i} + \epsilon_i \tag{1}$$

$$Migrants_{2008,i} = \alpha + \beta_1 land_{2008,i} + \beta_2 HHsize_{2004,i} + \epsilon_i \tag{2}$$



(a) Dispersion in yields
1999-2000 season cross section

(b) Dispersion in the number of migrants
2007/2008 season cross section

Figure 1: Dispersion of outcomes for farming households

Notes: The left panel of Figure 1 plots the difference between the linear projection of yields from Equation 1 (which regresses yields on landholdings and labor inputs) and the actual yields against the ratio of landholding to household size. the right panel of Figure 1 plots the difference between the actual number of migrants per household and the linear projection from Equation 2 (which regresses the number of migrants on landholding and household size.

This large dispersion in outcomes for farmers highlights potential gains from reallocating inputs (labor and land) for the least productive farmers, which could be facilitated by some farmers migrating away.

The 2008 cross-section shows that a larger proportion of farmers divest from agriculture and invest in migration. Indeed, the right panel of Figure 1 illustrates the difference between the actual number of migrants per household and the linear projection from Equation 2 (which regresses the number of migrants on landholding and household size—analogous to Equation 1). The figure shows that by the end of the panel, many households have divested from agriculture to some extent.

In this paper, I examine the effect of the ISP on both decisions to upgrade agricultural technologies and to migrate. I focus on migration because it represents the extreme case of divestment from agriculture and is easier to measure than the intensification of non-agricultural rural activities. Although agriculture and food security are the main goals of the subsidy, I use the ISP as an exogenous variation in liquidity in the short run and agricultural productivity in the long run, to understand how households' labor allocation decisions change because of the subsidy.

2.2 The Zambian fertilizer input subsidy program

In 2001, much like many African countries, the Zambian agricultural sector contributed 16% to the country's GDP; at the time, the sector employed about 72% of the Zambian labor force with remarkably low productivity (Ritchie and Roser, 2020). In response to low fertilizer take-up, the Zambian government along with a dozen other African countries, pledged to increase the use of fertilizer and set up farmers' cooperatives (Jayne et al., 2018).

In the 2002/2003 agricultural season, Zambia launched the Fertilizer Support Program (FSP).[5] The FSP is a cash-only program, offering 50% rebate vouchers on the price of fertilizer inputs (later increased to 60% then 76% starting in the 2010/2011 season). In the 2003/2004 agricultural season, the FSP provided $2\times$200kg of fertilizer to each recipient farmer; in the following years, the amount of fertilizer provided was halved, making the 2004 transfer substantially larger in value than the subsequent transfers.

Area selection: In 2003/2004, the ISP reached 8% of smallholder farmers and has since expanded to cover around 85% of them. Importantly, the program did not target specific geographic areas, which has been a subject of criticism within the ISP (Resnick et al., 2016). Despite this lack of geographic targeting, areas with ISP recipients had higher initial rates of fertilizer use. There were instances of political clientelism observed within the program; Mason et al. (2013) report

[5]The FSP was later renamed Farmer Input Support program (FISP) and replaced a much smaller Fertilizer Credit Program

that areas that received the fertilizer had a higher probability of being areas that voted for the incumbent in prior elections. I use these findings of political clientelism to test the robustness of the empirical strategy in Appendix A.6.1.

Farmer selection: The program targets smallholder farmers with landholdings ranging from 1 to 5 hectares. Recipients had to be part of farmer cooperatives, which required paying a small cooperative fee. As a result, farmers who received the subsidy tended to be wealthier than those who did not (World Bank, 2010). The median pecuniary value of the subsidy was US$100.

Timing of the program: The ISP started in the agricultural 2002/2003 season but was relatively small in its first year. The panel contains observations in the agricultural years 1999/2000, 2000/2001, 2003/2004, and 2007/2008. In the 2003/2004 and 2007/2008 agricultural seasons, I can identify the treatment status of households, i.e. whether they received the ISP based on respondents' recall in the 2003/2004 and 2007/2008 agricultural seasons, respectively. Once introduced in a village, the program tends to remain, making it likely that any village receiving the subsidy between the years 2003/2004 and 2006/2007 continues receiving it in the 2007/2008 season. Out of the 78 villages that received the ISP in 2004, 33 (42%) continued receiving the subsidy in 2008, and 55 villages received the ISP in 2008 for the first time.[6] Although there are only two data points after the introduction of the subsidy, for the survey years 2003/2004 and 2007/2008, I observe whether households received the subsidy in the previous year (i.e. 2002/2003 and 2006/2007, respectively). In practice, the dataset only misses treatment status in the agricultural seasons 2004/2005 and 2005/2006.

2.3 Empirical strategy: a DID across villages

I use the gradual roll-out of the subsidy by the Zambian government to estimate the causal change in behavior across upgrading and migration outcomes for households that received the subsidy in 2004. Notably, some areas received the subsidy in 2004, others by 2008, and some never received the subsidy during the study period.

To leverage the staggered roll-out of the subsidy and use Callaway and Sant'Anna (2021)'s estimation strategy. This approach allows me to construct four different treatment status groups, which then allows me to estimate the

[6]For more details on the breakdown of treatment, see Table 6 in the Appendix.

policy's impact on upgrades, yields, and migration. I estimate the pre-trend using the panel 1999/2000 and 2000/2001 years, and check for pre-trends using repeated cross sections in the years 1995 through 1999, see Figure 3.

A village is considered treated if at least one household in the village receives the subsidy, thus the difference-in-differences estimates measure an intent-to-treat (ITT) effect and are a lower bound of the actual treatment-on-the-treated effect.

Households can decide whether to upgrade their agricultural technology and start using fertilizer (binary decision) and the amount of fertilizer to use (continuous decision) which can impact their yields. When making migration decisions, households can alter five margins: it can decide whether to have imigrants or outmigrants (extensive margins), it can decide on the number of inmigrants or outmigrants (intensive margin), and whether to relocate the household (*en masse*).

3 Results of the natural experiment: effects of the ISP on upgrading and migration

In this section I present the resulting change in agricultural upgrade and migration decisions induced by the ISP. First, I show the causal and direct impacts of the ISP on agriculture-specific outcomes, in line with prior research on subsidies for agricultural upgrade Carter et al. (2021). Second, I show important and novel indirect causal effects of the ISP on household migration decisions.

3.1 Results: direct effects on upgrading

The subsidy program designed to increase the adoption of fertilizer, indeed improved agricultural outcomes. Figure 2 shows the difference-in-differences results on agricultural technology upgrades (fertilizer use), member inflow (labor in farms), and maize yields in villages that received the subsidy in 2004.[7]

Agricultural upgrades in villages that received the subsidy increased by an aggregate 79%. This effect is a composite of a short term effect (observed in 2004 for households that received the ISP in 2004) and a medium term effect

[7] For pretrend, Figure 2 shows the trend between 1999/2000 and 2000/2001, further checks are shown in Figure 3.

effect (observed in 2008 for households that received the ISP in 2004) of the subsidy on upgrade. In the short run, upgrades improved by 1 percentage point, implying a 5% increase in the likelihood that a household upgrades to an upgraded technology (see Figure 2). Within four years of the introduction of the ISP, the upgrade rate further increased by 23 percentage point (71%), indicating a medium term snowball effect of the subsidy, which targets 20% of farmers within treated areas. This increase in the likelihood of upgrading is coupled with a 57 kg increase in the quantity of fertilizer used by farmers. As a result of this increase in inputs, maize yields for treated farmers increased by 249kg per hectare (15%). Using a macroeconomic framework, Mazur and Tetenyi (2022) have found a 26% in yields due to the introduction of a fertilizer ISP in 10 African countries.

Finally, I find that the input subsidy also increased the likelihood that households host inmigrants, proxied by the household hosting additional adult members to assist with activities. When labor markets are not fully functioning, this inmigration margin can be a way to increase labor supply (Singh et al., 1986). Panel 1 of Figure 2 shows that the ISP increases the propensity for a household to host any additional member (extensive margin) by a statistically meaningful 3 percentage points in the short run and by the same 3 in the medium run. However, the number of inmigrants is very small compared to the number of total outmigrants over the study period.

Who are the upgraders (descriptives): Households that upgraded in 2004, are on average wealthier than both those that never upgraded or upgraded by 2008. Upgraders who remain upgraders through 2008 are substantially wealthier at baseline, more educated, larger, and hold more land. They are also the most likely to have outmigrants by 2008 and have larger household sizes. These households are less likely to be women-headed and more likely to send members out for migration in 2008. More details are available in Table 13 of the Appendix.

I have shown that the ISP had direct effects on the outcomes it was designed to alter: increasing the probability of farmers upgrading their agricultural technology by using fertilizer by 79% (intent-to-treat), and thus increasing their yields for the target crop, maize, by 15% (intent-to-treat). Next, I explore the indirect effects of the subsidy on migration.

3.2 Results: indirect effects on migration

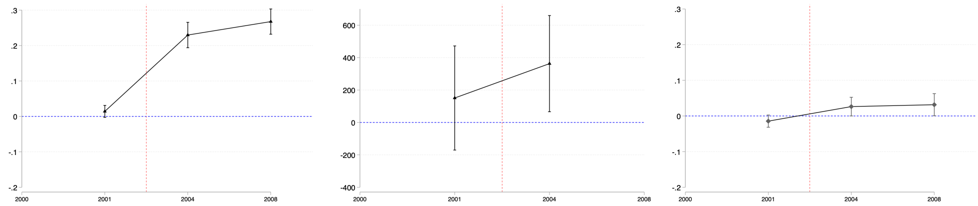
In this section, I present the results on the indirect effects of the ISP on household propensity to re-llocate, individual propensity to migrate, and the number of outmigrants. I show that the input subsidy decreased households' likelihood of a household migrating *en masse* (i.e. a household entirely rellocating) but increased both the extensive and intensive margins of indiviudal outmigration.

I find that individuals are more likely to outmigrate in areas that receive the subsidy primarily to join relatives or for income generating activities, rather than for marriage purposes. This finding implies that the ISP triggered a diversification of income sources for households in treated villages leading to a divestment from agriculture. The probability that a household has at least one outmigrant increases by 4 percentage points (12%) across years (intent-to-treat; see Panel 2 of Figure 2). This increase in the extensive margin of individual migration is coupled with an increase in the intensive margin of individual outmigration, with an increase of .08 in the number of individuals per household who outmigrate across all households in treated villages. Panel 3 of Figure 2 plots these findings.

I find that households are less likely to migrate *en masse*, which is consistent with the increased opportunity cost of migrating with the new place-based transfer that is the ISP for farmers. These households' best response is to stay, and thus households' propensity to move (intent-to-treat) dropped by -3 percentage points (-19%, see Figure 2).

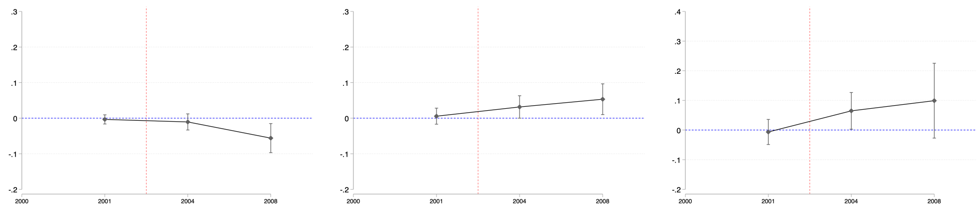
Who are the migrants (descriptives): Outmigrants in 2004 are on average from households that are more educated, larger, and have more agricultural input endowments than households migrating in 2008. These characteristics are consistent with households facing fewer liquidity and credit constraints to fund expensive migration in 2004. These differences are consistent with households with outmigrants in 2004 being less credit-constrained than those migrating in 2008. Households with migrants in 2008 used the extra years to generate income to fund migration. In Section A.3 of the appendix, I show averages for a range of variables for groups of households with outmigrants leaving in 2004 and outmigrants leaving in 2008, as well as households with inmigrants. I show these averages at baseline (in 2001) and at endline (in 2008). More details are

Panel 1: Direct effects on upgrading: difference-in-differences results



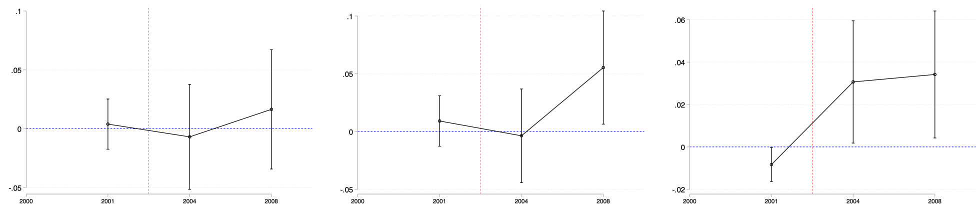
(a) Upgrade (Fertilizer use) (b) Kg Maize Harvest/Ha (c) Extensive inmigration

Panel 2: Indirect effects on migration: difference-in-differences results



(d) Household outmigration (e) Extensive outmigration (f) Intensive outmigration

Panel 3: Reasons to outmigrate: difference-in-differences results



(g) Outmigration for marriage (h) Outmigration to relatives (i) Outmigration to work

Figure 2: Difference-in-differences (Callaway and Sant'Anna, 2021)

Notes: Results are from the difference-in-differences estimation at the household level within treated areas using Callaway and Sant'Anna (2021). Dependant variables are given in each graph's subtitle. Showing actual data for the 1999/2000, 2000/2001, 2003/2004, 2007/2008 agricultural seasons. Showing results for areas treated in 2004. For different specifications, see Figure 16 in the Appendix. Standard errors are clustered at the village level and asymptotically derived from Influence Functions.

available in Table 14 of the Appendix.

3.3 Robustness: parallel trends and alternative identification

In this section, I test the robustness of the natural experiment's estimates. First, I use complementary data going back 13 years prior to the introduction of the subsidy to show that trends in agricultural outcomes are parallel for that period. I then present a test for the Stable Unit Treatment Assumption (SUTVA) using prices. Finally, I show that using voting behavior as a instrument for receiving the subsidy, the Local Average Treatment Effect (LATE) is qualitatively similar to the ITT from the difference-in-differences.

Parallel trends in agriculture over ten years

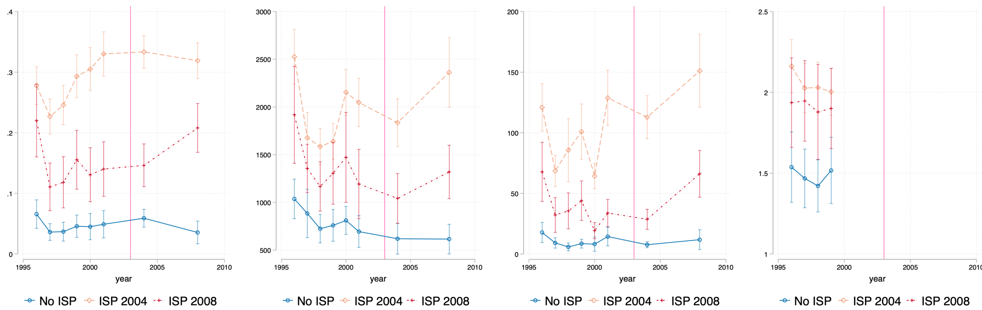
I use repeated cross-sections of the Post-Harvest Survey (PHS) between 1990 and 1999 to further investigate the parallel trend assumption in the difference-in differences estimation above. In Figure 3, I show the evolution over time of different treatment groups between 1990 and 2008.

Trends are parallel prior to the introduction of the subsidy for the quantity of fertilizer used by farmers[8], the quantity of maize harvested and the total landholdings of farmers. The share of households upgrading in areas treated in 2004 appears to have diverged in 2001. To account for this divergence, I control for baseline levels of upgrading in 2001 (Callaway and Sant'Anna, 2021) (see Figure 2).

Stable unit treatment value assumption (SUTVA)

One concern with the difference-in-differences estimation is the potential violation of the Stable Unit Treatment value Assumption (SUTVA). In the context of the Zambian ISP, this could lead to spillover effects across villages (the primary treatment units), affecting both migration and agricultural upgrading estimates. Specifically, we should see changes in prices within treated villages, but not across villages, which would be a threat to the identification. To assess spillovers, I analyze price variations of commercial fertilizer in high and

[8]The quantity of fertilizer used by farmers is subject to higher volatility due to the fact that I am pooling all types of fertilizer. Some fertilizer types require more/less quantity for the same acreage.



(a) Upgraders (b) Kg maize /Ha (c) Kg fertilizer used (d) Landholding

Figure 3: SEA level parallel trends for agriculture outcomes

Notes: The Figure plots historical data using prior cross sections of the Post-Harvest Survey (PHS) from 1990 to 1999. Each graph plots one variable (given in each graph's subtitle) for villages that never received the subsidy, received the subsidy in 2004, and received the subsidy by 2008. Upgraders corresponds to households that use any fertilizer on their farm. Each marker represents the average of the variable for the year. For the years 2000, 2001, 2004, and 2008 the 1999-2000 and its supplemental surveys (i.e. the panel used for the rest of the paper) are plotted. The observations are aggregated at the village level and the ISP groups are based on years at which villages receive the subsidy.

low treatment density regions (which are larger units than villages) in 2004 (the year of treatment). If there are spillovers across treatments, fertilizer prices in provinces with a large number of treated villages should be lower than in provinces with a fewer treated villages.

Figure 17 of Appendix A.5 shows that fertilizer prices did not significantly change for control households in high-density ISP recipient regions.

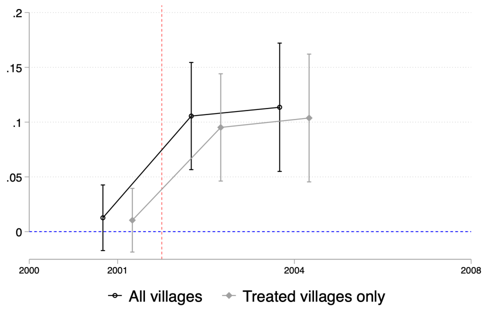
Household level analysis

Another way to check the robustness of the results is to re-run the analysis at the household level, rather than the village level. These results estimate an average treatment-on-the-treated (TOT). Panel 1 of Figure 4 shows individual extensive migration on the left and the likelihood of upgrading on the right.

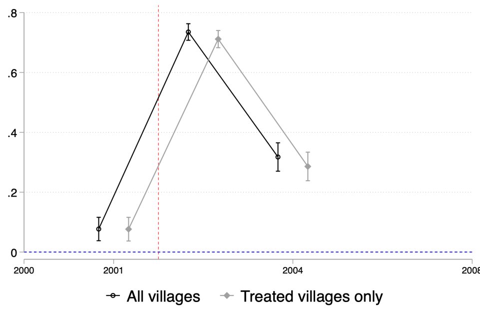
The results are qualitatively the same, showing both an increase in the propensity for a household to send individual migrants out and upgrade its agricultural technology. However, on the right of Panel 1 in Figure 4 I show that households that receive the ISP are positively selected based on their likelihood to upgrade their agricultural technology. This positive selection is consistent with households that received the subsidy in 2004 being more likely to have already upgraded their agricultural technology in 2001.

The outcomes also show that households that received the subsidy in 2004 had more of their income coming from in-farm activities in 2004, but their off-farm activities did not statistically differ from those of households that did not receive the subsidy. The right-hand panel of Figure 4 shows the difference in income for households that received the ISP in 2004 and those that did not, in both 2004 and 2008, i.e. after the introduction of the subsidy.[9]

Panel 1: Treatment-on-the-treated estimates (household level analysis).

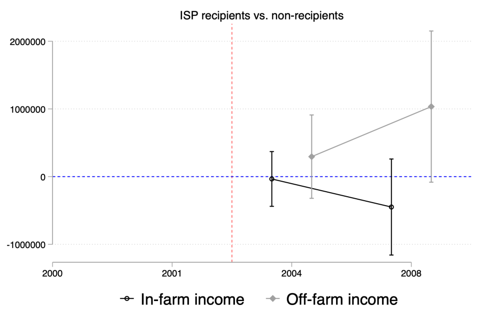


(a) Individual extensive outmigration

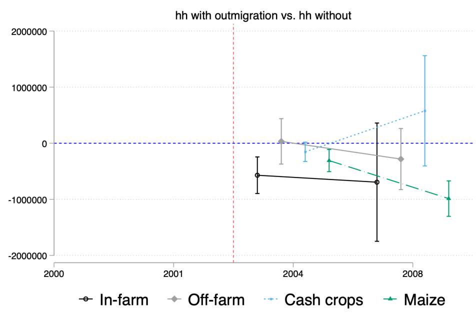


(b) Household likelihood of upgrading

Panel 2: Heterogeneity analysis at the household level.



(c) Income source:Treated vs. Non-Treated



(d) Income source:HHs w/ oumigrants vs. w/o

Figure 4: Individual extensive outmigration (household level analysis)

Notes: Results from the difference-in-differences estimation at the household level within treated areas using Callaway and Sant'Anna (2021) are shown. Dependant variables are given in each graph's subtitle. Showing actual data for the 1999/2000, 2000/2001, 2003/2004, 2007/2008 agricultural seasons, and recall for the seasons 2003/2004, and 2006/2007. Figure shows that households who receive the subsidies are more likely to migrate than the households that did not receive the subsidy. Standard errors are clustered at the village level and asymptotically derived from Influence Functions.

[9]There are no pre-period for the income estimates, and so results needs to be taken with a lot of caution

Instrumenting treatment with political clientelism

Many characteristics — observable and unobservable — can correlate with being in an area that receives the subsidy; these characteristics could include, for example the marginal benefits of fertilizers in some areas or the baseline soil fertility over space. In such an event, the difference-in-differences estimates would overestimate the effect of the policy and yield biased estimates of the impact of the ISP on migration.

However, in the main difference-in-differences analysis, the parallel trends in Figure 3 rule out these issues of unobservables. Nonetheless, to further alleviate concerns about omitted variables, I use a different estimation strategy and find results qualitatively consistent with the difference-in-differences estimates in Section 3. I estimate a local average treatment effect on farmers who receive the ISP due to the voting behavior of their constituency and estimate an instrumental variable (IV) using political clientelism (Mason et al., 2013, 2017). Section A.5 of the Appendix details the results of the estimation.

4 Mechanisms: structural transformation, resale markets, and price effects

In this section, I explore different mechanisms that can lead the ISP to have simultaneous direct effects on agricultural upgrades and indirect effects on migration. Farmers who did not receive the program, can still purchase ISP-branded fertilizer through resale markets. Indeed, 3 to 5% of households that did not receive the subsidy in treated areas report using ISP-branded fertilizer, which is likely an lower-bound of the true leakage as these resales are prohibited; suggesting that some farmers are using a mixed strategy by selling part of their vouchers. For households that fully invest in agriculture—i.e. option (i)—these households could increase their earnings in the medium run by becoming more productive, thereby finance migration. In the data, 51% of households that received the subsidy and upgraded their technology without any migrants in 2004 had outmigrants by 2008, indicating a medium term effect of investing in upgrading agricultural technology.

These mechanisms will be incorporated into the modeling exercise in the second part of the paper. First, changes in migration decisions for farmers are a composite of short term migration consistent with migration occurring as a result of a relaxation in credit constraints, and medium term migration consistent with structural change mediated by an increase in productivity. Second, recipients of vouchers who need liquidity use resale markets to monetize the subsidized vouchers and relax their credit constraints allowing them to migrate in the short run. Third, changes in prices for ISP recipients, and resale market users, are consistent with the heterogeneity of migration decisions. Finally, both an increase in inmigration and outmigration occur and can be rationalized by the specialization of farmers in activities for which they have a comparative advantage.

4.1 Structural transformation vs. liquidity constraints

One of the key findings in the literature on structural transformation is that various factors such as labor-saving technologies, rural overpopulation, or productivity shocks can drive migration out of rural areas (Bustos et al., 2016; Lewis et al., 1954; Imbert et al., 2022). However, in contexts where households are trapped in agriculture despite being better off outmigrating, the distinction between labor-saving and labor-augmenting technologies may not be the primary concern. Indeed, farmers can make sequential choices that lead to increased outmigration even with labor-augmenting technologies. Specifically, they may invest in agriculture first, reap the returns from their investment (income effects), and then use these earnings to finance migration.

In the short run, households that receive the subsidy can adopt one of three strategies: (i) fully utilizing the subsidy to upgrade their agricultural technology without engaging in migration, a behavior observed in 45% of the households in the sample; (ii) selling all their vouchers to finance migration; or (iii) adopting a mixed strategy by selling a portion of the vouchers to facilitate the migration of some members while allocating the remainder to their farm. For households that fully commit to agricultural investment (option i), enhancing their earnings in the medium term becomes possible by boosting productivity to support migration financially. These households may initially upgrade their agricultural technology by adopting fertilizer to increase productivity and later use their increased earnings to fund migration.

In Section 3, I presented the intent-to-treat, pooling both the short term and medium term indirect effects on migration. Table 1 shows that intent-to-treat effect and disaggregates the results across short term and medium term margins using Callaway and Sant'Anna (2021). I show the results for households that received the subsidy in 2004, which are the focus of the analysis. Column (1) shows the results for the likelihood that households relocating *en masse*, Column (2) shows the likelihood that households have at least one outmigrant (extensive individual outmigration), Column (3) shows the change in the number of outmigrants (intensive individual outmigration), and Columns (4) and (5) provide results for the corresponding proxies for extensive and intensive individual inmigration. I proxy inmigration by the addition of adult household members into the household.

The intent-to-treat effect of the ISP on the likelihood of *en masse* migration is primarily driven by households changing their migration decision in the medium run, consistent with the change in opportunity cost of migrating in 2008.

For individual extensive and intensive out- and inmigration medium term migration decisions, consistent with structural transformation, contribute to the intent-to-treat estimates with outmigration effects in the medium run of 14% for the extensive margin (vs. 12% in the ITT), 12% for the intensive margin (vs. 12% in the ITT). For the proxy of in-migration, effects in the medium run are 22% for the extensive margin (vs. 23% in the ITT) and -9% for the intensive margin (vs. -2% in the ITT).

Table 1: Short term and medium term migration

	(1)	(2) Outmigration	(3)	(4) Inmigration Proxy	(5)
	HH extensive	Individual extensive	Individual intensive	Individual extensive	Individual intensive
Intent-to-treat	-.03	.04	.08	.03	-.01
(Pooling 2004 & 2008)	(.01)	(.02)	(.04)	(.01)	(.04)
Short term	-.01	.03	.06	.03	.02
(effect in 2004)	(.01)	(.02)	(.03)	(.01)	(.05)
Medium term	-.06	.05	.1	.03	-.04
(effect in 2008)	(.02)	(.02)	(.06)	(.02)	(.05)
Number HHs	7690	7690	7690	7690	7690
Number of villages	394	394	394	394	394
Controls: HH size	Yes	Yes	Yes	Yes	Yes
Pretrend pvalue (Chi2)	.38	.38	.71	0.18	0.02

Notes: Showing estimates for farmers treated in 2004. Intent-to-treat is the effect aggregated across the years 2004 and 2008. The short term effects are the effects on the year of the treatment. The medium term effects are effects four years after the initial treatment. Standard errors are clustered at the village level and asymptotic derived from Influence Functions.

4.2 Resale markets allow recipients to cash out on the ISP

When the subsidy is introduced, one mechanism consistent with migration occurring in the year of the subsidy is that farmers can relax their liquidity constraints through resale markets. Households that change their members' migration decisions in the year they receive the subsidy, i.e. 2004, resell their subsidized fertilizer to households that in turn double down in the agricultural technology. The Zambian agricultural system operates through cooperatives, where farmers initially received vouchers to purchase a set amount of subsidized fertilizer[10] which creates a market for vouchers among farmers outside of these cooperatives.

Although there are no direct data on resale markets, there is strong evidence of their existence. First, 12% of the ISP recipients do not have agriculture as their main activity (World Bank, 2010), making these farmers high-potential

[10]The set amount of offered by the government is eight bags of 50 kg of fertilizer (i.e. four basal and four top-dressing), which the government recommends to use for one hectare of maize (World Bank, 2010).

resellers. Second, descriptive statistics on the self-reported use of fertilizer are consistent with the existence of resale markets.[11] Many farmers report using a substantially larger or substantially smaller quantities of subsidized fertilizer than they should have received. Furthermore, some farmers who report not being part of the ISP recipients record having fertilizer from the program (see Figures 11 and 12 in the Appendix).

Within the treated villages, households that receive the vouchers are more likely to migrate in the short run. This result is expected if households that received vouchers can monetize the subsidy and relax their credit constraints to migrate. Table 1 shows the contribution of short term migration decisions to the intent-to-treat estimates. Specifically, I find that households do not change their decision to migrate *en masse* in the short term, but individual extensive and intensive out- and inmigration decisions in the medium term, consistent with the existence of resale markets contribute equally to the ITT effects. The intent-to-treat estimates show short run outmigration effects of 11% for the extensive margin (vs. 12% in the pooled ITT) and 13% for the intensive margin (vs. 12%in the pooled ITT). For the proxy of inmigration, medium run effects are 23% for the extensive margin (vs. 23% in the ITT), 3% for the intensive margin (vs. -2% in the ITT).

Furthermore, using data from a randomized control trial by Carter et al. (2021), I find that 30% of vouchers intended for the treatment group were redeemed by the control group after the treatment group did not redeem their vouchers. This fact implies that if there were no strict control for the adherence of farmers to the randomization, these vouchers could have been transferred through resale markets.[12]

Finally, villages with the most potential resellers are also those with the most households sending outmigrants in the short run. This increase tapers off as time goes by (see Figure 19 in the Appendix).

[11] Figures 11 and 12 show the distribution of basal fertilizer used on the farm.

[12] Author's calculations: Carter et al. (2021)'s data from neighboring Mozambique.

4.3 An income effect: lower input prices increase liquidity for recipients and productivity for non-recipients

A third mechanism occurs through prices. Migration can occur in two ways: i) making resale available to households that receive vouchers, or ii) by pricing out of agriculture farmers who did not receive vouchers in those treated areas.

To test this short term income effect mechanism, I estimate a difference-in-differences where treatment, rather than being at the area level, is at the household level. I specifically compare households that received the vouchers to those that did not in treated areas.

I find that farmers who did not receive the vouchers are not priced out, rather those who receive the vouchers are able to migrate in the short run. Indeed, households that receive the vouchers are substantially more likely to migrate in the short run than their counterparts that did not receive vouchers, ruling out the possibility that migration occurs in households priced out of agriculture. This findings implies that the resale channel dominates the pricing out channel (see Panel 1 of Figure 4).

More broadly, the subsidy decreases prices of inputs for farmers who receive vouchers, and opens up the outside option of resale, allowing these households to fund migration. This lowering of prices can spill over to farmers who did not receive vouchers within treated areas because they are now able to purchase fertilizer in resale markets, with the commercial price as a ceiling (Cunha et al., 2019). This decrease in costs for farmers is a function of the number of farmers who received voucher and goes in the opposite direction to what one would expect from anti-poverty policies such as cash transfer programs. Cash transfer programs were found to increase commodity prices in general equilibrium (Angelucci and De Giorgi, 2009).

Despite being more likely to change their migration decision indirectly, farmers who receive the subsidy are also more likely to change their upgrading decision by adopting fertilizer in their agricultural technology. The right panel of Figure 4 shows that these treated households in treated areas are far more likely to adopt fertilizer than their non-treated counterparts. However, the control group converged in their use of fertilizer over time.

4.4 Suggestive specialization across migration and upgrades

A final mechanism relates to correlational evidence suggesting that the specialization of households in farming and other off-farm activities based on comparative advantage may lead to increases in both agricultural and migration outcomes. Following the subsidy in 2004, I can distinguish four groups of farming households: those that respond to the ISP by changing (a) their outmigration decision, (b) their inmigration decision, (c) both margins simultaneously, and (d) those with no changes in their migration decisions.

To estimate the effects of the subsidy on specialization, I focus on treated areas, and run a difference-in-differences across households with outmigrants, and other households. I examine choice and the share of income coming from agriculture. I find that households with outmigrants divest from maize production (see the second graph of Panel 3 in Figure 4) and diversify their activities by weakly investing more in cash crops (with limited statistical power). Meanwhile households that do not receive the subsidy, end up with some inputs, but remain more constrained than treated households preventing them from divesting from agriculture in the short run.

5 A model of selection: upgrading or migrating

This section builds on the natural experiment and addresses the gap in our understanding of how the ISP affects both upgrading and migration. Specifically, I rationalize resale markets as a primary mechanism influencing the choice across upgrading and migration.

The second part of the paper, which include the model, its estimation, and the comparison with counterfactual policies, provides a clear understanding of the channels leading to the results of the natural experiment. Furthermore, it allows for a comparison of the ISP with resale to other policies typically used in rural settings in countries with large populations of smallholder farmers.

The setup: I model the joint decision of a single household across migration and the upgrading of its agricultural technology from a traditional to a fertilizer-based technology. The household (indexed i) behaves like a firm and maximizes its surplus across all its options. Figure 5 summarizes the two joint decisions considered in the model. The decision to use or not the fertilizer and the decision on how many migrants to send under two environments.

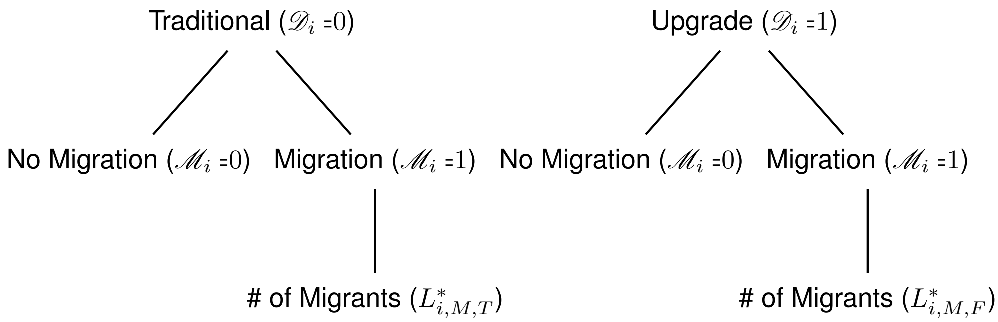


Figure 5: Household i Set of Choices in the Static Model
Notes: In this model the household makes three joint decisions. The decision to upgrade or not its technology by using fertilizer ($\mathscr{D}_i$), whether to send any migrants (binary decision $\mathscr{M}_i$), and how many migrants to send.

The household has L_i units of labor. It decides on units of labor $L_{i,A}$, $L_{i,M}$ to allocate to agriculture, and to migration respectively. $L_{i,A} \in [0, L_i]$, and $L_{i,M} \in [0, L_i]$, such that the household can divide an individual members' time across activities: $L_{i,A} + L_{i,M} = L_i$. Within a household, workers are homogeneous. If the household allocates any labor to agriculture, it has to choose across two technologies: i) the traditional technology which uses labor ($L_{i,A}$) and land (X_i) as inputs, and ii) a fertilizer technology that requires fertilizer as an additional input. The two agricultural technologies produce a homogeneous output.

Migration: the surplus generated by the labor allocated to migration is $\pi^M = L_{i,M} \cdot \tilde{w}_i - c_i^M$, where $\tilde{w}_i = (w_i - m_v)$, with w_i being each household's member's wage at destination. The wage at destination is assumed to be normally distributed, meaning that there are heterogeneous wages at destination for different households, reflecting variations in skills and education. m_v is the marginal cost of migration, it is function of the village the household lives in. c_i^M is the fixed cost of migration which can be interpreted as the initial cost the first migrant leaving the household has to incur to find a dwelling at their destination.

This cost is composed of the average cost to go to the closest city c_i, and a logit shock j_i.

5.1 The household optimization problem

The traditional agriculture: The production function for the traditional technology is $Y_i^T = a \cdot L_{i,A}^{\gamma} X_i^{\delta}$, the surplus stemming from the traditional technology alone is $\pi_i^T = paL_{i,A}^{\gamma} X_i^{\delta}$, where γ is the output elasticity of labor in the traditional agriculture, X the total available landholdings, and δ the elasticity of land.

The upgraded agriculture: The production function for the fertilizer-intensive technology is $Y_i^F = A_i \cdot L_{i,A}^{\alpha} F_i^{\beta} X_i^{1-\alpha-\beta}$, the profit function stemming from selling the production is $\pi_i^F = p \cdot A_i \cdot L_{i,A}^{\alpha} F_i^{\beta} X_i^{1-\alpha-\beta} - q_v(F_i)$, where A_i is the household's idiosyncratic productivity, X_i the landholdings of the household, F_i the total amount of fertilizer used on the farm, it is made up of the quantity received via the subsidy and the quantity traded in resale or commercial markets at a price q_v.

I make the simplifying assumption that the fertilizer is subsidized at 100%, and so the household receives a quantity of fertilizer $\bar{f}$ for free. When the planner introduces a fertilizer subsidy, i.e. $\bar{f} > 0$, by distributing vouchers, the household can either choose to use the subsidized fertilizer in their production; or trade the vouchers in resale markets at an endogenous village price q_v. The household can either choose to use the subsidized fertilizer in their production, i.e. $\mathscr{D}_i = 1$; in that event, each village incurs fixed cost C_v^F associated with upgrading the technology. The cost is allowed to vary across villages to account for different specific conditions such as whether there is a fertilizer store already set up, or the soil quality.

Alternatively, the household can trade the vouchers in resale markets at a price q. The household can sell its entire subsidized allocation ($\mathscr{D}_i = 0$) or buy any affordable quantity. When the household chooses the traditional technology, it receives a voucher to redeem a quantity $\bar{f}$ of subsidized fertilizer at the same location as the commercial fertilizer and sells it all in the resale market at an endogenous unit price of q_v. The total available quantity of fertilizer available for production is F_i. The household maximizes its surplus under the credit constraint, and its optimization problem is the following without the subsidy:

The household faces a credit constraint: it cannot borrow against its returns to migration. This constraint implies that the household's returns from both its agricultural activity and its use of resale markets must entirely cover its fixed cost of migration. This setup allows us to see, within a static model, how farmers fund migration through both a medium-term increase in their productivity, consistent with structural change, and a short-term increase in available cash, consistent with a relaxation of the credit constraint via resale markets.

The household maximizes its total surplus by combining its returns to migration and agriculture, subject to a credit constraint. Its optimization problem is:

$$
\begin{aligned}
\max_{L_{i,A,T/F}\in[0,L_i];F_i\geq 0;\mathscr{D}_i,\mathscr{M}_i\in[0,1]} & (1-\mathscr{D}_i)\left(paL_{i,A,T}^{\gamma}X_i^{\delta}-L_{i,A,T}\tilde{w}_i\right) \\
& + \mathscr{D}_i\left(pA_iL_{i,A,F}^{\alpha}F_i^{\beta}X_i^{1-\alpha-\beta}-q_v\tilde{F}_i-L_{i,A,F}\tilde{w}_i-C_v^F\right) \\
& + q_v\bar{f}+L_i\tilde{w}_i-\mathscr{M}_ic_i^M, && (3)\\
\text{s.t. } & L_i = L_{i,A}+(1-\mathscr{D}_i)L_{i,M,T}+\mathscr{D}_iL_{i,M,F}, && (4)\\
& paL_{i,A}^{\gamma}X_i^{\delta}+q_v\bar{f}\geq c_i^M \quad \text{if} \quad \mathscr{M}_{i,T}=1, && (5)\\
& pA_iL_{i,A}^{\alpha}F_i^{\beta}X_i^{1-\alpha-\beta}-C_v^F+q_v\tilde{f}_i\geq c_i^M \quad \text{if}\mathscr{M}_{i,F}=1, && (6)
\end{aligned}
$$

where $\mathscr{D}_i$ is the household's decision to upgrade its technology, it is equal to 1 if the household upgrades and 0 otherwise. $\mathscr{M}_{i,T}$ and $\mathscr{M}_{i,F}$ are the extensive individual migration decisions for a household that engages in the traditional agriculture and the upgraded technology respectively; they are equal to 1 and if the number of migrants if the household chooses the traditional technology, $L_{i,M,T}$ or the upgraded technology $L_{i,M,F}$ are greater than 0.

The endogenous price of fertilizer in the village q_v^*

Households in the village have access to both the resale market (when the ISP is available) and the commercial market of fertilizer. These markets of fertilizer clear and set the price of fertilizer within the village. More specifically, $\sum_{i=1}^{N}\int_{\zeta_i}\tilde{f}_idw_i+\bar{F}_v=0$, where $\bar{F}_v$ is the available commercial fertilizer in the village.

$$
\sum_{i=1}^{N}\int_{\zeta_i}\left(\tilde{f}_i\right)dw_i+\bar{F}_v=0 \tag{7}
$$

$$N_1\bar{f} + \bar{F_v} - \left[\alpha^\alpha p \left(\frac{\beta}{q_v^*}\right)^{1-\alpha}\right]^{\frac{1}{1-\alpha-\beta}} \sum_{i=1}^{N^u} \int_{\zeta_i} X_i \left(\frac{A_i}{\tilde{w_i}}\right)^{\frac{1}{1-\alpha-\beta}} dw_i$$
$$- \left(\frac{p}{q_v^*}\right)^{\frac{1}{1-\beta}} \sum_{j=1}^{N^c} \left[A_j X_j^{1-\alpha-\beta}\right]^{\frac{1}{1-\beta}} = 0 \qquad (8)$$

Within the village, N_1 is the number of households that receive the subsidy, while N^u and N^c are respectively the number of upgraders that are unconstrained (interior solution), and constrained to having all their labor in agriculture. q_v^* has no analytical solution, but can be estimated based on N^u, N^c, and the elasticities of production. Note that when $N^u = 0$, $q_v^{*c} = \frac{p}{N_1\bar{f}+\bar{F_v}} \cdot \left[\sum_{j=1}^{N^c} \int_{\zeta_i} \left[A_j x_j^{1-\alpha-\beta}\right]^{\frac{1}{1-\beta}} dw_j\right]^{1-\beta}$, and if $N^c = 0$, $q_v^{*u} = \beta \left(\frac{\alpha^\alpha p}{N_1\bar{f}+\bar{F_v}}\right)^{\frac{1}{1-\alpha}} \cdot \left[\sum_{i=1}^{N^u} \int_{\zeta_i} x_i \left(\frac{A_i}{\tilde{w_i}}\right)^{\frac{1}{1-\alpha-\beta}} dw_i\right]^{\frac{1-\alpha-\beta}{1-\alpha}}$

5.2 The choice to upgrade

Unconstrained households: the interior solution

The household will upgrade to the fertilizer agriculture if its surplus in the fertilizer agriculture is larger than in the traditional agriculture. In both cases, the household has the outside option of migrating. Formally, the household upgrades if iff $\pi_{i,T}^{u*} < \pi_{i,F}^{u*}$, which occurs if an unconstrained household's productivity in the upgraded agriculture A_i is above a threshold, such that:

$$\mathscr{D}_i = 1 : A_i \geq \frac{q_v^{*\beta} \tilde{w_i}^\alpha}{p X_i^{1-\alpha-\beta}} \left[\frac{\gamma^{\frac{1}{1-\gamma}}(1 - L_i\tilde{w_i})}{\Psi} \left(\frac{PaX_i^\delta}{\tilde{w_i}^\gamma}\right)^{\frac{1}{1-\gamma}} + \frac{C_v^F + c_i^M}{\Psi}\right]^{\frac{1-\alpha-\beta}{1-\gamma}} \qquad (9)$$

where $\Psi = \beta^{\frac{\beta}{1-\alpha-\beta}} \cdot \alpha^{\frac{\alpha}{1-\alpha-\beta}} - \beta^{\frac{1-\alpha}{1-\alpha-\beta}} \cdot \alpha^{\frac{\alpha}{1-\alpha-\beta}} - \beta^{\frac{\beta}{1-\alpha-\beta}} \cdot \alpha^{\frac{1-\beta}{1-\alpha-\beta}}$. And where q_v^* comes from the market clearing condition on the fertilizer resale market, see equation 8. There is no closed form solution to q_v^*, and its expression will stem from the estimation of the elasticities of production.

For these unconstrained households, migration levels for households choosing the traditional agriculture and those choosing the upgraded agriculture are

respectively:
$$L^{u*}_{i,M,T} = L_i - \left(\frac{\gamma p a X_i^{\delta}}{\tilde{w}_i}\right)^{\frac{1}{1-\gamma}} \tag{10}$$
$$L^{u*}_{i,M,F} = L_i - X_i\left[\left(\frac{\beta}{q_v}\right)^{\beta}\left(\frac{\alpha}{\tilde{w}_i}\right)^{1-\beta} pA_i\right]^{\frac{1}{1-\alpha-\beta}}. \tag{11}$$

Labor constraints bind

When the household is constrained to have $L_{i,A} = L_i$, it upgrades if its productivity in the upgraded agriculture A_i is above a threshold, such as:

$$\pi^{c*}_{i,F} \geq \pi^{c*}_{i,T} \tag{12}$$
$$A_i \geq \left[\frac{paX^{\delta} + C^F_v}{\beta^{\frac{1}{1-\beta}} - \beta^{\frac{1}{1-\beta}}}\right]^{1-\beta} \frac{q^*_v}{pX_i^{1-\alpha-\beta}} \tag{13}$$

For these constrained households, migration levels for households choosing the traditional agriculture and those choosing the upgraded agriculture are $L^{c*}_{i,M,T} = L^{c*}_{i,M,F} = 0$.

Testing the implications of the model

The model maps to some empirical results of the first part of the paper.

Implication 1: There are four groups of households (a) Households that upgrade, and do not have outmigrants; (b) households that upgrade, and have outmigrants; (c) households that do not upgrade and do not have outmigrants; (d) households that do no upgrade, and have outmigrants.[13]

Implication 2: We should observe households delaying their migration decision, to use the income from their agricultural upgrade to fund migration.[14]

Implication 3: migration increases as the resale value of the subsidized fertilizer increases: Another implication of the model is that as the resale value of the vouchers increases, migration becomes comparatively more attractive. This correlation results from the credit constraint being relaxed for more households. Additionally, it also implies that the opportunity cost of the marginal hectare of fertilizer agriculture is higher because it becomes too costly to top-up, and migration becomes relatively more attractive. The correlation between resale

[13] For corresponding propositions, see Propositions 1, 2 and 4 in Appendix B.
[14] For corresponding propositions, see Proposition 3 in Appendix B.

price (which I proxy using the commercial price) and individual migration at the extensive margin is 0.07 and 0.08 at the intensive margins.[15] Furthermore, for each additional US$1 of subsidy, there is a 0.2 percentage point increase in the likelihood that a household sends at least one member out and a .1 percentage point increase in the number of people sent out (for regression results, see Table 18 in the Appendix and Figure 22).

6 Estimation, in-kind and cash counterfactuals

In this section, I estimate the model of selection presented in Section 5 by maximum likelihood, I then use the parameters from the baseline model (ISP with resale) to back out the parameters of the model and estimate the following counterfactual policies: (i) an ISP without resale markets, similar to an in-kind transfer, and (ii) a cash transfer program, with the same pecuniary value as the subsidy for the same households that previously received the ISP.

6.1 Estimating the model of selection

The benchmark estimation: ISP and migration

To estimation of the baseline ISP is in three steps: first I estimate the production functions for the upgraded and the traditional agriculture, second, I estimate the amount of fertilizer that non-upgrader households would have used had they upgraded, that allows me to estimate the output Y_i^F for non-upgraders, and thus have the productivity in the upgraded agriculture for both upgraders and non-upgraders. Third, I estimate the joint decision to upgrade and to migrate for households.

Production functions:

The optimal levels of migration depend on elasticities and prices. As a first step here, I estimate the Cobb-Douglas production functions from Section 5. I do not instrument the inputs of the production function (Olley and Pakes, 1992), as inputs are mostly fixed and labor markets are incomplete (Rosenzweig, 1988).

I estimate the production functions for each technology by pooling all four

[15] Figures 21 and 22 in the appendix plot these correlations.

waves of the panel (2000, 2001, 2004, and 2008). For the fertilizer technology, I estimate the technology among adopting farms (i.e. farms that report using fertilizer) and compute the counterfactual production for non-adopters. This identification accounts for the inputs of the production function and the village fixed effect which is the deterministic component of A_i. The residual of $\log(\nu_i)$ is the idiosyncratic part of A_i. The estimation (see Appendix C) shows that the fertilizer technology has a constant return to scale while the traditional technology has a decreasing return to scale.

Fertilizer use, and production outputs:
I only observe the F_i and Y_i^F for upgraders, and Y_i^T for non-upgraders. To estimate their corresponding $\widehat{Y_i^T}$ for upgraders and $\widehat{Y_i^F}$ for non-upgraders, I focus on the year 2004, which is the year for which I am going to estimate the joint decision to upgrade and migrate. I estimate $F_{i,2004}$ as such:

$$F_{i,2004} = a_0 + a_1 \text{Production Value}_{2001} + a_2 \text{Fallow land} + \text{FE}_v + e_i \tag{14}$$

Once I estimate F_i among upgraders, I compute $\widehat{F_i}$ for the non-upgraders. Using $\widehat{F_i}$, I compute $\widehat{Y_i^F}$ for non-upgraders, and thus back out the household level productivity in the upgraded agriculture A_i.

To estimate $\widehat{Y_i^T}$, I use household landholdings, and the total labor units available to the households L_i as inputs.

Joint decision to upgrade and to migrate:
To estimate the binary decision to upgrade, as well as the number of migrants, I estimate simultaneously the three following OLS separately for villages that receive the subsidy, and villages that do not:

$$\begin{cases} \mathscr{D}_i &= \alpha_0 \log(X) + \alpha_1 \log(q_v) + \alpha_2 \log(A_i) + \alpha_3 \log(c_i) + FE_v + \epsilon_i \\ \mathscr{M}_i &= \beta_0 + \beta_1 L_{iM} + \beta_2 Y_T + \beta_3 \mathscr{D}_i (Y_F - Y_T) + \beta_4 q_v + \beta_5 c_i + \mu_i \\ L_{iM} &= \gamma_0 \mathscr{D}_i \log(A_i) + \gamma_1 \log(X) + \gamma_2 \log(c_i) + \gamma_3 \log(P_v) + \gamma_3 \log(L_i) \\ & \quad + \gamma_4 1_{\text{fsp}} \times \log(q_v) + \gamma_5 \log(q_v) + \theta_i \end{cases} \tag{15}$$

The estimation within ISP villages allows me to estimate the decisions stemming from Equations 9, 6, and 11. The estimation outside of ISP-villages provides the parameters when resale markets don't exist.

Each of the parameters used in the estimation is constructed using the description from Table 3. Table 2 summarizes the mean and standard deviations of the upgrading ($\mathscr{D}_i$), migration ($\mathscr{M}_i$), and labor unit migrating (L_{iM}) for 10% hold-out sample. Overall, the out-of-sample estimates (see Column 3 of Table 2) approximates well the moments of the data (see Column 2 of Table 2). The out-of-sample difference between the estimates and the actual value $\mathscr{M}_i$, L_{iM} are respectively .1% and 5%, while $\mathscr{D}_i$ is at -23%.

Table 2: Out-of-sample fit of the model

(1) Variable	(2) Statistics	(3) Estimates	(4) Actual	(5) Difference
$\mathscr{D}_i$	Mean	.762	.617	-.145 (-23.5%)
	SD	.427	.487	
$\mathscr{M}_i$	Mean	.606	.610	.004 (+0.1%)
	SD	.490	.489	
L_{iM}	Mean	1.933	1.851	-.082 (+4.3%)
	SD	1.398	2.238	

Notes: estimates of Joint Equations 15 using maximum likelihood. The estimates presented are from the computation of $\mathscr{D}_i$, $\mathscr{M}_i$, and L_{iM} on a 10% hold out sample. Column (1) lists all variables of the model estimated. $\mathscr{D}_i$ is one household's decision to upgrade its agricultural technology and start using fertilizer, $\mathscr{M}_i$ is one household's decision to send units of labor to outmigrate, and L_{iM} is the optimal number of labor units the household sends to outmigrate. Column (2) shows the statistics displayed (mean, and standard deviation). Column (3) is the fitted estimate from Equation 15 for the 10% out-of-sample households. Column (4) is the actual value of each of the variables (and statistics). Column (5) is the (4)-(3) and in parenthesis it is ((4)-(3))/(3), i.e. the out-of-sample percentage of error between the estimate and the actual value.

Estimating revenue from agriculture:

I compute the revenue from production by computing $p \times Y_i^T$ and $p \times \widehat{Y_i^F}$ for non-upgraders and $p \times Y_i^F$ and $p \times \widehat{Y_i^T}$ for upgraders.

Table 3: Estimation of the parameters of the model

(1)	(2)	(3)
Par.	Year	Source and Sample
Migration		
w_i	2004	Idiosyncratic shock
m_v	2004	Absorbed in the village fixed effect
c_i	2004	Transportation cost to closest city
j_i	2004	Idiosyncratic shock
Production inputs		
L_i	2004	# HH members (including outmigrants)
F_i	2004	*Upgraders*: Fertilizer used
		Non-upgraders: computed from upgraders
A_i	2004	*Upgraders*: Estimated among upgraders
		Non-upgraders: computed using estimates for upgraders
Elasticities and outputs		
α	2004	Estimated among upgraders
β	2004	Estimated among upgraders
γ	2004	Estimated among non-upgraders
δ	2004	Estimated among non-upgrader
Y_i^T	2004	*Upgraders*: Computing using estimated δ, γ
		Non-upgraders: Using harvest data
Y_i^F	2004	*Upgraders*: Using harvest data
	2004	*Non-upgraders*: Computing using estimated α, β, γ
Number of households		
N_1	2004	# HHs in the village that received ISP
N^u	2004	# HHs with outmigrate in 2004
N^c	2004-8	Total HHs in village minus N^u
Prices and others		
p	2004	Price of maize in 2004
q_v	2004	Computed from Equation 8
C_v^F	2004	Absorbed in the village fixed effect
$\bar{F}_v$	2004	Total fertilizer used in village net of subsidy

Notes: This table summarizes the variables needed to estimate the model. Column (1) lists the parameters of the model. Column (2) lists the years from which the parameter data is taken. Column (3) details the variables used for each parameter.

6.2 Counterfactual policies: subsidies vs. transfer programs

Using the estimates obtained from the model, I estimate the counterfactuals for several popular rural antipoverty policies. First, I explore, under the model assumptions what would happen with a cash transfer program, a ban on resale markets and finally a subsidy on the cost of the frictions.

The cash transfer programs have two main feature differences with the baseline ISP with resale model. First, the cost of transportation c_i goes down by the amount of the cash transfer, this drop in costs impacts both the decision to upgrade the household's agricultural technology $\mathscr{D}_i$, and its decision to migrate $\mathscr{M}_i$; for households with low transportation costs, the left-over cash is added to the total revenue. Second, the price of fertilizer increases as the total amount of fertilizer available in the village decreases, because the central planner no longer provides the subsidized quantity of fertilizer. To estimate the costs of fertilizer, I use Equation 8, and estimate the following:

Equilibrium fertilizer price q_v^*:

$$log(q_v) = \beta_0 + \beta_1(N_{1v}\bar{f} + F_v) + \beta_2 N_{1v} + \beta_3 N_v^u + \beta_4 N_v^c + \epsilon_v,$$

where $N_{1v}\bar{f}$, is the number of households in the village that receive the subsidy, N_v^u is approximated by the number of households that have migrants, and N_v^c is approximated by the total number of households net of the constrained households.

ISP without resale: shutting down the resale markets impacts the reallocation of fertilizer in the local market. Furthermore, farmers with a comparative advantage in migrating cannot generate liquidity to fund migration. This scenario results in substantial efficiency losses, with a decrease in both upgrading (-64.54%) and migration (-4.71%). In this case, the improvement in overall productivity is negative compared to the ISP with resale markets, which the latter generates a snowball effect as farmers can split their fertilizer transfer across several households.

I will test two ways of designing the cash transfer policy. First, I will use the targeting of the ISP, and provide a revenue neutral cash transfer to farming households who had previously received the subsidy. In a second design of the revenue neutral cash transfer program, there is no targeting and all farmers living in a treated village receive some amount of cash that is smaller than the targeted counterfactual.

Targeted cash transfer: the targeted cash transfer program decreases both migration rates (-5.32%) and the adoption of the fertilizer technology (-70.87%) compared to the baseline of ISP with resale markets. First, the market frictions in adoption are not internalized and adoption rates plummet compared to the ISP with resale markets. Second migration also decreases because unlike the ISP, the cash is fungible and there is no redistribution of the cash across households. In this case, only the households receiving the subsidy can change their migration decisions. Another aspect of the model is that households that upgrade and generate more profit with the fertilizer technology can fund migration. Because the targeted cash transfer leads to no adoption, there is no spillover effect (in the model) from the cash transfer program.

Untargeted cash transfer: the untargeted cash transfer program increases migration rates substantially (-5.32%) compared to the ISP with resale markets but has strong negative effects on the adoption of the fertilizer technology (-79.87%). That is because the market frictions in the fertilizer market remain.

Panel A of Table 4 summarizes the counterfactual estimates.

Table 4: Summary of counterfactual policies

Panel A: Structural estimates for upgrade and migration

	Channels	Upgrade	Migration	
		extensive	extensive	intensive
Baseline:				
- ISP + Resale	Upgrade: Resale, input prices	.779	.672	1.84
	Migration: Resale, Productivity	(0.05)	(0.015)	(0.05)
Counterfactuals:				
- ISP no Resale	Upgrade: Fertilizer prices	.276	.640	1.83
	Migration: Productivity	(0.097)	(0.032)	(0.06)
- Targeted CT	Upgrade: Lower transport costs	.227	.636	2.05
	Migration: Lower transport costs	(0.448)	(0.04)	(0.53)
- Untargeted CT	Upgrade: Lower transport costs	.157	.636	1.74
	Migration: Lower transport costs	(0.445)	(0.04)	(0.52)

Panel B: Back-of-the-envelope effects on income

	Input Subsidy		Cash Transfers	
	Baseline: Resale	No Resale	Targeted	Untargeted
Mean Revenue*	\$716	\$566	\$961	\$653
Median Revenue*	\$333	\$253	\$344	\$257

Notes: Estimates of the model using maximum likelihood. The extensive upgrade, and migration are obtained splitting the probability into a binary variable = 1 if the estimated probability is greater or equal to 0.5, and 0 otherwise. Standard errors are in parenthesis and are reported from using the standard deviation over 300 bootstrap replications of the estimation (with replacement). *— Mean and median revenue include include the returns from agriculture as well as the lump sum for the cash transfer.

6.3 Discussion: first best, and second-best policies

First-best policy

Considering both the credit constraint and the market frictions in the economy, a first-best policy to minimize distortions and improve the efficiency of the policy could be to identify the two types of farmers—those who are better off migrating and those who are better off upgrading—and lifting the corresponding constraints. Farmers with high productivity in the fertilizer-based technology could see their constraints lifted via the ISP, addressing both affordability and increasing available quantities. Conversely, farmers "trapped" in agriculture—who would be better divesting from agriculture —could receive a cash transfer to address the financial frictions preventing their relocation. Such a policy relies on the central planner's ability to observe farmer types for which elicitation is costly.

Second-best policies

ISP with resale markets (currently in Zambia): Resale markets for fertilizers enhance allocative efficiency by reallocating fertilizer towards farmers in greater need, while generating income for the net-sellers. The amount of fertilizer can be split across farmers, creating a snowball effect. However, this policy may introduce distortions (Diamond and Mirrlees, 1971; Mirrlees, 1986). When resale transaction costs are low, this second-best policy approximates the first-best policy in a decentralized manner. The adequacy of the subsidy hinges on the trade-off between a price distortion-induced efficiency loss, increased technology upgrade, and redistribution components.

ISP without resale markets: Without resale markets, the price effect benefits only ISP recipients, but farmers' ability to relax their credit constraint is reduced. In this setting, farmers can only increase their migration by increasing their productivity in the medium term. Furthermore, unless the planner can elicit types and only provide the subsidy to farmers with the highest returns to upgrading, this policy would introduce a deadweight loss from the inability of farmers to efficiently distribute the subsidized fertilizer. This deadweight loss can be lowered if the cost of eliciting farmer types is low. Alternatively, the central planner could encourage and remove the frictions in resale markets.

Targeted cash transfer: The cash transfer program given only to the recipients of the ISP in 2004 improves migration outcomes but only in the short run. The channel of increased income from upgrading is reduced for recipients. In this cash transfer program, the multiplier effect of the subsidy disappears. However, with various estimates of the returns to a cash transfer program, it may be a better alternative for poverty reduction but only for the 8% who receive the transfer. Farmers that receive the cash transfer can fund migration but farmers who do not receive the subsidy experience unaltered outcomes. Unlike the ISP with resale markets, the policy's returns do not spill over to the other farmers (no snowball effect), market frictions remain and upgrade rates plummet.

Untargeted cash transfer: This cash transfer program is given to all farmers residing in targeted areas. It relaxes the credit constraint for a larger number of households who can then migrate. However, similar to the targeted cash transfer, upgrade rates are very low as a result of the transfer.

Optimal policy

If the central planner has a dual objective of moving farmers from a low to a high equilibrium of fertilizer adoption while also redistributing income to those facing financial constraints, then resale markets could be an improvement over the no-subsidy alternative. In the setting of the Zambian agricultural system, a limited ISP randomly provided to farmers could lead to efficiency gains (Giné et al., 2022), and a rise in both adoption and migration rates. Carter et al. (2021) find that temporary subsidies can lead to long-lasting effects on adoption by moving farmers to a better fertilizer-use equilibrium. Based on their findings, an optimal policy may involve introducing the subsidy with resale markets and phasing out the subsidy once a critical mass of farmers upgrades their agricultural technology and starts using fertilizer. The ISP can then be phased out and replaced by an untargeted cash transfer program. This optimal policy does not require the central planner to elicit farmers types, and so the planner does not need to invest in costly targeting. Instead, the central planner can encourage resale markets and remove frictions that may lower the efficiency of these markets.

In neighboring Malawi, (Boone et al., 2013) show that combining cash transfers with ISPs can have a multiplicative impact of improving fertilizer adoption, increasing farm production, improving soil quality in the long run but also further relaxing the credit constraint for individuals living in extreme poverty.

Conclusion

I examine the effects of a large-scale Zambian input subsidy program (ISP) on farmers' investment choices, focusing on agricultural upgrading (fertilizer use) and outmigration. Using the staggered rollout of the ISP, I estimate a difference-in-differences and find that the ISP significantly increased both fertilizer use and outmigration rates. Building on these findings, I develop a static choice model to generalize the observed behaviors. The model incorporates key features such as resale markets for subsidized fertilizer—with endogenous fertilizer prices—credit constraints which are relaxed by the ISP, and the productivity gains stemming from increased fertilizer availability. I then estimate the model, and compare the current ISP with resale markets to three revenue-neutral counterfactual policies.

The findings suggest that a subsidy on agricultural inputs can simultaneously address the market frictions affecting the adoption of fertilizer in agriculture and credit constraints. Alleviating credit constraints alloes farmers to sort based on comparative advantage, while the potential allocative inefficiency of subsidies is partially offset by the existence of resale markets.

This paper shows that agricultural input subsidy programs (ISPs) impact both agricultural productivity and migration. It further demonstrates that ISPs with resale markets are more effective than unconditional cash transfers in achieving policy objectives like increased agricultural productivity by addressing fixed costs and market frictions. Lastly, it highlights how resale markets enhance policy outcomes by enabling farmers to convert ISPs into cash, facilitating migration for households that were previously trapped in agriculture, and reallocating resources efficiently.

The empirical part of this paper, which offers a unique setting to examine the impact of an input subsidy on a variety of household decisions, also has limitations. First, I do not observe the destination of outmigrants or the origin of inmigrants, which limits the extent to which I can infer the changes in welfare for beneficiary households. Furthermore, I do not directly observe resale markets, which implies a loss in precision regarding the demand for fertilizer within local areas. A third limitation stems from the frequency of data collection which occurs every four years and does not allow me to distinguish between seasonal and long term migration.

Future work can explore the dynamic effects of these policies. Although migration decisions are not the sole objective of these policies, this paper is a first step in exploring the indirect impacts policies might have on migration patterns over time and within countries. The findings can provide information to policymakers when deciding on the allocation of resources.

References

Aker, J. C. (2017). Comparing cash and voucher transfers in a humanitarian context: Evidence from the democratic republic of congo. *The World Bank Economic Review 31*(1), 44–70.

Angelucci, M. (2015). Migration and financial constraints: Evidence from mexico. *Review of Economics and Statistics 97*(1), 224–228.

Angelucci, M. and G. De Giorgi (2009). Indirect effects of an aid program:

how do cash transfers affect ineligibles' consumption? *American economic review 99*(1), 486–508.

Balboni, C., O. Bandiera, R. Burgess, M. Ghatak, and A. Heil (2022). Why do people stay poor? *The Quarterly Journal of Economics 137*(2), 785–844.

Banerjee, A., M. Faye, A. Krueger, P. Niehaus, and T. Suri (2023). Universal basic income: Short-term results from a long-term experiment in kenya.

Bazzi, S. (2017). Wealth heterogeneity and the income elasticity of migration. *American Economic Journal: Applied Economics 9*(2), 219–55.

Boone, R., K. Covarrubias, B. Davis, and P. Winters (2013). Cash transfer programs and agricultural production: the case of malawi. *Agricultural Economics 44*(3), 365–378.

Burgess, R., R. Jedwab, E. Miguel, A. Morjaria, and G. P. i–Miquel (2013, August). The value of democracy: evidence from road building in Kenya. STICERD - Economic Organisation and Public Policy Discussion Papers Series 45, Suntory and Toyota International Centres for Economics and Related Disciplines, LSE.

Burke, M., L. F. Bergquist, and E. Miguel (2019). Sell low and buy high: arbitrage and local price effects in kenyan markets. *The Quarterly Journal of Economics 134*(2), 785–842.

Bustos, P., B. Caprettini, and J. Ponticelli (2016). Agricultural productivity and structural transformation: Evidence from brazil. *American Economic Review 106*(6), 1320–65.

Cai, S. (2020). Migration under liquidity constraints: Evidence from randomized credit access in china. *Journal of Development Economics 142*, 102247.

Callaway, B. and P. H. Sant'Anna (2021). Difference-in-differences with multiple time periods. *Journal of Econometrics 225*(2), 200–230.

Carter, M., R. Laajaj, and D. Yang (2021, April). Subsidies and the african green revolution: Direct effects and social network spillovers of randomized input subsidies in mozambique. *American Economic Journal: Applied Economics 13*(2), 206–29.

Castañeda, A., D. Doan, D. Newhouse, M. C. Nguyen, H. Uematsu, J. P. Azevedo, et al. (2018). A new profile of the global poor. *World Development 101*, 250–267.

Chirwa, E. and A. Dorward (2013). *Agricultural input subsidies: The recent Malawi experience*. Oxford University Press.

Cunha, J. M., G. De Giorgi, and S. Jayachandran (2019). The price effects of cash versus in-kind transfers. *The Review of Economic Studies 86*(1), 240–281.

Diamond, P. A. and J. A. Mirrlees (1971). Optimal taxation and public production i: Production efficiency. *The American economic review 61*(1), 8–27.

Easterly, W. and L. Ross (1997, April). Africa growth tragedy. *The Quarterly Journal of Economics 112*, 1203–50.

Food and Agriculture Organization of the United Nations (2021). A multibillion-dollar opportunity: Repurposing agricultural support to transform food systems.

Gadenne, L., S. Norris, M. Singhal, and S. Sukhtankar (2021). In-kind transfers as insurance. Technical report, National Bureau of Economic Research.

Gazeaud, J., E. Mvukiyehe, and O. Sterck (2023). Cash transfers and migration: Theory and evidence from a randomized controlled trial. *Review of Economics and Statistics 105*(1), 143–157.

Ghatak, M. (2015). Theories of poverty traps and anti-poverty policies. *The World Bank Economic Review 29*(suppl_1), S77–S105.

Giné, X., S. Patel, B. Ribeiro, and I. Valley (2022). Efficiency and equity of input subsidies: Experimental evidence from tanzania. *American Journal of Agricultural Economics 104*(5), 1625–1655.

Gollin, D. (2014). The lewis model: A 60-year retrospective. *Journal of Economic Perspectives 28*(3), 71–88.

Gollin, D., D. Lagakos, and M. E. Waugh (2014). Agricultural productivity differences across countries. *American Economic Review 104*(5), 165–70.

Harasty, C., M. Kwong, and P. Ronnås (2015). *Inclusive growth and productive employment in Zambia*. ILO.

Imbert, C., M. Seror, Y. Zhang, and Y. Zylberberg (2022). Migrants and firms: Evidence from china. *American Economic Review 112*(6), 1885–1914.

Jayne, T. S., N. M. Mason, W. J. Burke, and J. Ariga (2018). Taking stock of africa's second-generation agricultural input subsidy programs. *Food Policy 75*, 1–14.

Jayne, T. S. and S. Rashid (2013). Input subsidy programs in sub-saharan africa: a synthesis of recent evidence. *Agricultural economics 44*(6), 547–562.

Lagakos, D., A. M. Mobarak, and M. E. Waugh (2023). The welfare effects of encouraging rural–urban migration. *Econometrica 91*(3), 803–837.

Lewis, W. A. et al. (1954). Economic development with unlimited supplies of labour. *The Manchester School 22*(2), 139–191.

Mason, N. M., T. Jayne, and R. Mofya-Mukuka (2013, November). Zambia's input subsidy programs. *Agricultural Economics 44*(6), 613–628.

Mason, N. M., T. Jayne, and N. v. d. Walle (2013, May). Fertilizer Subsidies and Voting Patterns: Political Economy Dimensions of Input Subsidy Programs. 2013 Annual Meeting, August 4-6, 2013, Washington, D.C. 149580, Agricultural and Applied Economics Association.

Mason, N. M. and T. S. Jayne (2013, 09). Fertiliser Subsidies and Smallholder Commercial Fertiliser Purchases: Crowding Out, Leakage and Policy Implications for Zambia. *Journal of Agricultural Economics 64*(3), 558–582.

Mason, N. M., T. S. Jayne, and N. Van De Walle (2017). The political economy of fertilizer subsidy programs in africa: Evidence from zambia. *American Journal of Agricultural Economics 99*(3), 705–731.

Mazur, K. and L. Tetenyi (2022). The Macroeconomic Impact of Agricultural Input Subsidies. Working paper, Peking University HSBC Business School, Bank of Portugal.

Minde, I. J., T. S. Jayne, E. W. Crawford, J. Ariga, and J. Govereh (2008, November). Promoting Fertilizer Use in Africa: Current Issues and Empirical Evidence from Malawi, Zambia, and Kenya. Food Security Collaborative Working Papers 54934, Michigan State University, Department of Agricultural, Food, and Resource Economics.

Mirrlees, J. A. (1986). The theory of optimal taxation. *Handbook of mathematical economics 3*, 1197–1249.

Ngai, L. R. and C. A. Pissarides (2007). Structural change in a multisector model of growth. *American economic review 97*(1), 429–443.

Olley, S. and A. Pakes (1992). The dynamics of productivity in the telecommunications equipment industry.

Ravallion, M. (2021, April). On the welfare gains from tradeable benefits-in-kind. Working Paper 28728, National Bureau of Economic Research.

Resnick, D., N. Mason, et al. (2016). *What drives input subsidy policy reform?: The case of Zambia, 2002–2016*, Volume 1572. Intl Food Policy Res Inst.

Ritchie, H. and M. Roser (2020). Agricultural production. https://ourworldindata.org/agricultural-production.

Rosenzweig, M. R. (1988). Labor markets in low-income countries. *Handbook of development economics 1*, 713–762.

Schmitz, T. G., A. Schmitz, and C. Dumas (1997). Gains from trade, inefficiency of government programs, and the net economic effects of trading. *Journal of Political Economy 105*(3), 637–647.

Singh, I., L. Squire, and J. Strauss (1986). A survey of agricultural household models: Recent findings and policy implications. *The World Bank Economic Review 1*(1), 149–179.

World Bank (2010, June). Zambia impact assessment of the fertilizer support program. Report. Sustainable Development Department, Agriculture and Rural Development, Africa Region.

World Bank (2021). Zambia's farmer input support program and recommendations for re-designing the program.

Xu, Z., Z. Guan, T. S. Jayne, and J. R. Black (2009). Factors influencing the profitability of fertilizer use on maize in zambia. Food Security Collaborative Policy Briefs 54639, Michigan State University, Department of Agricultural, Food, and Resource Economics.

A Appendix

A.1 Some context on rural antipoverty programs

A.2 Data and descriptives

First, Census Supervisory Areas (CSAs) were chosen within each district. Second, Standard Enumeration Areas (SEAs) were sampled from each CSA, and finally, households within each SEA were randomly chosen to be interviewed.

In addition to the household surveys conducted in 2000, 2001, 2004, and 2008, the 2008 survey includes community-level information gathered from the community headman. This dataset provides information on basic features of communities, rules, constituencies, and distances to main provincial landmarks.

Measurement: To measure upgrades, I use self-reported measures of whether the household used any fertilizer on their field (whether from the subsidized program or not). I report the extensive use of fertilizer, i.e., households going from not using fertilizer to using any quantity of fertilizer.

To measure yields, I use the quantity of maize produced (the target crop of the subsidy) per land owned including cultivated and fallow lands.

To disentangle the different types of migration, I construct several measures, each capturing either extensive or intensive margins.

First, I create a measure of each household's extensive outmigration which corresponds to a household outmigrating with all its members, i.e. a household migrating (*en masse*). I construct this variable using the survey response status of the sample. A household that moves away from the village is tagged as a migrant household. I am not able to observe households that migrated *en masse* conditional on receiving the subsidy on the same year, because migrant households do not take the survey that records whether they received the ISP. In 2008, some of the households that have moved are still interviewed. Using information on whether they "moved out of SEA" (all households that move have the reason for moving listed, here I exclusively use households that have moved outside of the village rather than households that attrited for other reasons — whether they took the survey), I constructed household outmigration dummy variable.[16] In this first case of household migration, I am only able to look at the

[16] This is a conservative measure of migration as some farmers are tracked after they moved out in the 2008 survey.

extensive margin of migration, as households can only make a binary decision at that level. I do not observe where households go after they move out. In either case, only rural households are interviewed in this survey, this implies that if a household moves to an urban area, it will not be found again.

Second, I create migration at the individual level for members of the household conditional on the household remaining. Using data from the baseline (in 2000) and for each subsequent follow-up, I create a measure of inmigration and outmigration that captures the extensive margins of migration using information on whether a household i) hosted new members since the previous survey, or ii) sent members out of the household. This measure of outmigration includes marriage, establishing a new household and moving to other relatives. The measure of inmigration includes added members who were never in the households, returnees, and marriage. At the intensive margins, I look at the number of members who migrated (intensive individual migrations).[17]

For the main explanatory variable, the ISP, I have built a dummy that takes the value 1 for households resides in an area that received the subsidy. I also construct a variable equal to the amount received by households through the program, which corresponds to the total quantity acquired through the Food Reserve Agency (FRA) multiplied by the proportion subsidized (0.5 of the price in 2004 and 0.6 in 2008).

Table 5 reports descriptive statistics on intensive migration and ISP. In 2001, no household receives the ISP. It shows in row 2 that the rate of migration is highest for households that receive the ISP, and that migration increases over time, between 2004.

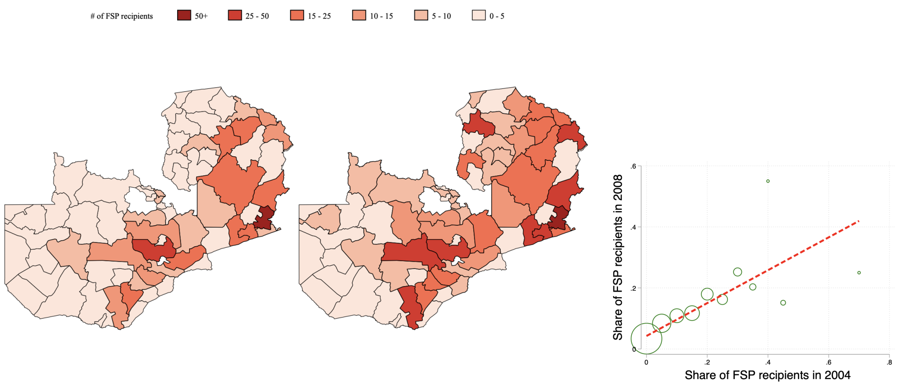
[17] At baseline, in the 1999-2000 agricultural season, there are by construction no household and individual migrants.

Table 5: Household receiving ISP

		2001		2004		2008	
		Total	Percent	Total	% Population	Total	% Population
Total ISP hh		0	0	496	7.17%	525	9.02%
		2001		**2004**		**2008**	
		Total	Percent	Total	% ISP subset	Total	% ISP subset
Received ISP	has outmigrant	0	0	226	46.56%	328	62.48%
	no outmigrants	0	0	270	54.44%	197	37.52%
Received ISP	has inmigrant	0	0	131	26.41%	165	31.43%
	no inmigrants	0	0	365	73.59%	360	68.57%

Source: Author's calculations using the Supplemental Survey to the 1999/2000 Post Harvest Survey - Zambia Data Documentation, revised June 2010.

Figure 6: Maps of ISP recipients per districts in 2004 and 2008



2004

2008

Correlation between the share of recipients (in an SEA) in 2004 and 2008

Notes: Based on the author's calculations. These are recipients in the sample. The shape files used correspond the time period of the study. There have since been changes in districting since 2011.

Table 6: Count of villages per treatment years

Years Receiving ISP	Number of Villages	% of total villages
2003, 2004, 2007, and 2008	133	33.76%
Never	115	29.19%
2007, and 2008	45	11.42%
2003, and 2004	28	7.11%
2004, 2007, and 2008	17	4.31%
2004, only	16	4.06%
2008, only	10	2.54%
2003, 2007, and 2008	7	1.78%
2003, 2004, and 2008	7	1.78%
2003, 2004, and 2007	5	1.27%
2003, only	3	0.76%
2007, only	3	0.76%
2004, and 2007	3	0.76%
2004, and 2008	2	0.51%

Notes: This table shows the count of villages, for each combination of treatment years, ranked by the count of villages in each category. Column (1) shows the combinations of panel years in which at least one household in the village is treated. Column (2) shows the number of villages in each of those treatment combinations, and Colum (3) the share of the total villages that is in this treatment combination. The treatment years 2003, 2004, 2007, and 2008 correspond to the agricultural seasons 2002/2003, 2003/2004, 2006/2007, and 2007/2008. The agricultural years 2002/2003, and 2006/2007 are based on farmer recall from the panel years 2003/2004, and 2007/2008 respectively. Most villages are treated in one year and get treated in subsequent years. Only a handful of villages get treated in years that are not adjacent.

A.2.1 More details on resale markets

Figure 7 plots the self-reported source of fertilizer used in farms. Panel 1 shows the source of fertilizer used in 2004 for households that did not migrate in 2008, and Panel 2 shows the sub-sample of households that migrated in 2008. Each graph plots fertilizer used by farmers owning farms of different sizes against the amount of fertilizer used from each source.[18]

[18] In the sample of Zambian small holders, only 20% report receiving the subsidized fertilizer on time for the 2003-2004 agricultural season. This implies that a large amount of fertilizer used

On the far left two graphs, I plot the fertilizer used on the farm, stemming from the fertilizer subsidy program. The red-dashed line is the 100kg voucher received by all farmers. Any farmer group using more than this amount has likely obtained their vouchers from other farmers (or through other unknown means), and any farmers using less than the red-dashed line have potentially sold their voucher to another farmer. The far-right panel plots the distribution of farm sizes in the sample. Most farms in the sample (1-5 hectares) use exactly the amount provided via the voucher subsidy and supplement with commercial markets. However, some farmers — with very large farms — use more subsidized fertilizer than officially received, and farmers with small farms use less than they have received. This implies a redistribution — across farmers, based on farm sizes and needs.

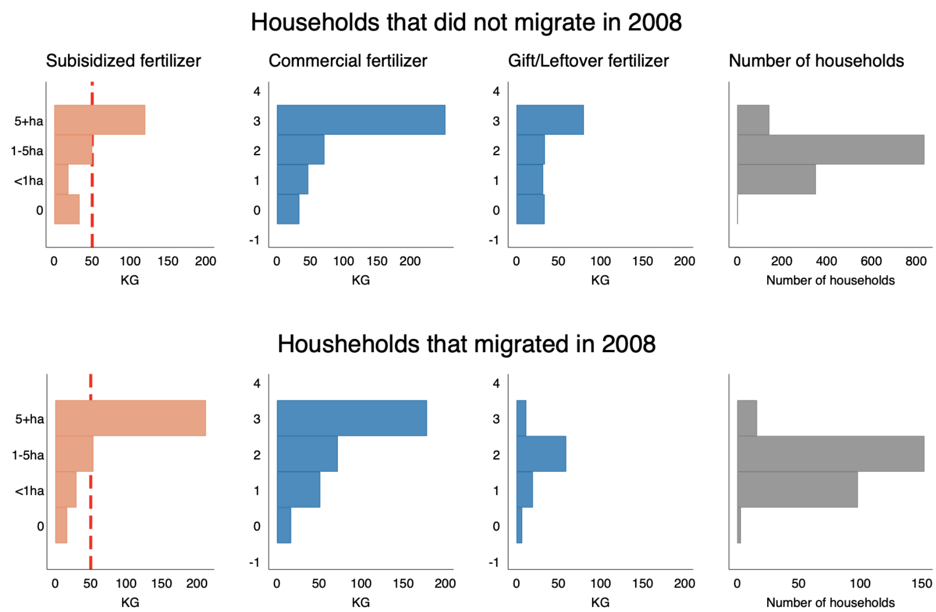


Figure 7: Source of fertilizer used on the farm in 2004

Notes: Using self-reported data from the post-harvest survey of 1999-2000 and its supplemental surveys (panel).

in a given season is from left overs from the previous season. This further implies that to use the fertilizer at the appropriate time in the planting season, most farmers need use left-over fertilizer (of lower quality), commercial or resale markets. Another implication of this delay is that migration becomes in this case more attractive than agriculture because of the lost revenue in agriculture.

Table 7: Number of administrative units in the sample

	2000	2001	2004	2008
Provinces	8	8	8	8
Districts	37	37	37	37
Census Supervisory Areas (CSA)	112	112	112	112
Standard Enumeration Areas (SEA)	394	394	394	394
Households	7,859	7,699	6,922	9,347
Communities				1,053

Source: author's Calculations using the supplemental the 1999/2000 Post Harvest Survey and its supplementary surveys.

Table 8: Characteristics of households in the panel

Panel A: Panel Classification of households		
	Frequency	Percent
Household is found in 2001,04,08	4,288	61.9
Household is found in 2001 only	1,273	18.4
Household is found in 2001 & 2004 only	1,070	15.15
Household is found in 2004 & 2008 only	52	0.8
Household is found in 2000 & 2008 only	230	3.3
Household is not found*	9	0.1
Household is found in 2000 only	777	-
Total number of households	7,699	-

* The household was interviewed in 2004 or 2008 but was not the same as the one interviewed in 2001

Panel B: household survey response status			
B.1 Non-migrant households	2001	2004	2008
Completed	6,922	5,419	4,301
Skipped & not interviewed	0	30	0
Currently away from home	0	0	55
Non-contact	337	362	0
Refusal	3	14	22
Dissolved	85	390	366
B.2 Migrant households	2001	2004	2008
Completed after moving to another village	0	0	269
Moved out of village	352	707	810
Total number of households	7,699	6,922	5,823

Source: author's Calculations using the supplemental Survey to the 1999/2000. Panel A of 8 shows when households are found in the panel, and Panel B displays the response statuses of households in the sample for each follow-up year of the panel. In section B.2. of Panel B, are the households I define as migrant households.

A.2.2 More details on the context of the Zambian ISP

In response to generally low fertilizer take-up, the Zambian government has designed several programs to improve the adoption of fertilizer and improved seeds by addressing both the lack of liquidity and the low profitability of fertilizers. Until 2001, a loan program called the *Fertilizer Credit Program* was in place, allowing farmers to mitigate credit constraints. As a loan program, the *Fertilizer Credit Program* did not meet its repayment goals, achieving a repayment rate of only 30%. In 2001, the *Fertilizer Support program* (FSP) later renamed *Farmer Input Support Program* (FISP) replaced the *Fertilizer Credit Program*. The FSP provided a 50% subsidy to farmers with holdings between one and five hectares of land. This subsidy increased to 60% in the 2006/2007 season and reached 76% in the 2010/2011 season.

The FSP represented a substantial financial effort by the Zambian government. Between 2004 and 2011, the FSP alone accounted for 38% of Zambia's agricultural spending and 47% of the government's agricultural sector Poverty Reduction Program (Mason et al., 2013).

Table 9: Public budget: Agricultural Sector, 2004/05, Zambia

Program	Percent
Fertilizer Support program	38%
Personal Emolument	21%
Food reserve agency maize marketing	13%
Food Security Pack (PAM) & Emergency Drought Recovery Project	12%
Operational funds	11%
Irrigation development	3%
Irrigation development	3%
Infrastructure	2%

Source: World bank Fertilizer toolkit

Improving agricultural productivity is the main goal of this policy. However, such large investments could have substantial indirect impact on migrations to urban poles. The share of the population living in rural areas has been shrinking rapidly while the share of the population living in urban areas has been rising. This phenomenon happened concurrently with large investment in input subsidies.[19]

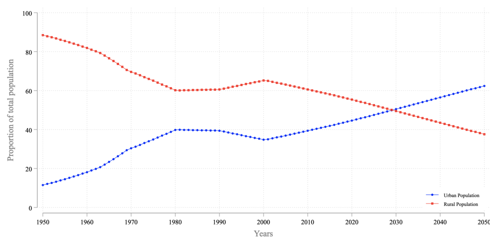


Figure 8: Rural and Urban Population in Zambia (with projections)
Source: United Nations, World Urbanization Prospects: The 2018 Revision.

[19]See Figure 8 in the Appendix showing the evolution and previsions of urban and rural populations in Zambia.

A.2.3 Timeline of agricultural programs

Zambia has a long history of fertilizer subsidy programs. In the wake of global structural adjustments initiated by the International Monetary Fund (IMF) and the World Bank, Zambia relied heavily on fertilizer subsidy programs to support its agricultural sector. With both a debt relief through the Heavily Indebted Poor Countries program and a transition from conditionality to direct budget support by the World Bank, the country was able to launch the *Fertilizer Support Program* (FSP) and scale up its subsidy agenda increasing from an average of roughly 40,000 metric tons of fertilizer delivered per year to about 65,000 metric tons per year (Minde et al., 2008). The FSP was a cash-only program, unlike previous credit programs; it subsidized fertilizer purchases at a at a 50% rate, focusing on maize production. In 2006 the program was extended to 84,000 metric tons per year and the subsidy was raised to 60% (Mason et al., 2013). In conjunction with the FSP and on a much smaller scale, the Food Security Pack or Program Against Malnutrition (PAM), an agricultural input grant targeting vulnerable households with holdings under 1 hectare was put in place. According to Mason et al. (2013), this program has very low political inference.

In Figure 9, I summarize the main agricultural programs from 1991 to 2008, including fertilizer subsidy programs that preceded the FSP. According the program guidelines, first a cooperative or farmer was chosen and then subsidized inputs were given to farmers. Selection criteria apply to both components and include wealth, financial capacity at the cooperative level, field size and financing capacity criteria. Farmer organizations as well as cooperatives are channels through which FSP inputs are distributed. Farmers are required to be members of a cooperative or an organization, and each organization proposes eligible farmers to benefit from the subsidy.
Below is a short presentation of the ex-ante eligibility rules on each layer.

Cooperative or farmer group eligibility rules (partially quoted from World Bank (2010))

1. Written by-laws to manage their funds and have appropriate accountability mechanisms;

2. Have an executive committee structure and should operate a bank ac-

count;

3. Demonstrate the need and ability to use the inputs well;

4. Should be registered by the Registrar of Cooperative Societies and Registrar of Societies;

5. Should have no outstanding loans from the past seasons;

6. Should be located in an agricultural area and should be engaged in agricultural activities;

7. Should demonstrate knowledge in cooperative and agribusiness 'management.

Farmer selection criteria

1. Should be a small scale farmer and involved in farming within the cooperative coverage area;

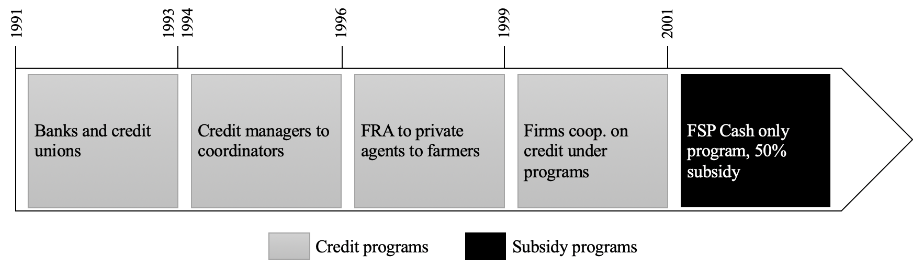
2. Has the capacity to grow 1-5 hectares of maize;

3. Should have the capacity to pay 40% of the cost of inputs;

4. Should not concurrently benefit from the Food Security Pack;

5. Should not be a defaulter from FRA and/or any other agricultural credit program.

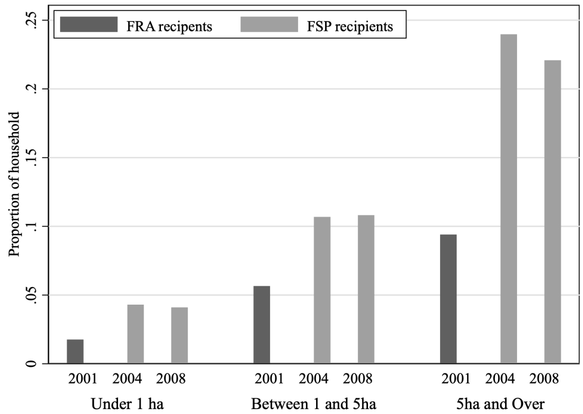
Figure 9: Timeline of agricultural programs (from 1991 onwards)



Source: Author.

These selection criteria do not fully apply. Figure 10 shows the distribution of FSP beneficiaries over the years and across land holdings. I use Mason et al. (2013) definition of land holdings as the sum of cultivated and fallow land. With this definition of landholdings, a striking inadequacy to FSP guidelines arises: a high proportion of the sample's "over five hectares landholders" receive a subsidy, when they should not be eligible. Similarly, a few farmers with landholdings under one hectare receive the subsidy; this proportion is however substantially than that of medium landholders. This limited discrepancy is likely due to the existence of the PAM program for farmers with landholdings under one hectare.

Figure 10: Proportion of FRA and FSP recipients over effective field size



Source: Author's computations

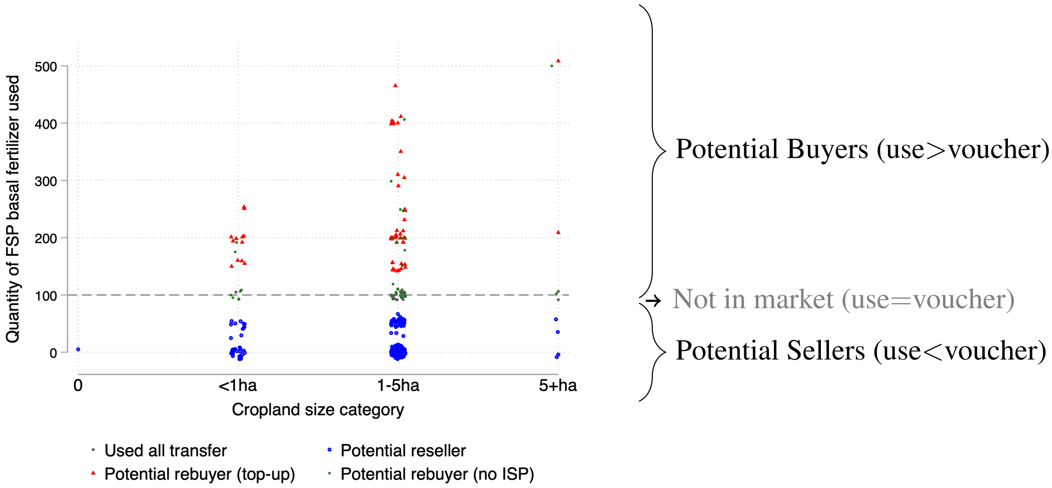
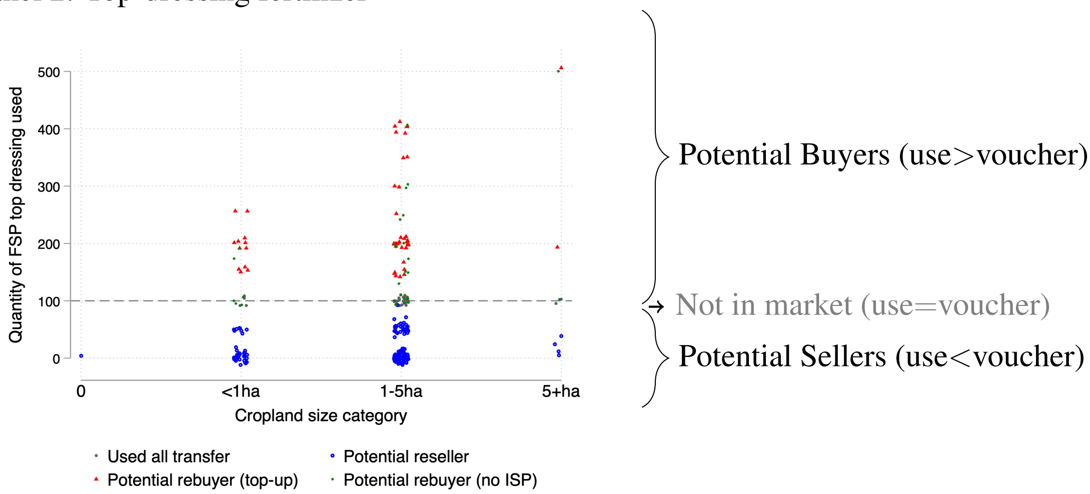


Figure 11: Subsidized basal fertilizer used vs. received

Notes: Using self-reported data on basal fertilizer for the year 2004 from the post-harvest survey of 1999-2000 and its supplemental surveys (panel). The horizontal line is 100kg (the amount received by farmers). Each dot represents the quantity of fertilizer used by one household with a random small perturbation to get a clearer representation of the number of households. The potential resellers are those who report to have used less than the 100kg received, and the potential re-buyers are those who report using more than 100kg.

Panel 2: Top-dressing fertilizer



Panel 2: Basal fertilizer

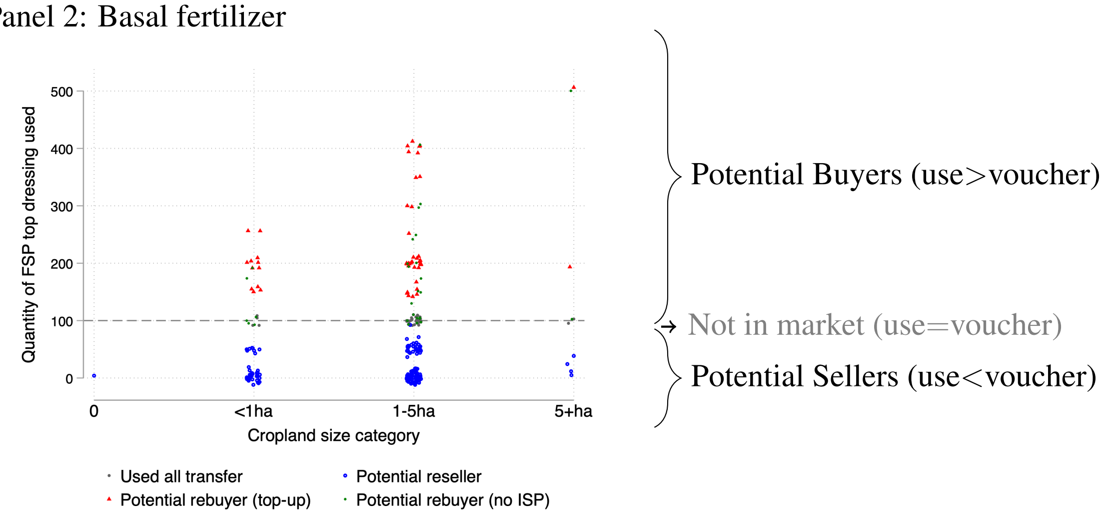


Figure 12: Subsidized fertilizer used on farm compared to quantity transferred

Notes: Using self-reported data on top-dressing fertilizer for the year 2004 from the Post-harvest survey of 1999-2000 and its supplemental surveys (panel). The horizontal line is 100kg (the amount received by farmers). Each dot represents the quantity of fertilizer used by one household with a random small perturbation to get a clearer representation of the number of households. The potential resellers are those who report to have used less than the 100kg received, and the potential re-buyers are those who report using more than 100kg.

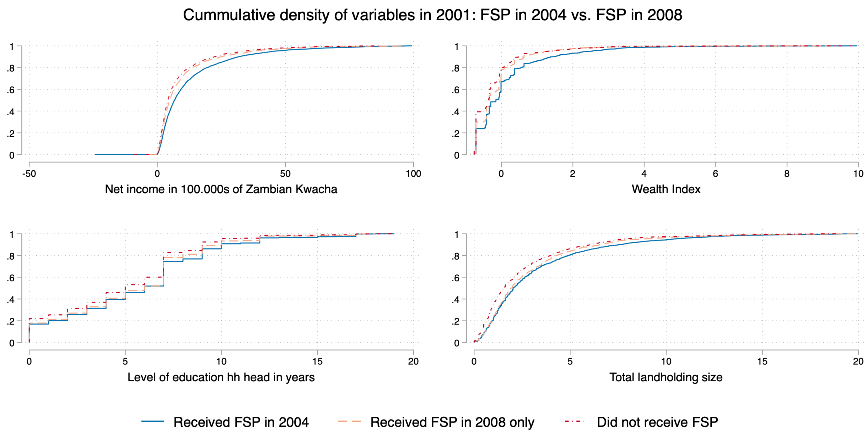


Figure 13: Baseline characteristics between households in areas that received the subsidy in 2004, 2008 and in areas that did not receive the subsidy

Table 10: Descriptive statistics: Check of the randomness of attrition

		2001 (marginal migration)						
		Control		hh that migrated		Overall population		Fstat
		Mean	Count	Mean	Count	Mean	Count	Fstat
Baseline Data (2000)	# of hh members at	6.4471213	7347	6.0596591	352	6.4294064	7699	3.810914
	Gender of hh head	.77991017	7347	.77272727	352	.77958176	7699	.10083262
	Age of the hh Head	43.742344	7347	40.849432	352	43.610079	7699	14.084706
	Wealth: plough/harrow/oxcart	.0197822	7347	-.24689173	352	.00758981	7699	23.535343
	hh head is relative to headman	.29875758	6922	.	.	.	.	.
Data from 1^{st} wave	Dwelling has concrete walls	.23793701	6922	.	.	.	.	.
	Dwelling has traditional doors	.63218723	6922	.	.	.	.	.
	Dwelling has traditional floor	.82692863	6922	.	.	.	.	.
	hh head is single	.02879051	6912	.	.	.	.	.
	hh head is monogamous	.68156829	6912	.	.	.	.	.
	hh head is polygamous	.10026042	6912	.	.	.	.	.
	hh head is divorced	.06438079	6912	.	.	.	.	.
	hh head is widowed	.11212384	6912	.	.	.	.	.
	hh head is separated	.01229745	6912	.	.	.	.	.
	hh head went over primary	.22468171	6912	.	.	.	.	.
	Crop land: purchased	.02531646	7347	.	.	.	.	.
	Crop land: inherited	.26391725	7347	.	.	.	.	.
	Crop land: allocated	.47515993	7347	.	.	.	.	.
	Crop land: rented or borrowed	.03906356	7347	.	.	.	.	.
	Crop land: walked in	.10984075	7347	.	.	.	.	.

		2004 (marginal migration)						
		Control		hh that migrated		Overall population		Fstat
		Mean	Count	Mean	Count	Mean	Count	Fstat
Baseline Data (2000)	# of hh members at	6.5129525	6215	6.115983	707	6.4724068	6922	7.4347452
	Gender of hh head	.78213998	6215	.78076379	707	.78199942	6922	.00705016
	Age of the hh Head	44.221078	6215	40.707214	707	43.862179	6922	39.076983
	Wealth: plough/harrow/oxcart	.04877885	6215	-.15651119	707	.02781092	6922	25.091304
	hh head is relative to headman	.30893001	6215	.20933522	707	.29875758	6922	30.177228
Data from 1^{st} wave 2001	Dwelling has concrete walls	.23604183	6215	.25459689	707	.23793701	6922	1.2051765
	Dwelling has traditional doors	.6305712	6215	.64639321	707	.63218723	6922	.68327767
	Dwelling has traditional floor	.83185841	6215	.78359264	707	.82692863	6922	10.345162
	hh head is single	.02690511	6207	.04539007	705	.02879051	6912	7.7428842
	hh head is monogamous	.67794426	6207	.71347518	705	.68156829	6912	3.6834954
	hh head is polygamous	.10359272	6207	.07092199	705	.10026042	6912	7.4969356
	hh head is divorced	.0650878	6207	.05815603	705	.06438079	6912	.50490163
	hh head is widowed	.11390366	6207	.0964539	705	.11212384	6912	1.9363841
	hh head is separated	.01192202	6207	.01560284	705	.01229745	6912	.70604446
	hh head went over primary	.21636862	6207	.29787234	705	.22468171	6912	24.219666
	Crop land: purchased	.02606597	6215	.03394625	707	.02687085	6922	1.5074044
	Crop land: inherited	.28897828	6215	.20226308	707	.28012135	6922	23.745211
	Crop land: allocated	.50329847	6215	.51343706	707	.50433401	6922	.260956
	Crop land: rented or borrowed	.03700724	6215	.08062235	707	.04146201	6922	30.509018
	Crop land: walked in	.11713596	6215	.11173975	707	.1165848	6922	.17942649

		2008 (marginal migration)						
		Control		hh that migrated		Overall population		Fstat
		Mean	Count	Mean	Count	Mean	Count	Fstat
Baseline Data (2000)	# of hh members at	6.6892917	4744	6.0889713	1079	6.5780526	5823	22.969793
	Gender of hh head	.78604553	4744	.79147359	1079	.78705135	5823	.15448711
	Age of the hh Head	44.657884	4744	41.947173	1079	44.15559	5823	32.295405
	Wealth: plough/harrow/oxcart	.10329099	4744	-.14177328	1079	.05788066	5823	46.175744
	hh head is relative to headman	.32145868	4744	.26227989	1079	.31049287	5823	14.410725
Data from 1^{st}wave 2001	Dwelling has concrete walls	.22934233	4744	.28174235	1079	.23905204	5823	13.294638
	Dwelling has traditional door	.65029511	4744	.52548656	1079	.62716813	5823	59.135948
	Dwelling has traditional floor	.83579258	4744	.80537535	1079	.83015628	5823	5.772057
	hh head is single	.02617138	4738	.03061224	1078	.0269945	5816	.65922519
	hh head is monogamous	.68235542	4738	.70315399	1078	.68621045	5816	1.7641794
	hh head is polygamous	.10827353	4738	.09276438	1078	.1053989	5816	2.2403616
	hh head is divorced	.05951878	4738	.07606679	1078	.06258597	5816	4.1004275
	hh head is widowed	.11059519	4738	.09183673	1078	.10711829	5816	3.2316019
	hh head is separated	.01266357	4738	.00556586	1078	.01134801	5816	3.944645
	hh head went over primary	.20768257	4738	.26437848	1078	.2181912	5816	16.589879
	Crop land: purchased	.01499758	8268	.02780352	1079	.01647587	9347	9.6670785
	Crop land: inherited	.16872279	8268	.26506024	1079	.1798438	9347	60.430249
	Crop land: allocated	.29354136	8268	.48007414	1079	.31507436	9347	156.43007
	Crop land: rented or borrowed	.01717465	8268	.06209453	1079	.02236012	9347	88.91885
	Crop land: walked in	.06470731	8268	.1334569	1079	.07264363	9347	67.433468

Table 11: Descriptive statistics on migrant households

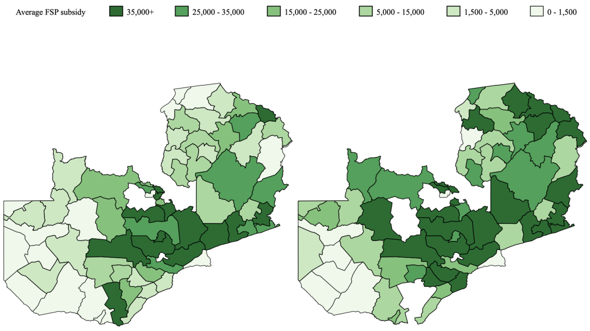
		2001 Over whole population			2004 Over Household migrant groups		
	variables	Control SEAs	Treated SEAs	Overall mean	Control SEAs	Treated SEAs	Overall mean
	head count	2,824	4,098	6,922	314	393	707
Baseline Data (2000)	Gender of hh head	.7510623	.8033187	.7819994	.7611465	.7964377	.7807638
	Age of the hh Head	43.85021	43.87043	43.86218	41.707	39.9084	40.70721
	Wealth: plough/harrow/oxcart	-.0898935	.108923	.0278109	-.2271424	-.1000781	-.1565112
	hh head is relative to headman	.3427762	.2684236	.2987576	.2133758	.2061069	.2093352
Data from 1^{st} wave	Dwelling has concrete walls	.207153	.2591508	.237937	.2070064	.2926209	.2545969
	Dwelling has traditional floor	.8626062	.8023426	.8269286	.8184713	.7557252	.7835926
	Dwelling has traditional doors	.6745751	.602977	.6321872	.6910828	.610687	.6463932
	hh head is single	.030873	.0273571	.0287905	.0319489	.0561224	.0453901
	hh head is monogamous	.6628815	.6944309	.6815683	.7060703	.7193878	.7134752
	hh head is polygamous	.092264	.1057645	.1002604	.0638978	.0765306	.070922
	hh head is divorced	.0798439	.0537372	.0643808	.0798722	.0408163	.058156
	hh head is widowed	.1192335	.1072301	.1121238	.1022364	.0918367	.0964539
	hh head is separated	.0138396	.011236	.0122974	.0159744	.0153061	.0156028
	hh head went over primary	.1816891	.2542745	.2246817	.2428115	.3418367	.2978723

Table 12: Quantity and revenue per hectare (ha) in 2001 for ISP recipients in 2004, by migration status in 2008

2001 harvest per ha	Household migrated in 2008							
	Outcomes in 2001				Outcomes in 2008			
	Migrated	Stayed	Diff.	P-value	Migrated	Stayed	Diff.	P-value
Total land holdings	9.53	5.28	81%	0			.	
Adults in the household	4.16	4.39	-5%	.033			.	
Kg of maize	1085	1021	6%	0			.	
GV of maize	245032	227986	7%	0			.	
GV of all	348680	346478	1%	.112			.	
GV of cash crops	17804	30761	-42%	.635			.	
GV of other staples	63352	60578	5%	.792			.	
GV of high value food	22492	27153	-17%	.889			.	
	Household with 1+ inmigrant in 2008							
	Inmig.	No inmig.	Diff.	P-value	Inmig.	No inmig.	Diff.	P-value
Total land holdings	5.68	6.07	-7%	0	5.8	5.17	12%	.041
Adults in the household	4.76	3.94	21%	0	6.66	5.21	28%	0
Kg of maize	1033	1028	0%	0	966	878	10%	0
GV of maize	219829	241390	-9%	.004	715023	616373	16%	0
GV of all	341323	352501	-3%	.11	1085416	936524	16%	0
GV of cash crops	38171	19307	98%	0	127045	115201	10%	.001
GV of other staples	58693	63343	-7%	.284	155017	97158	60%	.052
GV of high value food	24630	28461	-13%	.748	87596	105605	-17%	.461
	Household with 1+ outmigrant in 2008							
	Outmig.	No outmig.	Difference	P-value	Outmig.	No outmigrants	Difference	P-value
Total land holdings	5.56	6.28	-12%	0	5.59	5.37	4%	.041
Adults in the household	4.9	3.64	35%	0	6.79	4.42	54%	0
Kg of maize	1078	966	12%	0	1039	708	47%	0
GV of maize	224586	238055	-6%	.001	753906	508279	48%	0
GV of all	349180	343600	2%	.055	1109458	841663	32%	0
GV of cash crops	36798	18515	99%	0	153395	59489	158%	0
GV of other staples	65806	54527	21%	.416	110925	165616	-33%	.001
GV of high value food	21991	32504	-32%	.998	91030	104578	-13%	.599

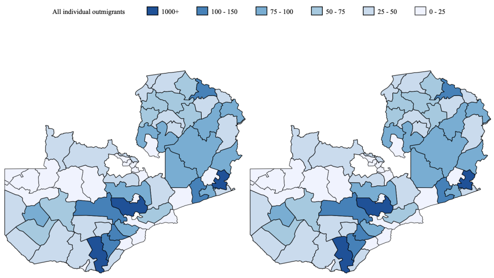
GV: Gross value

A.3 Comparing households with different labor allocation choices

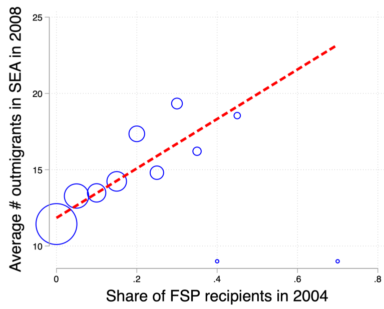


2004 2008

Figure 14: Average amount (ISP) disbursed per household in 2004 and 2008 - by district



2004 2008



Average count of outmigrants in SEA in 2008 vs. Share of ISP recipients in 2004

Figure 15: Maps of the number of individual outmigrants in 2004 and 2008 - Per district

Table 13: Characteristics of households across upgrading decisions

	No outmigration		Migration by 2004		Migration by 2008		Migration in 2004 and 2008	
Mean at	Baseline	Endline	Baseline	Endline	Baseline	Endline	Baseline	Endline
				Household characteristics				
HH size	5.73	5.48	6.59	6.30	6.73	6.38	7.78	7.30
Share upgraders	.18	0	.46	0	.46	1	.72	1
Share with inmigrant	0	.01	0	.01	0	.05	0	.05
Share with outmigrant	.07	.36	.10	.40	.10	.56	.11	.62
Number Outmigrants	.12	.94	.12	1.25	.11	1.22	.18	1.42
Education outmigrants	.40	0	.46	0	.41	0	.75	0
				Household's head characteristics				
HHH education	5.07	4.51	6.57	5.69	5.71	5.90	6.65	6.71
Share woman	.20	.20	.17	.15	.14	.15	.14	.18
				Farming characteristics				
Total landholding	2.39	1.83	2.86	2.20	3.40	2.89	4.69	4.28
Share of maize	.56	.52	.56	.55	.55	.55	.57	.60
Fertilizer per ha maize	60	33	138	114	110	229	192	297
Fertilizer per ha total	27	12	62	54	51	107	103	163
Maize Yields	1622	1321	1962	1524	1878	1953	2190	2324
				Financial characteristics				
Remittances received	21349	97548	34631	133835	28419	155842	34867	325285
Remittances sent	13986	61467	20722	143945	23642	228724	34946	326411
Wealth index 2001	-.10	-.17	.28	.28	.18	.18	.76	.76
N	2473	1567	624	624	407	407	633	633

Table 14: Characteristics of households across outmigration decisions

	No outmigration		Migration by 2004		Migration by 2008		Migration in 2004 and 2008	
Mean at	Baseline	Endline	Baseline	Endline	Baseline	Endline	Baseline	Endline
				Household characteristics				
HH size	5.09	6.17	7.03	6.13	6.26	6.05	9.05	6.48
Number Outmigrants	.07	0	.23	0	.09	1.96	.25	2.25
Share upgraders	.25	.23	.37	.23	.37	.37	.47	.50
Share with inmigrant	0	.01	0	.01	0	.02	0	.07
Share with outmigrant	.05	0	.18	0	.07	1	.17	1
Education outmigrants	.28	0	.91	0	.23	0	.93	0
				Household's head characteristics				
Share woman	.15	.10	.21	.17	.20	.25	.18	.25
HHH education	5.86	5.55	5.69	5.25	5.28	5.19	5.5	5.80
				Farming characteristics				
Total landholding	2.38	2.13	3	2.33	3.26	2.72	4.11	3.39
Share of maize	.56	.52	.56	.56	.55	.55	.57	.58
Fertilizer total	46	56	50	72	44	66	58	93
Fertilizer maize	99	121	110	164	97	147	123	181
Maize Yields	1702	1624	1871	1808	1867	1722	1996	1824
				Financial characteristics				
Remittances received	23105	101743	35749	181735	19933	140002	35662	274593
Remittances sent	17706	88786	17446	201084	17140	138898	30326	268956
Wealth index 2001	-.05	-.05	.15	.15	.11	.11	.55	.55
N	2080	1174	610	610	812	812	635	635

Table 15: Characteristics of households across inmigration decisions

	No inmigration		Migration by 2004		Migration by 2008		Migration in 2004 and 2008	
Mean at	Baseline	Endline	Baseline	Endline	Baseline	Endline	Baseline	Endline
				Household characteristics				
HH size	6.57	6.23	5.94	.	7.11	6.80	7	6.36
Share upgraders	.37	.40	.34	0	.40	.51	.38	.38
Share with inmigrant	0	0	0	0	0	1	0	0
Share with outmigrant	.09	.52	.10	0	.20	.67	.09	.80
Number Outmigrants	.12	1.08	.14	.	.33	1.70	.10	2.05
Education outmigrants	.43	0	.51	.	1.38	0	.50	0
				Household's head characteristics				
HHH education	5.46	5.44	6.11	.	5.01	5.15	5.21	5.25
Share woman	.17	.20	.20	0	.33	.41	.25	.34
				Farming characteristics				
Total landholding	3.17	2.58	2.54	.	3.88	4.32	3.27	2.97
Share of maize	.55	.56	.57	.	.60	.58	.56	.55
Fertilizer per ha maize	105	142	99		99	201	107	180
Fertilizer per ha total	47	69	48		53	93	51	77
Maize Yields	1843	1716	1755		1626	1945	1931	1737
				Financial characteristics				
Remittances received	23137	159927	34464		30086	227614	34895	238670
Remittances sent	17644	155509	22567		23722	173409	26658	231895
Wealth index 2001	.14	.14	.12	.12	.5	.5	.27	.27
N	2212	2212	508	508	83	83	188	188

A.4 More on the reduced-form estimation

A.4.1 Source of variation

The post-harvest panel starts in 2000 (the baseline year) and follows-up with households in 2001, 2004, and 2008. The 2004 surveys constitute the first round of data after the introduction of the subsidy policy. Given this data structure, I observe four village groups: i) areas that never received the ISP subsidy, ii) areas that received the ISP subsidy in 2004, iii) areas that received the ISP subsidy in 2008 and finally iv) areas that received the subsidy in both 2004 and 2008.

A.4.2 Difference-in-differences

A.5 Robustness checks

A.6 SUTVA test for difference and difference

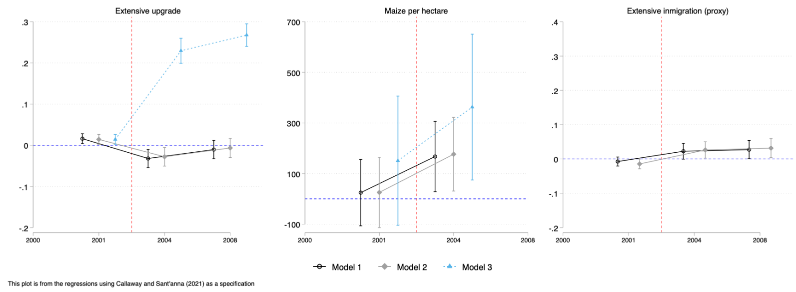
A first issue with the estimation of the difference-in-differences is the possibility that the stable unit treatment value assumption (SUTVA) does not hold. In the Zambian ISP setting that would imply two things: a) the spillover effects could occur across treatment units, i.e. farmers in treated areas selling to farmers in control areas, and thus relaxing credit constraints for farmers in the treated areas, while increasing access to fertilizer in control areas. With these spillovers, migration is overestimated — as the control group increases its demand and thus puts pressure on fertilizer prices — and upgrading is underestimated as the control group would adopt because of the ISP; b) the roll-out of the subsidy should also affect the network of fertilizer suppliers, thus making it easier for farmers in control groups to adopt fertilizer due to the ISP.

Both channels — through trade across treatment status and through the network of suppliers — could bias the results presented in the paper. There are however limitations in the panel that hamper my ability to check for the existence of these sources of the SUTVA violation.

The sampling of villages[20] is such that villages are unlikely bordering each other. However, to check for the importance of spillovers in our sample, I look at the variations in the price of commercial fertilizer across high and low treat-

[20]These villages correspond to Standard Enumeration Areas (SEA) and are the least aggregated and include typically one village (see Table 7 of the Appendix).

Panel 1: Direct effects on upgrading: difference-in-differences results



Panel 2: Indirect effects on migration: difference-in-differences results

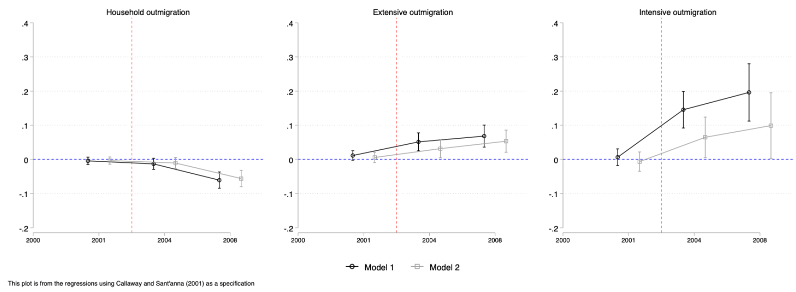


Figure 16: Difference-in-differences results using Callaway and Sant'Anna (2021)

Notes: Results from the difference-in-differences estimation at the household level within treated areas using Callaway and Sant'Anna (2021). Dependant variables are given in each graph's subtitle. Showing actual data for the 1999/2000, 2000/2001, 2003/2004, 2007/2008 agricultural seasons. Showing results for areas treated in 2004. Each model corresponds to a different specification. Model 1 does not include baseline controls, Model 2 includes household size at baseline, Model 3 includes upgrade at baseline. Standard errors are robust and asymptotic derived from Influence Functions.

ment density areas. If spillovers are important, the expectation is that high treatment density areas to have more variations in prices (both a potential increase in prices if demand effects dominate or decrease in prices if supply network effects dominate). The results are presented in Figure 17 of Appendix A.5.

Prices have not significantly changed in for control households located in areas with a high concentration of ISP recipients in 2004. Albeit representing a large portion of farmers in Zambia, the 1 to 5 hectare holders do not have as much market power as would larger farms, and in 2004, at the onset of the ISP the effect of the subsidy may not have been as important on national prices as they would have been in the later years of the ISP.

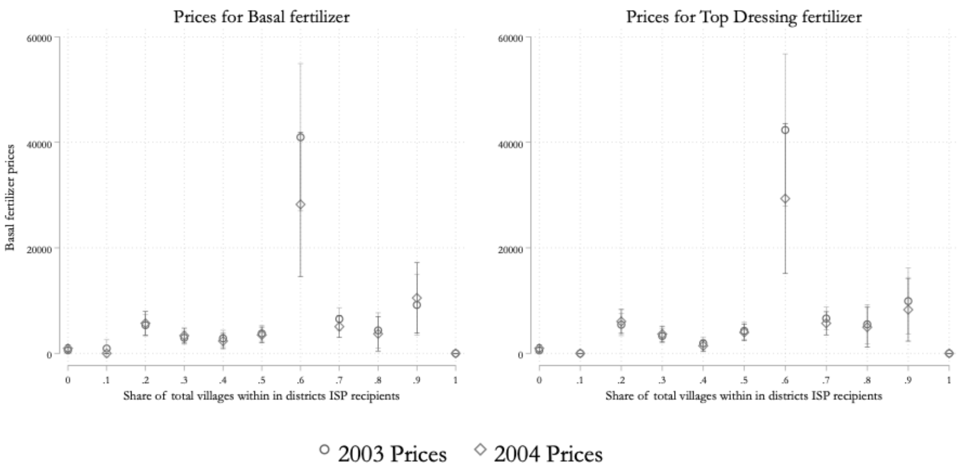


Figure 17: Sutva test: change in fertilizer prices for non ISP recipients, depending on concentration of ISP villages in districts

A.6.1 An instrumental variable approach to political clientelism

To circumvent potential issues of omitted variable bias in identifying the impact of the subsidy on individual migrations I will use political clientelism findings by Mason et al. (2013) and Mason et al. (2017) in an instrumental variable design. Mason et al. (2013) find high dependence of the allocation on political variables — farmers in constituencies won by the incumbent president receive higher quantities of subsidized fertilizer — confirming political clientelism in the allocation of ISP subsidies. We can exploit the variations in the distribution of subsidies at the constituency level created by political clientelism to measure the impact of the policy on migrations.[21] In this setting we would only be capturing the variations in migrations due to political-clientelism-motivated-subsidies; a Local Average Treatment Effect (LATE) on those who benefited from the subsidy due to presidential elections outcomes in their constituency. In this section I explore the variations in the probability of receiving the subsidy within across constituencies rather than the villages of the main specification. An instrumental variable strategy offers the opportunity to see if the ISP impacts migrations disproportionally through political clientelism, which would differ from the the difference-in-differences estimator of the main specification.

To pursue this strategy, I use results of the 1996, 2001 and 2006 presidential elections from the the Electoral Commission of Zambia (ECZ).

In this design, I use the interaction between the election results at the constituency level — I matched all household in the sample to constituencies results at the presidential elections of 1996, 2001 and 2006 — and the distance to the closest subsidized inputs' provider to instrument the reception of subsidies by a household. I estimate the effects with the following model:

$$\begin{aligned}
\text{1st Stage:} \quad T_{h,t} &= \pi_0 + \pi_1 V_{c,t} * dist_{h,t} + \pi_2 V_{c,t} + \pi_3 dist_{h,t} + \nu_h + \eta_t + u_{h,t} \\
\text{2nd Stage:} \quad Y_{h,t} &= \alpha + \beta \widehat{T}_{h,t} + \nu_h + \eta_t + \epsilon_{h,t}
\end{aligned}$$

Where Y_k is alternatively extensive and intensive margin of individual out- and inmigration at the household level; $T_{h,t}$ is the endogenous variable: a dummy for ISP recipientship; $V_{c,t}$ is a dummy variable equal to 1 if the household lives in a constituency won by the incumbent president at the previous elections; $dist_{h,t}$ distance to closest buying point; ν_h household fixed effect; η_t time fixed effect. Standard errors are clustered at the household level.

There are two ways to interpret this instrument. A first interpretation is a measure of the effort produced by the governments to reach constituents that are far away from subsidized inputs' providers. If the first stage of the IV estimation yields a positive coefficient, then, we can infer that the incumbent's administration is making more efforts to reach its constituents who voted for the incumbent than its constituents who did not vote for him. An alternative interpretation of

[21] The constituencies in Zambia are larger than the SEA, so these political economy results should not invalidate the cross-village measures of migration found with the difference-in-differences estimation.

the IV could be a measure of the incumbent's administration likelihood to place input providers closer to constituents who voted for the incumbent president. Both of these interpretations suggest that a positive coefficient in the first stage demonstrates political clientelism in the allocation of subsidies.

This IV estimation is a local average treatment effect (LATE) on households that benefited from the program due to their votes and their proximity to an FRA buying point[22]. For this interaction term to be a valid instrument it needs to have two basic features. First it needs to be correlated with the endogenous variable and second it needs to be excluded from the second stage, meaning it is necessary for it to be correlated to the dependent variable only through its correlation with the endogenous variable.

Mason et al. (2013) showed that areas in constituencies won by the Movement for Multi-Party Democracy (MMD) at presidential receive more quantity of fertilizer at a subsidized price, i.e. fertilizers are used as a reward voting behaviors. Mason et al. (2017) find that this political impact switches when the incumbent wins a constituency and does not change gradually with the margin of the win. Because I use the data from presidential elections preceding each survey dates, the clientelism is about rewarding a vote for an incumbent. The FRA being the main distributor of subsidized fertilizer, and a major tool for political clientelism, therefore the interaction will capture most of the existing political clientelism.

Voting behaviors and distance are both endogenous variables as they can affect receiving ISP through channels such as distance to the capital and distance spatial correlation of party affiliation. It is unlikely that voting patterns in a constituency influences the decision to migrate only through the ISP subsidy. That is because, the distance to Lusaka could be both correlated with decisions to migrate and voting outcomes. Although this can be addressed with panel fixed effects, we assume that other variables such as the level of information and the size of cooperative heads' network are correlated with both the outcomes (propensity to migrate and number of migrants) and the instrument, challenging the use of voting pattern only as an instrument. In addition, there is evidence that voting patterns affect public goods provision (Burgess et al., 2013; Easterly and Ross, 1997), including the provision of roads which clearly affects migrations outside of the ISP framework. Yet, because constituencies are higher level

[22]Distance to FRA buying point is measured at the community level.

of aggregation than villages, we can assume that voting pattern at the village level have little impact on the voting pattern at the level of constituencies and thus I believe the bias through this variable to be lower than if constituencies corresponded to villages.

Proximity to an FRA buying point alone could also be correlated to other agricultural programs such as the PAM (another fertilizer program for very small land owners)[23], which could also have an impact on migrations. Furthermore, it is hard to believe that proximity to fertilizer providers cab have an impact on decisions to migrate through other channels. Yet, if ISP fertilizer providers' locations are highly correlated (positively or negatively) with urban areas, there might be an issue in terms the decision to migrate. One can argue that distance to main cities have an impact on migrations through, for instance, determinants of the labor markets in the city. This could bias the estimation (though unlikely) and to address this concern, I can control for distance to urban areas and other relevant landmarks.

The interaction of these two variables on the other hand should rule out most biases. Indeed Mason et al. (2013) showed that PAM program is not subject to much political manipulations and it is hard to think of variables correlated with the interaction of both variables that can affect migrations. If one considers the example used earlier, i.e. non-related policies being sensitive to election results, I believe they should not be sensitive to the distance to FRA buying points and thus the interaction should capture only the ISP. On the other hand, if the reception of the PAM is correlated to the distance to FRA buying points, it was shown by Mason et al. (2013) not to be very sensitive to political variations, again in this case the interaction should capture only the effect of the ISP.

Table 16 shows the first stage regression of the Instrumental variable estimation. There is a strong positive correlation between the instrument and the ISP variable, and an F-statistic at 74.58. It means that households further away from FRA collection points get more subsidies when they are in constituencies won by MMD. In other words, authorities put more efforts in reaching households

[23]In conjunction with the ISP and on a much smaller scale, the Zambian government rolled out another program called the Food Security Pack or Program Against Malnutrition (PAM). PAM is seen primarily as a social transfer program, rather than a productivity enhancing program; it targets vulnerable households with holdings under one hectare and promotes diversification and conservation farming (Chirwa and Dorward, 2013). According to Mason et al. (2013), PAM has very low political interference and has no overlap at the household level with the ISP.

further away from FRA points when they voted for MMD. Albeit, a small point estimate, if scaled by the distance of each individual dwelling to the FRA buying point, it can become quite substantial. For instance, the average household lives 21.7km from the closest FRA buying point, this implies that there is a 3 percentage points change in the likelihood that the average household gets the FRA if they are from a constituency that has voted for the incumbent. Note that living in a constituency won by MMD offsets the negative effect of distance.

In the second stage, we see a strong and significant effect of the ISP on outmigrations and inmigration, implying an arbitrage of the household on who to assign to which activity. Table 16 shows results of the IV-estimation of the impact of the ISP on the outmigration and inmigration. Similarly to implications of the model in section 5, when additional income is given to the household, and relaxes the credit constraint of households, they make allocative decisions on who to send and who to host based on respective comparative advantages of household current and prospect members. Keeping in mind the LATE interpretation of the coefficient, we can only make these conclusions for households that benefit from the subsidy due to the ISP.

Table 16: Individual outmigrations and inmigration IV estimations

	First Stage		Extensive Migration		Intensive Migration		
	Stage 1 OLS iv	Stage 1 probit	Outmig 2SProbit	Inmig 2SLS	Outmig 2SProbit	Inmig 2SLS	Netmig 2SLS
MMD*Distance	0.00141***	0.000915***					
	(0.000166)	(0.000214)					
ISP			0.123	0.174**	3.031***	0.691*	2.435***
			(0.114)	(0.0786)	(0.739)	(0.375)	(0.796)
MMD won	-0.0986***	-0.0569***	-0.119***	-0.0683***	-0.167***	-0.0939***	-0.0676
	(0.00758)	(0.00518)	(0.00977)	(0.00761)	(0.0567)	(0.0273)	(0.0615)
Distance to FRA (km)		-0.00132***	-0.000383***	-0.000306**			
		(0.000197)	(0.000141)	(0.000120)			
Observations	11,464	14,056	14,056	14,056	11,464	11,716	11,464
R-squared					-0.251	-0.028	-0.141
F-Statistic	74.58						
Number of hhid	4,258	5870	5870	5870	4,258	4,290	4,258
hh fixed-effect	Yes	No	No	No	Yes	Yes	Yes
Cluster hh level	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Standard errors clustered at the household level in parentheses.
*** p<0.01, ** p<0.05, * p<0.1

On the household level (Table 17), the IV estimation shows a positive impact of the ISP on agricultural work however that is an impact through political clientelism. This finding seems quite surprising as it implies that although on average, treated areas do not see a change in their labor supply in agriculture. That is likely due to many frictions impeding the functioning of these labor markets. However, areas taht benefit from political clientelism do. A potential mechanism could be that households who benefit from clientelism also get other infrastructure and access that may dampen the effect of these frictions. Households can thus make a set of adjustments (or adjustment with higher marginal returns) than other households who have had earlier opportunities to do them (and who face diminishing marginal return of income).

Table 17: Instrumental Variable: Labor market impacts of the ISP program

	(1) 1st Stage	(2) Agricultural-work	(3) Non-Agricultural
MMD won * Distance to FRA	0.00106***		
	(0.000196)		
FISP		1.146***	0.159
		(0.345)	(0.256)
Observations	13,997	13,997	13,997
Number of households	5,237	5,237	5,237
Household and year FE	yes	yes	yes

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

The results of this instrumental variable estimation strengthen the results of the DID estimation. The results are qualitatively similar with the exception of the sign of the intensive margin of individual inmigration, which speaks to the underlying heterogeneity of households. That is, the estimators — a LATE in the case of the IV and a treatment on the treated identified in the DID — are picking up different heterogeneities. However, one remaining factors in these estimations is the positive effect of the subsidy on outmigration, both at the household and the individual level, on all margins.

Having shown that the subsidy has indeed led to an increase migration, as suggested by the model, I next show, using the model of section 5 the impact different policies could have on the choices households make on the allocation of their members to migration.

Table 18: Impact of the Volume of Subsidy on Migration Decisions of Individuals

	(1)	(2)
	Indiv - Rate Out	Indiv - Count Out
Extra dollar subsidy	0.00257***	0.0105***
	(0.000360)	(0.00152)
Square extra dollar subsidy	-1.71e-06***	-3.10e-06*
	(3.77e-07)	(1.84e-06)
Total in-kind and cash remittances	0.000193**	0.000394
	(7.98e-05)	(0.000254)
Constant	0.0930***	0.301***
	(0.000663)	(0.00276)
Observations	31,078	31,078
R-squared	0.008	0.020
Number of hhcode	11,166	11,166
Household and year FE	yes	yes

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

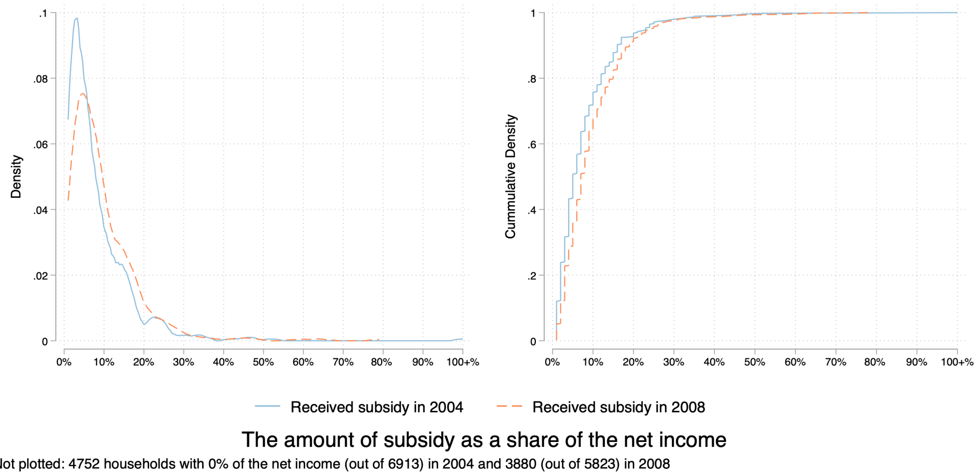


Figure 18: Total amount of the subsidy over the net income of the household

Note: The variable plotted is $\frac{\text{Subsidy}}{\text{Subsidy + Income}}$

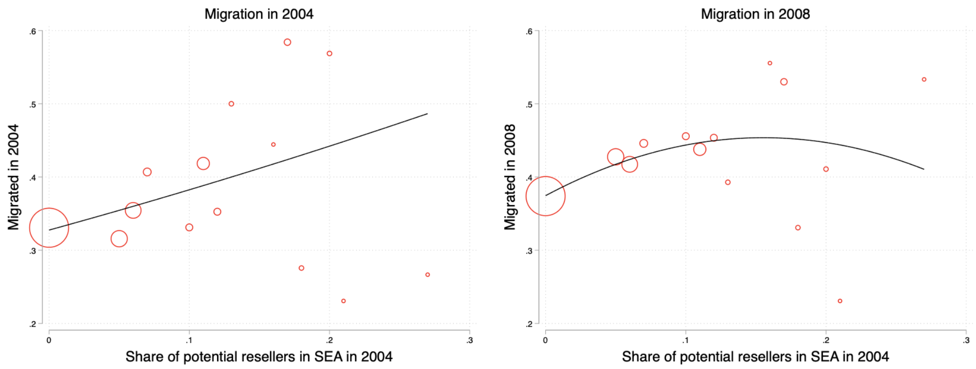


Figure 19: Migration in 2004 and 2008 by share of potential resellers in a villages

Notes: Using self-reported data from the Post-harvest survey of 1999-2000 and its supplemental surveys (panel). I plots the correlation between the share of potential re-seller in the village and rates of migration. In 2004, villages with the most potential resellers are also those with the most households sending outmigrants. This increase tapers off as time goes by (see right-hand side graph in Figure 19). The migrants of 2008 are likely migrating due to increased productivity rather than a relaxation of the credit constraint for migration.

B A model of selection

B.1 Solutions for traditional agriculture

Unconstrained households: the interior solution

When the household's labor units in agriculture, or credit constraints are not binding, the household's set of choices is in the interior solution, leading to the following first order conditions:

$$\frac{\partial \pi^{u*}_{i,T}}{L_{i,A}} = paL_{i,A}^{\gamma-1}X_i^{\delta} - \tilde{w}_i = 0; \tag{16}$$

Which leads to the household to choose the below levels of migration, and leading to the profits $\pi^{u*}_{i,T}$

$$\text{Unconstrained migration } L^{u*}_{i,M} = L_i - \left(\frac{\gamma paX_i^{\delta}}{\tilde{w_i}}\right)^{\frac{1}{1-\gamma}} \tag{17}$$

$$\text{Unconstrained profit} \quad \pi^{u*}_{i,T} = \gamma^{\frac{\gamma}{1-\gamma}}(1-\gamma\tilde{w}_i)\left(\frac{paX_i^{\delta}}{\tilde{w_i}^{\gamma}}\right)^{\frac{1}{1-\gamma}} + \tilde{w}_iL_i + q_v\bar{f} - c_i^M \tag{18}$$

Labor constraints bind

If the household that has an optimal labor demand that is larger than its endowment of labor units ($L^*_{i,A} > L_i$), or a household for which the credit constraint binds (i.e. $PY_i + q_v\bar{f} > c_i^M$) meaning that the household would want to migrate but cannot afford to), its constrained migration units of labor, and profits are the following:

$$\text{Constrained migration } L^{c*}_{i,M} = 0 \tag{19}$$

$$\text{Constrained profit} \quad \pi^{c*}_{i,T} = paL_i^{\gamma}X_i^{\delta} + q_v\bar{f} \tag{20}$$

B.2 Solutions for upgraded agriculture

Unconstrained households: the interior solution

When the household's labor units in agriculture, or credit constraints are not binding, the household's set of choices is in the interior solution. The household optimizes over its labor units and its fertilizer use, leading to the following first order conditions:

$$\frac{\partial \pi^{u*}_{i,T}}{L_{i,A}} = \alpha p A_i L_{i,A}^{\alpha-1} F_i^{\beta} X_i^{1-\alpha-\beta} - \tilde{w}_i = 0; \tag{21}$$

$$\frac{\partial \pi^{u*}_{i,T}}{F_i} = \beta p A_i L_{i,A}^{\alpha} F_i^{\beta-1} X_i^{1-\alpha-\beta} - q_v = 0; \tag{22}$$

These FOCs, lead to the optimal unconstrained solutions over migration, fertilizer use, the resulting profits to be:

$$\text{Unconstrained migration } L^{u*}_{i,M} = L_i - X_i \left[\left(\frac{\beta}{q_v}\right)^{\beta} \left(\frac{\alpha}{\tilde{w}_i}\right)^{1-\beta} p A_i \right]^{\frac{1}{1-\alpha-\beta}}, \tag{23}$$

$$\text{Unconstrained fertilizer } \quad F^{u*}_i = X_i \left[\left(\frac{\beta}{q_v}\right)^{1-\alpha} \left(\frac{\alpha}{\tilde{w}_i}\right)^{\alpha} p A_i \right]^{\frac{1}{1-\alpha-\beta}}, \tag{24}$$

$$\text{Unconstrained profit } \quad \pi^{u*}_{i,F} = X_i \left[p A_i \frac{1}{q_v^{\beta} \tilde{w}^{\alpha}} \right]^{\frac{1}{1-\alpha-\beta}} \Psi + q_v \bar{f} + L_i \cdot \tilde{w}_i - C^F_v - c^M_i, \tag{25}$$

where $\Psi = \beta^{\frac{\beta}{1-\alpha-\beta}} \cdot \alpha^{\frac{\alpha}{1-\alpha-\beta}} - \beta^{\frac{1-\alpha}{1-\alpha-\beta}} \cdot \alpha^{\frac{\alpha}{1-\alpha-\beta}} - \beta^{\frac{\beta}{1-\alpha-\beta}} \cdot \alpha^{\frac{1-\beta}{1-\alpha-\beta}}$.

Labor constraints bind

If the household has an optimal labor demand that is larger than its endowment of labor units ($L^*_{i,A} > L_i$), or has a binding credit constraint (i.e. $PY_i + q_v \bar{f} > c^M_i$ meaning that the household would want to migrate but cannot afford to), its constrained migration units of labor, and profits are the following:

$$\text{Constrained migration } L^{c*}_{i,M} = 0 \tag{26}$$

$$\text{Constrained fertilizer } \quad F^{c*}_i = \left[\frac{p A_i X_i^{1-\alpha-\beta}}{q_v} \right]^{\frac{1}{1-\beta}} \tag{27}$$

$$\text{Profit } \quad \pi^{c*}_{i,F} = \left(\beta^{\frac{1}{1-\beta}} - \beta^{\frac{1}{1-\beta}} \right) \left[\frac{p A_i X_i^{1-\alpha-\beta}}{q_v} \right]^{\frac{1}{1-\beta}} + q_v \bar{f} - C^F_v \tag{28}$$

Proposition 1 *There exist at most two cut-offs in X_i that determine whether the* *household has any migrants. For X_i lower than a cuttoff X_i^L, the household is not productive enough and thus cannot afford to migrate (the credit constraint is binding). Similarly for X_i higher than X_i^H, the household is very productive in agriculture, and no household member migrates. For values of X_i between X_i^L and X_i^H the number of migrating labor units is an inverted U-shape.*

Proof of Proposition 1.

$$\frac{\partial \pi_{i,T}^{u*}}{X_i} =$$

■

Proposition 2 *For the unconstrained household, there exist at most two cut-offs in $\tilde{w}_i$ that lead to different migration decisions. For $\tilde{w}_i$ lower than $\tilde{w_i^L}$, the household specializes in agriculture, and for $\tilde{w}_i$ higher than $\tilde{w_i^H}$, the entire household migrates. For values of $\tilde{w}_i$ between $\tilde{w_i^L}$ and $\tilde{w_i^H}$ the number of migrating labor units is increasing.*

Proof of Proposition 2. an interior solution requires that $L_{i,M} > 0$, or equivalently, $L_{i,A} < L_i$. Taking the derivative of ex-post returns with respect to $\tilde{w}_i$:

$$\frac{\partial \pi_{i,T}^{u*}}{\tilde{w}_i} = \frac{\gamma^{\frac{\gamma}{1-\gamma}}(1-\tilde{w}_i)}{(\gamma-1)\tilde{w}_i}\left(\frac{paX_i^\delta}{\tilde{w}_i}\right)^{\frac{1}{1-\gamma}} + L_i;$$

For a given endowment of land and labor units, if $\tilde{w}_i$ is under a threshold $\tilde{w_i^L}$, $1-\tilde{w}_i$ is positive, making $\frac{\gamma^{\frac{\gamma}{1-\gamma}}(1-\gamma\tilde{w}_i)}{(\gamma-1)\tilde{w}_i}$. Above $\tilde{w_i^L}$, the household returns to migration are large enough to send increasing number of labor units, until all its units migrate, which is reached when $\tilde{w}_i > \tilde{w_i^H}$ ■

Proposition 3 *When the subsidy is introduced and for migration costs that sufficiently low, resale markets make the number of households who can afford to migrate larger, thus increasing migration rates within a village.*
For some households with very low migration costs, the entire households can migrate, funding migration entirely with the proceed from the resale of the subsidized fertilizer.

Proof of Proposition 3. Without the subsidy $q\bar{f} = 0$. Equation 5 shows for households with a binding credit constraint, i.e. $paL_{i,A}^\gamma X_i^\delta + q\bar{f} < c_i^M$, migration does not occur. Note that:

$$\forall \bar{f} > 0; q > 0 : paL_{i,A}^{\gamma} X_i^{\delta} + q\bar{f} > paL_{i,A}^{\gamma} X_i^{\delta} \tag{29}$$

$$\Rightarrow \sum_{i=1}^{N_v} 1_{\{paL_{i,A}^{\gamma} X_i^{\delta} + q\bar{f} > c_i^M\}} \geq \sum_{i=1}^{N_v} 1_{\{paL_{i,A}^{\gamma} X_i^{\delta} > c_i^M\}} \tag{30}$$

Which implies that when households can trade their fertilizer in resale markets, they end up with more disposable income. Some households for which the credit constraint binds prior to the subsidy see their constraints relaxed, and they can afford to migrate. ■

Proposition 4 *If q^* is sufficiently low, a household that has high returns to migration want to put all their labor into migrating but need to fund it by using some in agriculture for profits. Said more precisely, their unconstrained labor choice would cause profit to fall below the amount required by credit constraint. Therefore, they set their labor to exactly cover the cost of migrating, making some households' optimal choice to both upgrade & migrate. This household's upgrading decision may lead to the household overusing fertilizer, such that $F_i > F_i^*$.*

Proof of Proposition 4. The credit constraint is of the form $pY_i + q\bar{f} \geq c_i^M$ where $Y_i = a \cdot L_{i,A}^{\gamma} X_i^{\delta}$ for non-upgraders, and $Y_i = A_i \cdot L_{i,A}^{\alpha} F_i^{\beta} X_i^{1-\alpha-\beta}$ for upgraders. For households with A_i large enough, the household upgrades (see Equation 9).

Households who have high returns to migration ($\tilde{w}_i$), and whose optimal interior choice is binded by the credit constraint will increase their agricultural production just enough to cover the migration cost.

For non-upgraders, this means that $paL_{i,A}^{\gamma} X_i^{\delta} + q\bar{f} = c_i^M$, which implies $L_{i,A} = \frac{c_i^M - q\bar{f}}{X_i^{\delta}}^{\frac{1}{\gamma}}$.

For upgraders, this means that $pA_i \cdot L_{i,A}^{\alpha} F_i^{\beta} X_i^{1-\alpha-\beta} + q\bar{f} = c_i^M$. For the extreme where $q = 0$, we have $L_{i,A} = \left(\frac{\tilde{w}}{\alpha}\right)^{\frac{1}{\alpha}}$ and $F_i = \left(\frac{c_i^M \alpha}{\tilde{w} p A_i X_i^{1-\alpha-\beta}}\right)^{\frac{1}{\beta}}$

Both solutions deviate from the optimal solutions, and for high enough costs of migration, and returns to migration, there may be some over-investment in the upgraded agriculture, due to this shadow cost of the constraint.

■

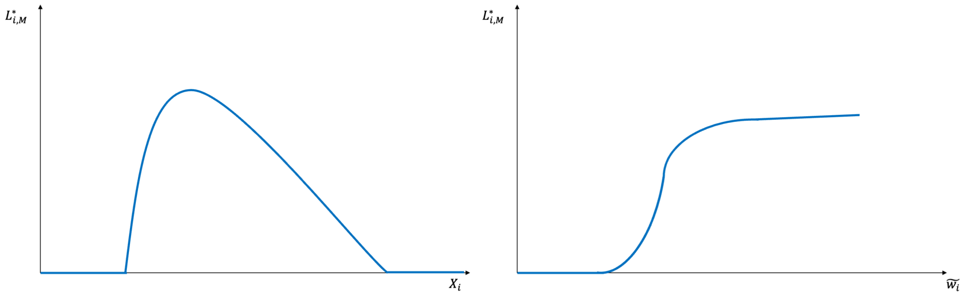


Figure 20: Comparative statics: changes in migration as land (X_i), and returns to migration ($\tilde{w}_i$)

Notes: Plots the number of labor units within households migrating as a function of landholding X_i on the left panel, and as a function of $\tilde{w}_i$ on the right panel.

C Structural estimation

Fertilizer Technology: $\log(Y_{maize,i}) = \log(A_i) + \alpha \log(L_{i,A}) + \beta \log(F_i) + \nu \log(X_i) + \theta_{vil}$

Sample: ISP + Adoption	α	ν	β	$\alpha + \nu + \beta$	P-value $H_0 : \alpha + \nu + \beta = 1$
Estimates	.116	.736	.306	1.158	.00
Standard Errors	(.037)	(.037)	(.029)		

Traditional Technology: $\log(Y_{maize,i}) = \gamma \log(L_{i,A}) + \mu \log(X_i) + \theta_{vil}$

Sample: ISP + No adoption	γ	μ		$\gamma + \mu$	P-value $H_0 : \gamma + \mu + \beta = 1$
Estimates	.133	.828		.961	0.26
Standard Errors	(.030)	(.028)			

Table 19: Estimation of simultaneous Equations 15

	(1)	(2)	(3)	(4)	(5)	(6)
	Villages **with** subsidy			Villages **without** subsidy		
Variables	$\mathscr{D}_i$	$\mathscr{M}_i$	$L_{i,M}$	$\mathscr{D}_i$	$\mathscr{M}_i$	$L_{i,M}$
$\log(X_i)$	0.123***		0.123***	0.144***		0.136**
	(0.0116)		(0.0442)	(0.0208)		(0.0658)
$\log(q_v)$	0.827*		0.299	0.297		0.0673
	(0.431)		(0.184)	(0.683)		(0.230)
$\log(c_i)$	-0.0224		-0.178***	-0.0155		0.0187
	(0.0284)		(0.0453)	(0.0816)		(0.0637)
L_{iM}		0.161***			0.183***	
		(0.00433)			(0.00734)	
Y_T		-1.54e-08**			-2.45e-08**	
		(7.23e-09)			(9.70e-09)	
$(Y_F - Y_T) \times 1_{\mathscr{D}_i=0}$		-4.55e-09			-2.20e-08*	
		(1.04e-08)			(1.28e-08)	
$(Y_F - Y_T) \times 1_{\mathscr{D}_i=1}$		-1.79e-09			-1.49e-09	
		(1.93e-09)			(5.32e-09)	
q_v		7.98e-05*			6.01e-05	
		(4.08e-05)			(4.73e-05)	
c_i		-3.67e-07			7.82e-07	
		(6.74e-07)			(7.17e-07)	
$\log(A_i) \times 1_{\mathscr{D}_i=0}$			-1.121***			-0.759
			(0.418)			(0.476)
$\log(A_i) \times 1_{\mathscr{D}_i=1}$			0.0514			0.0398
			(0.0839)			(0.166)
$\log(P_v)$			-0.568***			-0.536*
			(0.216)			(0.284)
$\log(L_i)$.			2.447***			2.308***
			(0.0735)			(0.110)
$1_{FSP} \times \log(q_v)$			-0.0137			
			(0.0132)			
Constant	-5.028*	0.323***		-1.719	0.284***	
	(2.991)	(0.0535)		(5.328)	(0.0664)	
Village FE	Yes	No	No	Yes	No	No
Observations	1,495	1,495	1,495	580	580	580
R-squared	0.402	0.288	0.664	0.470	0.352	0.659

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

C.1 Optimal policy design and discussion of results

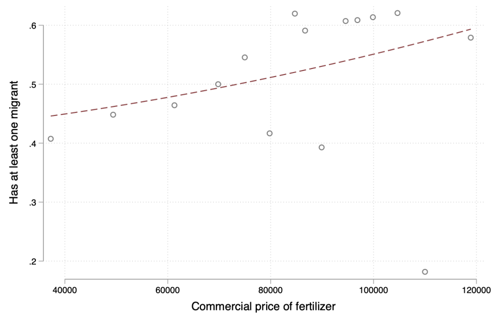


Figure 21: Commercial price of fertilizer vs. extensive individual migration

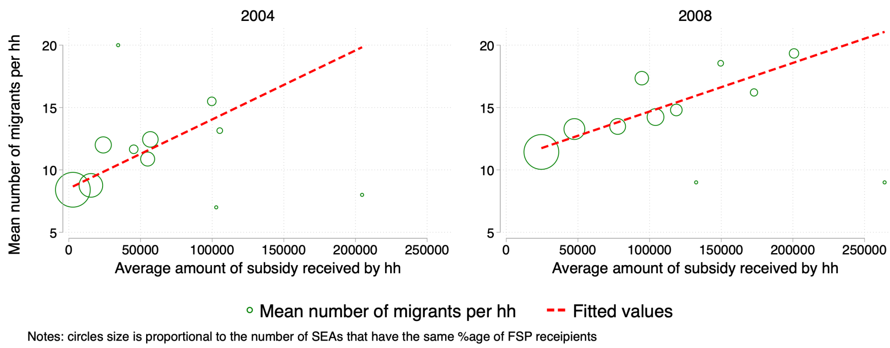


Figure 22: Impact of the Volume of Subsidy on Migration Decisions of Individuals