

THREE ESSAYS ON SMALLHOLDER WELFARE: MARKET ACCESS AND
THE DYNAMICS OF TECHNOLOGY ADOPTION

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THREE ESSAYS ON SMALLHOLDER WELFARE: MARKET ACCESS AND THE DYNAMICS OF TECHNOLOGY ADOPTION

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The last decade has witnessed an increase in policies with the dual objective of tackling food insecurity and poverty. Whether both objectives can be optimally achieved with the same policy instrument, however, warrants closer examination. This dissertation is comprised of three independent studies examining such policies. The first study evaluates a local food aid procurement project conducted in Guatemala for food emergency relief based on five different dimensions: impact on market prices, recipient satisfaction, timeliness, costliness and smallholder development. We find no price or price volatility associations with local procurement but find mixed results along the other dimensions highlighting the need for decision-makers to clearly identify and prioritize among the objectives of food assistance interventions.

The second study examines the impact of a significant demand shock in the export pineapple market on smallholder farmer welfare in southern Ghana. Using two stage least squares, we estimate duration pre- and post-shock using a bivariate tobit model in the first stage and a fixed effects model in the second stage. We then compare mean asset wealth for different categories of farmers defined by their time of entry and exit relative to the shock. Early adopters (disadopters) are better off than later adopters (disadopters), and non-adopters are as well off as early adopters who

disadopt early, questioning the long-term welfare gains of smallholders often associated with the adoption of cash crops.

The final study uses panel experimental data from maize field trials geographically dispersed throughout Malawi to estimate the expected marginal physical returns to fertilizer use conditional on a range of agronomic factors. Using these estimated returns and historical price and weather data, we simulate the expected marginal profitability of fertilizer application and the correlation of those expected returns with headcount poverty rates. We find that the fertilizer bundles distributed under Malawi's subsidy program are almost always profitable, but the correlation between the expected gains to increased fertilizer use and a location's poverty level is weak at best, calling into question how effectively fertilizer subsidies help reduce rural poverty.

BIOGRAPHICAL SKETCH

Aurélie Patricia Harou completed her undergraduate degree at the University of Sussex, Brighton, obtaining a B.Sc. in Environmental Science and Geography in 2003. Interest in the interaction and influence of the physical sciences on a country's economy led her to pursue a Master's degree at the University of California at Davis in Agricultural and Resource Economics. During and in between her B.Sc. and M.S., she supplemented her academic experience with various professional experiences, including working on sustainable agriculture practices in India and Honduras, working for the United States Public Interest Research Group and working on the United States National Flood Insurance Program with the Federal Emergency Management Agency. After her M.S. she worked for an economics litigation-consulting firm in Berkeley, CA, conducting analyses for expert witnesses testifying on anti-trust issues. She decided to pursue a PhD after working on a humanitarian food security project for nine months in eastern Democratic Republic of Congo.

For Bahati and her brothers and sisters.

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CHAPTER 1

INTRODUCTION

1. Introduction

There has been an increased focus in the last decade by governments, donors and policy-makers to tackle both food insecurity and poverty by helping smallholders participate in modern supply chains and/or facilitating their access to improved agricultural production inputs. Indeed, despite significant migration to urban centers and evidence of significant rural non-farm income in the last several decades, estimates show that $\frac{3}{4}$ of the world's poor continue to live in rural areas, relying on agriculture as their primary livelihood (Davis *et al.* 2010, World Bank 2008, Reardon 1997).

From approximately the 1950s to the 1980s, food supply chains were commonly state-led, large-scale operations. State-controlled marketing boards, for example, controlled the sale or purchase of agricultural commodities, fixing prices and absorbing any excess production through well-established buying networks and storage facilities. While marketing boards provided farmers with a guaranteed market, usually at prices below import parity, it reduced competition and induced large inefficiencies, ultimately leading towards their elimination (Reardon *et al.* 2009). Nonetheless, there was some support for small-scale production. For example, several governments promoted fertilizer use during the 1970s and early 1980s, e.g., through direct subsidies, input credit programs, centralized fertilizer procurement and distribution sites, etc., with some success (Denning *et al.* 2009). However, there was a general phase out of input subsidy programs in the 1990s, generally due to fiscal constraints or corruption or inefficiency.

Since the 1980s liberalized rules of trade and foreign direct investment, as well as improvements in logistics and infrastructure, have spurred foreign and domestic private investment in the processing and retail segments of agrifood supply chains. These trends, partly driven by broader income growth and urbanization, have led to the rapid emergence of supermarkets, convenience stores and fast food chains in the developing world (Reardon *et al.* 2009). Furthermore, due in part to severe climate events and the 2007-2008 price crisis, there has been a resurgence of policies promoting agricultural input use, e.g. subsidization of fertilizer, that have had a certain degree of success (Denning *et al.* 2009). The last decade has also witnessed an increase in structured public sector demand for locally and regionally procured (LRP) food aid, a procurement tool that can increase the timeliness and reduce the cost of emergency food aid deliveries. For example, the LRP share of World Food Program (WFP) deliveries reached 67% in 2010, up from 11% as recently as 1999 (WFP 2011a). Since launching a five-year pilot project called Purchase for Progress (P4P) in 21 countries in 2008, WFP estimates that in 2010 it purchased 14% of its food from smallholders (WFP 2011b). At the same time, there has been growing demand by consumers and regulators for information regarding the sustainability attributes of products. Purchasers seek additional product information including the economic gains to historically disadvantaged groups (“fair trade”), energy use in delivery, food safety and environmental contaminants used. Leading retailers are developing multi-dimensional sustainability indices that aim to incorporate these different environmental, economic and social attributes. To date, there is limited consistency, however, in establishing such indices and little understanding of how consumers might view the tradeoffs among social, environmental, nutritional and

economic product attributes (Gomez *et al.* 2011). These recent trends of increased and specialized agricultural activity have presented new opportunities for smallholders.

This chapter begins by briefly reviewing the conceptual framework for most studies regarding technology adoption or smallholder access (Section 2) and then describes some recent relevant background literature (Section 3). Finally, Section 4 introduces the three subsequent chapters of this dissertation and how they specifically contribute to their respective specific literatures.

2. Conceptual framework

The theoretical starting point for most studies examining market access and technology adoption begins with the agricultural household model whereby households maximize utility of consumption and leisure subject to a cash income constraint, labor time constraint and production technology constraint. Under the assumption that markets exist for each good consumed and produced and that all prices are exogenous, solving for the first order conditions reveals that the household model can be decomposed into independent production and consumption decisions, known as the separable household model. As a producer, the household maximizes profit subject to prices of inputs and outputs and the available technology. As a consumer, the household chooses consumption and leisure to maximize its utility under the income and labor supply constraints. If on the other hand, a certain market for a commodity or labor does not exist then prices become endogenous linking the two sets of decisions, known as the nonseparable household model. Indeed, when households do not participate in markets, production and consumption decisions are jointly determined based on the households'

shadow prices (themselves a function of preferences, endowments and technologies) (de Janvry *et al.* 1991). While the conditions necessary for separability are likely rare in practice, the separable household model is often used due to its simplicity.

The canonical non-separable model was developed to examine how the variation in transactions costs helps explain why farmers do not engage in markets (de Janvry *et al.* 1991). Transaction costs depend on crop- (e.g., storage requirements and processing needs) and household-specific features (e.g., education, age and gender that affect search costs and negotiating skills) as well as public goods and services (e.g., extension services, road access, etc.) (Barrett 2008). These costs create a difference between farmgate and market prices, potentially creating participation non-economic depending on a households' shadow price for the good in question. The poorer the institutional and physical infrastructure, for example, the greater the price band making a good less tradable. The price band creates a kinked demand and supply, decreasing a households' response to prices. Goetz (1992) further develops this model separating the decision of market engagement into two stages – whether to trade (either as a buyer or seller) and how much to trade, conditional on buying or selling. The factors affecting the amount to buy or sell are the same as those affecting the decision of whether to participate in the market as a buyer or seller, but not vice versa. There are fixed cost variables affecting the participation decision, but not the extent of participation. Key *et al.* (2000) further examine the role of fixed and proportional transaction costs on the household supply decision finding that proportional costs are important in selling and fixed transaction costs matter for both sellers and buyers. Bellemare and Barrett (2006) find that rural

households make the decision to participate in a market and the resulting volume decisions sequentially rather than simultaneously.

The decision to sell or buy at a market is linked to a smallholders' decision to adopt a technology. Indeed, a smallholder's production technology affects its productivity and hence the set of available market participation choices. Moreover, the returns to adopting a certain technology depend on the market and the aggregate supply response. For example, if markets are well integrated, excess supply can reach more distant locations. Finally, a household wishing to consume a certain good can either produce it or purchase it. The decision to do so will depend on its comparative advantage of producing a certain good (Barrett 2008, Alene *et al.* 2008).

3. Empirical research

Considerable research in development economics has been dedicated to the issue of technology adoption in an attempt to help increase production and the income of the majority of the poor in least developed countries. The more recent studies surrounding technology adoption examine the low observed technology adoption rates, especially in sub-Saharan Africa, in contrast to countries like India or Mexico which have benefited from the Green Revolution. The literature offers a host of explanations for low observed adoption rates, including lack of information, credit constraints, taste preferences, differences in agroecological conditions and local costs and benefits (Feder *et al.* 1985, Foltz *et al.* 2011, Suri 2011). A smaller set of the literature examines the dynamics of adoption, including the disadoption of technologies (Suri 2011, Moser and Barrett 2006,

Neill and Lee 2000). Yet another set of the more recent literature examines the role of social learning and networks on technology adoption (Conley and Udry 2010).

The empirical literature on market access is sparser, perhaps in part due to the difficulty of finding adequate measures of access. It is often thought that smallholders in remote areas face higher input costs, lower output prices, fewer buyers and a weak access to extension services, ultimately reducing their incentives to adopt new technologies and participate in the market. However, limited rigorous evidence supports these claims. Part of the difficulty lies in the lack of agreement on what market access is, and consequently how to best measure it. Most often it is categorized by physical access captured by access to roads, costs of transportation and/or travel time to urban markets (Chamberlin and Jayne 2012).

Nonetheless, there are several recent trends in the literature examining different aspects of smallholder market access. A large part of this literature examines smallholders' role in the so-called "supermarket revolution". Modern supply chains tend to favor small farmers that can produce consistent volumes of a satisfactory quality. The smallholders capable of supplying this quantity and quality are typically better off than the average smallholder, e.g., having access to irrigation and/or greenhouses. Even controlling for the initial advantages enjoyed by those who participate in modern agrifood value chains, smallholders suppliers tend to enjoy higher net earnings per hectare or per unit of output marketed, although this is by no means universal nor uniform (Barrett 2008, Michelson 2013).

Nevertheless, participation in modern supply chains can expose smallholders to increased risk. For example, if farmers reallocate land and other scarce inputs to an

export crop, they become vulnerable to factors outside local market control, e.g., changing foreign consumer preferences, exchange rates or trade barriers such as changing quality standards. For example, Ashraf *et al.* (2008) find that an NGO in Kenya offering smallholders a package of credit, extension and marketing support services to help smallholders grow and sell baby corn and French beans for export initially yielded significantly higher incomes for participants. However, their epilogue notes the subsequent catastrophic effect when farmers did not meet the new Euro-Retailer Produce Working Group Good Agricultural Practices (EurepGap) requirements established in 2005, driving many farmers to go back to growing staple crops. Maertens and Swinnen (2009) study the welfare and labor effects of more stringent standards on smallholder contract farming and smallholder welfare of French beans in Senegal. They find significant income gains for participants in the French bean value chain, 60 to 110 % higher than the average income in the research area.

Another strand of the literature focuses on the sourcing decisions of wholesalers, processors and retailers and their relationships with farmers. In some cases, wholesalers or processors source predominantly from larger farms or even vertically integrate to run their own farms. For example, a study in Kenya shows that in the 1990s the fresh vegetable export sector sharply reduced their purchases from small farms to 18%, sourcing 40% from their own farms and 42% from large commercial farms (Dolan and Humphrey 2000). However, in other cases, sourcing from small farms is more common and seen as advantageous. Sourcing from small farmers can be less risky for processors or wholesalers because they do not have to rely solely on one or a few suppliers. Furthermore, small farmers may be more willing and able to perform highly labor-

intensive field management practices that are difficult to perform on larger plots. Because wholesalers or processors aim to minimize their transaction costs, smallholders closer to roads or those with their own transportation means are typically also favored (Reardon *et al.* 2009).

Because smallholder production is often limited by production inputs such as fertilizer, water or credit to buy tools or seeds, *resource-providing contracts* have emerged between wholesalers, processors or retailers and small farmers. Under such arrangements, buyers give smallholders access to credit, farm inputs or extension services in exchange for a commitment to sell the firm a pre-specified quantity of their output. In *forward contracts*, firms agree to buy products at a pre-specified price, without necessarily providing farmers with inputs or other resources. These forward contracts insure smallholders against uncertain future prices.

Partly in order to attract either sort of contract, smallholders may organize themselves into cooperatives or other groups in an attempt to make themselves more competitive vis-à-vis larger commercial farms or to give them greater bargaining power with firms. Farmer based organizations (FBOs) rarely self-organize but are often facilitated by an NGO, the government or private companies. The success of collective action varies significantly, depending on many factors including the institutional arrangement and external environment. The size of the group matters -- while smaller groups can benefit from eased governance, larger groups can achieve larger economies of scale. The trustworthiness and motivational capacity of the leadership of the FBO is critical to its success (Markelova *et al.* 2009). Furthermore, the type of product also affects the potential for collective marketing. Staple foods are bulkier but easier to store

than horticultural or livestock products. On the other hand, the importance of transportation, equipment and cold chains with more perishable goods may encourage cooperation. Generally, longer market chains make it more difficult for smallholders to access markets.

4. Thesis contributions

The three subsequent chapters of this dissertation are independent research papers, each contributing to a small subset of the vast literature that was briefly and broadly mentioned above. This section briefly describes these chapters, their key findings and how they contribute to their respective relevant literatures.

A. Local and Regional Procurement

Chapter 2 evaluates a locally procured food aid emergency relief program in the department of Santa Rosa in Guatemala. The primary objective of food aid remains to help food insecure households combat malnutrition and food insecurity whether caused by economic shocks, drought, political unrest or chronic poverty. A host of new food assistance instruments, e.g., cash, vouchers, prepositioned food aid and local and regional procurement (LRP), have emerged over the last decade with the objective of improved timeliness, cost reduction and/or improved nutrition. Additionally, LRP, whether in-kind or through cash or vouchers, has been proposed to help stimulate growth through agricultural development and promoting smallholder market accessibility. Despite the rise of LRP, limited rigorous evidence exists on its impacts and its potential benefits and drawbacks. Some evidence suggests that it may reduce time to delivery and costs. Little

rigorous evidence exists to support the claim that LRP can improve farmer profitability. The paucity of evidence can in part be explained by the difficulty of having an appropriate counterfactual group with which to compare LRP. We begin to fill this void in chapter 2 by offering a comprehensive evaluation of LRP measured against a concomitant multi-year assistance program (MYAP) distributing food aid shipped from the United States. We compare these programs along five dimensions: timeliness, costliness, price impacts, recipient satisfaction and producer impacts.

Between August 2010 and September 2011 a private voluntary organization (PVO) distributed locally procured monthly rations of white maize, black beans and a locally produced fortified corn soy blend (CSB) called Incaparina to 3,000 households in the department of Santa Rosa in Guatemala. Meanwhile the same PVO distributed rice, pinto beans, CSB and vegetable oil shipped from the US to communities in the department of Baja Verapaz. We find that LRP commodities consistently arrived to the PVO distribution warehouses sooner than the food coming from the US. Time savings ranged from less than one week for CSB to over eight weeks for the cereals (LRP maize and US rice), a practically and statistically significant difference. We find that the Guatemalan LRP was more expensive than transoceanic food aid. The difference in average costs of beans procurement in favor of the US-sourced commodities is small (9 percent) and not statistically significant. However, the costs for the locally-procured fortified CSB, Incaparina, were much higher than for the CSB purchased in and shipped from the US. Part of this difference can be explained by the differences in the two products where Incaparina is a branded product sold in small (450 gram) retail bags whereas the CSB arrived from the US in 25-pound bags.

Because procurement could potentially increase prices by causing a demand increase or decrease prices in regions distributed, it is important to monitor prices. We find no evidence that LRP has an economically or statistically significant effect on prices or price volatility in the department of Santa Rosa or markets outside the LRP project zone. Food aid recipients in both LRP and MYAP zones were surveyed to elicit how satisfied they were with different attributes of the commodities they received and how expensive and time consuming it was for them to prepare meals. Food aid recipients preferred locally sourced commodities along most criteria studied. LRP commodities also required statistically significantly less fuel, time, water use, cooking oil and effort than the counterpart MYAP commodities.

Finally, the PVO sought to procure food locally semi-competitively in an effort to support smallholder development by soliciting bids from local farmer based organizations (FBOs). However, the inability of the selected FBO to fulfill its contract and supply sufficient quantities at the agreed price required, mid-project, that the PVO procure competitively by soliciting bids nationally, illustrating the particular challenges associated with procuring from smallholders.

The nuanced results of this in-depth case study highlight the importance of carefully considering the objectives of a food assistance intervention and the context in which it might be undertaken when deciding whether to procure rations locally. LRP does appear to be preferred when time is of the essence, such as in emergency response relief situations. LRP may entail higher costs, as was the case here, which must be weighed against timeliness gains and potential nutritional gains and recipient satisfaction. Finally, while there may be situations in which local sourcing generates synergies between

smallholder gains and recipient preferences, the Guatemala case underscores that such synergies are by no means guaranteed. The attempt to support smallholder agriculture should not be made at the expense of the food insecure in food aid programs justified on humanitarian grounds.

B. Duration and timeliness of adoption

Chapter 3 examines the effect of duration and timing of entry of pineapple farmers on welfare in four villages in southern Ghana. There has been much optimism about the potential of agriculture and export crops specifically to reduce poverty. For example, there is some evidence that smallholders who participate in modern supply chains by supplying supermarkets have enjoyed higher net earnings per hectare. In response, some aid agencies and NGOs have made efforts to train and equip farmers to grow cash crops. In doing so, aid agencies may actually be exposing smallholders to increased risk, especially when export crops are susceptible to price collapses due to demand shocks, potentially decreasing farmer welfare in the longer-term. Using panel data from 1998 and 2009, we study the welfare of pineapple farmers who experienced an exogenous demand shock around 2005. Using a two stage least squares approach, we first predict the number of months pre- and post-shock a farmer grows pineapple. Using these predicted values, we then estimate the effect of duration of pineapple cultivation pre- and post-shock on farm household welfare.

We find that the number of months a farmer grows pineapples before the shock has a positive effect on welfare, while duration post-shock has a negative effect. Given the second stage estimation, we categorize five types of farmers based on different times

of entry and exit of cultivating pineapple. We find that early adopters that exit before the shock are the best off among adopters. Nonadopters are as well off as early adopters who disadopted early. Early disadopters are always better off than late disadopters. Our results suggest that caution must be exercised when introducing and encouraging the adoption of new technologies. In the long-run, adopters may be worse off than nonadopters.

C. Poverty and the returns to fertilizer

The final chapter of this dissertation examines the returns to fertilizer in Malawi. Following a severe drought in 2004, Malawi reinstated a subsidized fertilizer program resulting in high reported yields. Despite the program's success, some have criticized it for its high costs while others have questioned whether the high yields resulted from the program or favorable weather conditions. Furthermore, there is some evidence that while subsidies may have increased crop yields, poverty levels have remained the same, raising questions about the program's efficacy in reducing poverty and food insecurity.

Using nationally representative panel data of plot-level yield experiments, we are able to disentangle the productivity impacts of Malawi's fertilizer subsidy program from those of favorable weather while controlling for heterogeneous soil conditions and pest pressures. Given this estimated maize production function and historical climate data, we generate spatially explicit estimates of the distribution of the expected marginal profitability of fertilizer use, given prevailing maize and fertilizer prices during the subsidy era. Finally, we correlate those results with spatially disaggregated estimates of headcount poverty rates so as to establish whether yield gains reasonably attributable to fertilizer subsidies accrue primarily in poorer or richer areas of the country.

We find that given 2009-2010 maize and fertilizer prices, the fertilizer bundle recommended under Malawi's Agricultural Input Subsidy Program is almost always and everywhere profitable in expectation. Indeed, fertilizer use would remain profitable in expectation even in the face of significant fertilizer price increases and drought year conditions. While the program does appear to favorably affect maize yields and farm profits, however, the spatial pattern of those gains is largely uncorrelated with headcount poverty rates, calling into question the extent to which Malawi's fertilizer subsidies have been pro-poor.

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CHAPTER 2

AN EVALUATION OF A LOCALLY PROCURED FOOD AID EMERGENCY RELIEF RESPONSE PROJECT IN GUATEMALA¹

1. Introduction

The last decade has witnessed a dramatic increase in public sector demand for locally and regionally procured (LRP) food aid. In 2010, the LRP share of United Nations World Food Programme (WFP) deliveries reached 67 percent, up from 11 percent as recently as 1999 (WFP 2011a), as various donor governments have shifted from food aid based on commodities they ship to cash-based food assistance (Barrett *et al.* 2011). Similar changes have occurred in the United States, the world's largest food aid donor. In the fiscal year 2008, new legislation authorized the United States Department of Agriculture (USDA) to begin using LRP under a 4-year pilot project for \$60 million. The United States Agency for International Development (USAID) also received over \$240 million in fiscal year 2010 and \$230 million in fiscal year 2011 in supplemental appropriations under the Emergency Food Security Program, much of which has also been spent on LRP (US Agency for International Development 2012). Thus, by 2010, in terms of volume, the US was not only the largest donor of food aid produced and sourced from the donor country but also the largest donor of locally and regionally (i.e., “triangular transactions”) procured food aid (WFP FAIS 2012). As LRP has grown, the use of other food assistance instruments – such as cash and voucher distributions – has likewise

¹ This chapter was written by Aurélie P. Harou, Miguel I. Gómez, Christopher B. Barrett, Erin C. Lentz and Teevrat Garg. The results from this chapter were combined with results from a similar study that took place in Burkina Faso to create the following published paper:

Harou A and Upton J, Gomez M, Barrett C and Lentz E (2013). “Trade-offs or synergies? Assessing local and regional procurement through case studies in Burkina Faso and Guatemala”, *World Development*, 49(9): 44-57.

expanded, sparking the development of various response analysis tools to help agencies identify the best form of assistance to use in a given context (Barrett *et al.* 2009).

The primary objective of food aid today is to help food insecure households combat chronic and/or acute malnutrition and food insecurity, whether caused by economic shocks, catastrophic weather events, political unrest or chronic poverty. Food aid can serve as a safety net to help vulnerable households smooth consumption and preserve assets in desperate times, helping them avoid poverty traps (Gilligan and Hoddinott 2007, Barrett and Maxwell 2005). LRP and the host of new tools associated with it, however, have also triggered an interest in using LRP to stimulate growth through agricultural development and promoting smallholder market accessibility. Most notably, the WFP's Purchase for Progress (P4P) five-year \$140 million pilot project committed to purchase food aid from smallholders and farmer based organizations (FBOs) in 21 countries (<http://www.wfp.org/purchase-progress>) (Mitchell and Leturque 2011).

Despite the increased use of and funds dedicated to LRP, limited rigorous evidence exists on its impacts and on the potential benefits and drawbacks across the range of stated objectives, especially relative to transoceanic food aid delivery. Some evidence suggests that LRP, whether in-kind or through cash or vouchers, may reduce delivery time and costs. For example, Lentz and Barrett (2008) find that the median transoceanic food aid delivery in Eastern Africa was 21 percent more expensive than local procurement during the same calendar quarter. Tschirley and del Castillo (2007) find cost savings of between 23 and 46 percent when procuring maize in Kenya, Uganda and Zambia relative to distributing US maize, taking into account delivery costs. Some studies examine the effects and additional costs of tied food aid. A report by the OECD (2005) finds that tied food aid costs at least 30 % more than untied food aid. More specifically,

Bageant *et al.* (2010) calculate that the US' agricultural cargo preference requirement costs US taxpayers an estimated \$140 million in 2006, representing approximately a 46% increase over competitive freight costs. Additionally, there is some evidence that cost savings may be even higher for cash and vouchers than for in-kind LRP, although the adoption of any new distribution mechanism entails learning costs for food aid agencies (Upton and Lentz 2011).

Closely related to studies of cost savings are studies of time savings of delivery for food sourced closer to recipients. Replicating earlier findings from Barrett and Maxwell (2005), a study by the US Government Accountability Office (2009) finds that food coming directly from the US required on average 147 days to reach its destination compared to 35 days on average for locally procured food and 41 days for regionally procured food. The increased use of prepositioning of food aid, where in-kind food aid is stored in donor countries or in regions with high historic food aid demands, has helped diminish the time needed to deliver traditional food aid. These time savings come at a price, however, as donors can bear significant extra storage and transshipment costs (USGAO 2009).

It has also been suggested that LRP can improve farmer profitability and stimulate local and regional markets, though little rigorous evidence exists to date that the authors are aware of to support such claims (Upton and Lentz 2011). Because the WFP's P4P pilot is still in progress, its full impacts are as yet unknown, though a midterm evaluation suggests an average income gain of \$25 per farmer from participating in P4P in Africa (Mitchell and Leturque 2011). Farmer profitability and market stimulus of course depend not only on quantities purchased but also on commodity prices. The potential risk that the demand stimulus of LRP may increase market prices in procurement regions, rendering poor consumer households food insecure, has been a key concern and criticism against LRP. LRP can also have supply-side effects akin to traditional,

transoceanic food aid shipments, possibly decreasing prices in distribution markets. Garg *et al.* (2012) estimate price effects of LRP in distribution, procurement and adjacent markets, while controlling for possible confounding factors. They find that few LRP activities are statistically or economically significantly correlated with market prices or market price volatility, which, they explain, may in part result from the low quantities of goods procured relative to local market consumption and production.

Contract default is a commonly cited concern about LRP (Hanrahan 2010, USDA 2009). For example, defaulting on contracts has been common under the WFP's P4P project; as of September 2011, 23 percent of P4P's contracts defaulted (WFP 2011b). Suppliers can default for any number of reasons, including lack of product available at the contracted price, difficulty meeting quality standards, opportunities to side-sell, and lack of affordable transportation. Therefore, supplier default, as discussed in detail later in this study, is an important risk faced by agencies undertaking LRP, particularly those agencies interested in procuring from small producers or traders. Thus, the cost and time savings associated with LRP must be weighed against the potential difficulty of finding local and regional suppliers who can supply the required volumes while meeting appropriate food safety and quality standards within the specified time-frame.

This paper contributes to the literature by offering a comprehensive evaluation of the use of LRP by a private voluntary organization (PVO) that distributed food aid for a food emergency response project in Guatemala between August 2010 and September 2011. Our evaluation analyzes several dimensions of LRP. We a) compare the timeliness and cost-effectiveness of commodity delivery to the PVO warehouses relative to traditional food aid shipments from the US by the same donor to the same PVO; b) estimate the price impacts of local purchases and

distributions on local food markets; and c) examine recipient satisfaction with LRP commodities relative to commodities shipped from the US along multiple attributes. While some studies have compared recipients' preference of cash versus vouchers versus in-kind food aid (Michelson *et al.* 2012, Gentilini 2007, Meyer 2007, Ahmed 2005), to date there exists limited quantitative evidence regarding recipients' preferences of locally procured versus transoceanic foods. Additionally, there are few documented, publicly available case studies of directed procurement (i.e., semi-competitive tendering). Because the PVO was committed to offering smallholders the opportunity to sell to the PVO, it sought to procure food locally semi-competitively, by soliciting bids from local farmer based organizations (FBOs). However, the inability of the selected FBO to fulfill its contract and supply sufficient quantities at the agreed price required, mid-project, that the PVO procure competitively by soliciting bids nationally, illustrating the particular challenges associated with procuring from smallholders. Based on a comprehensive examination of the LRP project in Guatemala, the paper concludes with a discussion of tradeoffs that donors and PVOs should take into account when deciding among food aid modalities.

2. Background

Guatemala has both high levels of poverty and extreme inequality, with a poverty rate of 51 percent, with approximately 70 percent of the poor living in rural areas, largely depending on agriculture for their livelihood (World Bank 2009). In addition to problems of chronic poverty, Guatemala's location between the Caribbean Sea and the Pacific Ocean has made it vulnerable to violent tropical storms. Furthermore, its location on the Caribbean and North American tectonic plates makes mudslides, earthquakes and volcanoes a constant threat.

In 2009, Santa Rosa and other departments of the country's Dry Corridor² suffered from droughts, adversely affecting harvests. The following year, the same region suffered from severe floods caused by Tropical Storm Agatha, ruining many crops for a second consecutive year. The international community responded with an inflow of aid, including the USDA-run Local and Regional Procurement Pilot Program (LRPPP), which granted funding to support an emergency food security project in five municipalities in Santa Rosa (Figure 1). The implementing PVO distributed locally-procured monthly rations of white maize, black beans and a locally made branded fortified corn soy blend (CSB) called Incaparina to 3,000 households during the months of October - December 2010, and April - September 2011.

Meanwhile, the same PVO was running a Multi-year Assistance Program (MYAP) distributing comparable commodities (rice, pinto beans, CSB and vegetable oil) shipped from the US to communities in the department of Baja Verapaz, which suffered from high chronic rates of malnutrition. The simultaneous implementation of the LRPPP and MYAP projects in the same country by the same PVO enables us to conduct a rigorous evaluation, controlling for country- and-PVO-specific and period-specific unobservables that routinely confound comparisons of LRP and in-kind food aid programs. The LRP and MYAP program objectives differed slightly, with the MYAP designed to reduce high rates of chronic malnutrition while the LRP aimed to relieve families whose harvests suffered from the 2009 droughts and 2010 floods. The commodities distributed and the ration sizes differed slightly between the projects.³ Because of these differences, there may remain differences in program characteristics that limit our ability to

² The Dry Corridor is a strip of land that runs through several central and eastern departments of Guatemala, as well as a 6 km strip of land along the Pacific Coast. A Department is the Guatemalan political division unit equivalent to a State in the US or a Province in Canada.

³ LRP recipients received 100 pounds of maize, 12 pounds of black beans and 13 pounds of Incaparina while MYAP recipients received 8 pounds of rice, 7 pounds of pinto beans, 10 pounds of CSB and 14 pounds of vegetable oil.

identify observed differences in recipient satisfaction with food aid commodities as strictly attributable to local procurement versus transoceanic deliveries. Still, given the ethical and practical infeasibility of randomized assignment of food aid, and the extensive controls applied to carefully matched programs, we believe the inferences reported below are the best feasible and are highly informative.

3. *Timeliness analysis*

The timely arrival of food to the PVO distribution center is of utmost importance for households facing emergency food needs. We compare the timeliness of LRP relative to that of food aid shipped from the US. Following the methods described in Lentz *et al.* (2012) who compare timeliness across a range of countries, delivery lags were calculated based on the time that passed between the PVO's initiation of the procurement and the delivery to the PVO's final distribution warehouses. For transoceanic shipments, the lag is thus the difference between the release of an invitation for bids by the US government for commodity and ocean freight services for a USAID or USDA food aid program and the arrival at the PVO warehouse in the recipient country. For the LRP program, the PVO sought to procure maize and beans semi-competitively from smallholder FBOs and other vendors sourcing directly from smallholders (the PVO modified this strategy during the course of the program, as explained in section 7 below). Likewise, the PVO procured fortified CSB semi-competitively from a small number of food processors operating in the country. For all procurements, the time was calculated as the difference between the date the tender (i.e., invitation for bids) was released to prospective suppliers and the arrival at the PVO warehouse.

Transoceanic food aid shipments data to Guatemala were acquired from USDA and USAID. Dates of port arrival and arrival at final warehouses were acquired from three PVOs that received USAID or USDA food aid shipments in Guatemala during the time span of the LRP project. The LRP data were acquired from the implementing PVO. Commodities shipped from the US were not exactly the same commodities as those procured by the LRP program. Consequently, commodities from the US were chosen that most closely resembled the commodities purchased in Guatemala: LRP black beans were compared to MYAP pinto beans; LRP maize was compared to rice shipped from the US; and LRP Incaparina was compared to CSB.

Table 1 shows the average number of weeks it took for commodities procured locally or shipped from the US to arrive at PVO warehouses. The LRP commodities consistently arrived to the distribution warehouses sooner than the food coming from the US. Time savings ranged from less than one week for CSB to over eight weeks for the cereals (LRP maize and US rice), a practically and statistically significant difference. Thus, we find evidence that LRP generates unambiguous timeliness gains relative to delivery of commodities from the US, even for a nearby recipient country with an ocean port, like Guatemala. This suggests that, when feasible, LRP may be preferred to transoceanic food aid in emergency relief situations that require an immediate response.

4. Cost analysis

Cost considerations are an important part of comparing LRP with other food aid procurement mechanisms. Given tightly constrained budgetary resources, cost savings can result in projects reaching more vulnerable families, improving rations, or both. Following the

methodology described in more detail in Lentz *et al.*'s (2012) multi-country comparative study, we compare the costs of purchasing food from the US to the costs associated with the Guatemalan LRP. The analysis includes the costs of the commodity, ocean freight, and internal transport, storage and handling (commonly referred to as ITSH). Commodities from the US were chosen that most closely resembled the commodities purchased in Guatemala, as explained above. However, LRP maize and transoceanic rice were deemed too dissimilar for comparison in terms of cost efficiency due to the differences in commodity characteristics, including taste, texture and color.

USDA and the USAID provided the data for the commodity and ocean freight costs for the commodities coming from the US. The three PVOs that received CSB or pinto beans from the US during the course of the LP project provided the associated ITSH costs. The costs of LRP were obtained from the implementing PVO. Local suppliers delivered the commodities to the PVO warehouses and thus combined ITSH costs and commodity costs in their bids. Accounting practices for administrative costs vary widely across PVOs, so since we use data from multiple PVOs in these comparisons, we exclude administrative costs from this analysis.⁴

Table 2 reports the cost comparisons in US dollars per metric ton of food aid distributed. The analysis suggests that the Guatemalan LRP was more expensive than transoceanic food aid. The difference in average costs of beans procurement in favor of the US-sourced commodities is small (9 percent) and not statistically significant. However, the costs for the locally-procured fortified CSB, Incaparina, were much higher than for the CSB purchased in and shipped from the US. Part of this difference can be explained by the differences in the two products. The CSB

⁴ Calculating dollars spent per gram of micronutrient is an alternative costing approach. We do not have detailed micronutrient information on the locally sourced food and therefore are unable to compute this comparison. However, this is an interesting avenue for future research and we thank an anonymous reviewer for the suggestion.

procured in Guatemala was a branded product sold in small (450 gram) retail bags whereas the CSB from the US arrived to warehouses in 25-pound bags. Additionally, the CSB made in Guatemala was fortified with higher quantities of vitamins A, B1, B2, B12, folic acid, niacin, iron and zinc than US-sourced CSB. CSB more comparable to the CSB coming from the US can be found in Guatemala, but the PVO chose to distribute a highly fortified CSB regularly consumed by local customers. Whether the higher costs of locally-procured CSB are warranted depends on the quality, nutritional content and preferences of recipients and the tradeoffs the PVO and donor are willing to make for such objectives. A thorough quality and nutritional study was not conducted in this evaluation, although higher quantities of vitamins and minerals presumably have greater nutritional benefits.

5. Price analysis

Economic theory predicts that LRP could potentially disrupt source and/or recipient markets. Procurement in a market causes a demand increase, potentially increasing prices, while distributions – whether sourced locally or in the donor country – generate a supply shock, possibly decreasing prices. If the procurement and distribution regions are the same, as in the Guatemala case⁵, the overall effect may be entirely attenuated because LRP affect prices in opposite directions. Furthermore, the shift in demand or supply and thus the level of price change, if any, are affected by the quantities procured relative to the markets' average production (supply), the level of market integration into national and global markets, and the elasticity of demand and supply of the procured and substitute goods. Thus, LRP is likely to have little effect

⁵ Procurement and distribution occurred in Santa Rosa, a department that is geographically and agriculturally diverse. Thus, while the drought and subsequent flooding affected certain regions, other regions within the same department were unharmed.

on prices if the quantities procured are small and/or if local and regional markets are well-integrated, since adjustments may occur entirely through trade flows instead of price fluctuations.

While price increases are desirable for producers, many smallholder producers are net consumers (Barrett 2008) so that price increases are likely to increase the number of food insecure households, highlighting the importance for monitoring and evaluating the effect of LRP on prices. We estimate whether LRP had any impact on retail market price levels and price volatility. These effects are estimated both across time, by assessing LRP's effect on prices up to two or three months after the purchase, and across space by assessing the effect of LRP not just in the procurement-and-distribution department (Santa Rosa) but also in other markets in Guatemala. Inter-temporal price effects may occur because of induced changes in storage behavior or delayed adjustments associated with temporary disequilibrium in response to shocks. Prices are jointly determined by any factor that affects demand and supply in local, national and international markets. As is explained in detail below, we control for possible confounding factors (e.g., rainfall, temperature and fuel costs) to better isolate the relationship between LRP and prices.

The framework and econometric strategy is adapted from Tadesse and Shively (2009) and is explained in further detail in Garg *et al.* (2012), whose approach we almost exactly follow (the lone methodological deviation is noted below). Briefly, we estimate LRP price impacts using the following model,

$$p_{it}^c = \alpha + \beta' p_{it-k}^c + \lambda' LRP_{it-d}^c + \delta' X_{it} + \psi_i^c + \varepsilon_{it}^c \quad (1)$$

where p represents the natural logarithm of market prices (in quetzals per metric ton) of commodity c at time t in spatial market i . β represents the vector of k autoregressive coefficients needed to eliminate serial correlation in prices and λ is a vector that captures contemporaneous and up to the d^{th} -period lagged impacts of LRP activity on prices (optimal distributed lag structures were chosen using the Akaike Information Criterion). X includes controls for possibly confounding variables and shocks, including rainfall and temperature – both expressed as standard deviations from long-term monthly means – inflation, world market prices, domestic transport costs, seasonality dummies and food aid quantities procured by WFP in Guatemala and in neighboring countries, as well as market fixed effects, ψ^c , to control for time invariant unobservable spatial price differences. The maximum likelihood estimates of λ , the parameter of interest, are consistent as long as the series are stationary and there is no serial correlation in the residuals (Hamilton 1994). The coefficient estimate on lagged prices will be biased given the fixed effects framework, so – unlike Garg *et al.* (2012) – we instrument lagged prices using twice-lagged prices (e.g., replacing p^c_{it-1} with p^c_{it-2}) by including the instrument in place of the lagged price in equation (1).

The absolute value of the residuals from equation (1) can be used to study price volatility – expressed as the conditional standard deviation of the natural logarithm of price – by estimating an Autoregressive Conditional Heteroskedasticity model using the same regressors as in equation (1), just replacing lagged prices with lagged absolute values of residuals. For more details on the estimation strategy, please refer to the multi-country comparative study by Garg *et al.* (2012).

This method is applied to monthly retail price data for white and yellow maize, Incaparina (the locally-procured CSB) and black beans collected between January 2000 and

November 2011 by the Guatemalan National Statistical Office (INE). The INE price data available were organized by region, eight in total, representing 22 of the 23 departments in Guatemala, as shown in Table 3. The data used to control for possible confounding factors come from a variety of sources. Monthly temperature and rainfall data were obtained from the Instituto Nacional de Sismología, Vulcanología, Meteorología, e Hidrología (INSIVUMEH) from December 2000 - December 2010. For January 2011 – April 2011, monthly temperature and rainfall data were averaged using data from the Global Historical Climatology Network (GHCN) in Belize, Honduras and El Salvador. Exchange and inflation rates were obtained from the World Bank’s Global Economic Monitor. Transport costs were obtained from INE. USDA black bean prices were used as a proxy for world bean prices. World prices for maize were obtained from the World Bank’s Global Economic Monitor Commodity Databank.⁶ The World Food Program provided WFP monthly procurement quantities in Guatemala and in neighboring countries.

Three sets of regressions are run to study LRP correlations with prices and price volatility, for both procurement and distribution: a) the correlation of LRP with prices in all departments nationwide for which data were available, b) the LRP-price conditional correlation within the procurement-and-distribution markets of Santa Rosa, and c) the LRP-price conditional correlation in all departments outside of Santa Rosa, in order to get a sense of whether LRP has spatial spillover effects in other markets. The estimated percentage price effects of LRP are shown in Table 4.⁷

We find no evidence that LRP has an economically or statistically significant relationship with retail food prices within Guatemala. As one would expect, the point estimates were

⁶ We use those US gulf ports maize prices as world market price controls in the price and price volatility regressions for white maize and Incaparina as well as for yellow maize.

⁷ Full regressions results are shown in the Appendix, tables A1-A12.

routinely greater in magnitude in Santa Rosa, where procurement and distribution occurred, than in markets outside the LRP zone. However, none of the estimated price effects were statistically significantly different from zero at the five percent level, within the Department of Santa Rosa, much less in other markets outside the LRP project zone, or nationwide. Moreover, the point estimates were all small in magnitude and/or negative, suggesting that the food distribution (supply-side) effect common to all direct food distribution or monetization programs dominates the procurement (demand-side) effect unique to local procurement programs. The only series for which the point estimate is positive and of non-negligible magnitude was for beans in Santa Rosa during the procurement month, with an estimated effect of just under seven percent, which is statistically significant at the ten percent level.

Table 4 also reports the estimated correlation between LRP and price volatility. There is no evidence that PVO local purchases of beans, maize and Incaparina in Guatemala had an economically meaningful relationship with food price volatility in local markets. The only statistically significant point estimates were for Incaparina in markets outside of Santa Rosa, where LRP procurement activity is associated with less price volatility. However, the magnitude of this effect is small, as the estimated reduction in price volatility was less than one percent.

As noted above, the Guatemalan LRP was a relatively small pilot program. It is possible that larger purchases might have greater price effects. Indeed, the results indicate that WFP's far larger LRP of Incaparina in neighboring countries – WFP procured 675 MT/months, on average, in neighboring countries versus just 24 MT by the PVO whose program we study – were associated with statistically significant price decreases of 0.145 percent in Guatemala ($p < 0.10$). Likewise, the much larger WFP LRP of beans in Guatemala – average monthly procurement of 216 MT versus 22 MT for the focal PVO – were statistically significantly negatively associated

with retail bean prices in the country⁸, but only by -0.632 percent. But even these market price correlations are economically unimportant, suggesting that it would likely be feasible to implement LRP at a larger scale in Guatemala than under the LRPPP without causing market disruptions.

6. Recipient satisfaction analysis

Food aid recipients in the LRP and MYAP regions were surveyed to elicit how satisfied they were with different attributes of the commodities they received and how expensive and time intensive it was for them to prepare meals with these commodities. Analyzing recipient satisfaction and the costliness to recipients of preparation is important for at least two reasons. First, recipients who are satisfied with the commodities they receive may be more likely to consume them. Thus, if a program objective is to reduce malnutrition and hunger, that objective will more likely be met by commodities that satisfy recipients. Conversely, recipients who are more satisfied with the foods they receive are less likely to waste them or to find other uses for the commodities, for example, as livestock feed, in alcohol brewing, or to sell in the market. Second, the overall wellbeing of the recipients increases the greater their satisfaction with the commodities received and the fewer the required preparation inputs (e.g., fuel, water, time).

As mentioned, the simultaneous distribution of LRP commodities to one group of recipients and of US-sourced commodities to another group by the same PVO provides a natural experiment for more rigorous identification of impacts directly attributable to the local sourcing of commodities. A subset of *municipios* (or municipalities), and communities within the

⁸ Percent price and price volatility associations with WFP LRP were calculated in the same way as correlations of the PVO LRP listed in Table 3. Full regression results are shown in the Appendix, tables A1-A12.

municipios, was selected in each department to participate in the LRP and MYAP projects by the PVO's local partner organization based on the needs of the department and discussions with local community leaders. Five *municipios* participated in the LRP program, while three participated in the MYAP program. In the LRP communities, recipient households were selected based on the PVO's Household Food Insecurity Access Study, a short questionnaire designed to distinguish food insecure from food secure households. Rations were distributed freely to the most vulnerable families and distributed conditionally to other targeted families in exchange for working on community projects, such as improving local roads or bridges, building irrigation systems, and working on conservation projects, among others. At the time of the surveying, the MYAP project in Baja Verapaz was approaching its fifth and final year. Families receiving food aid were those with children under the age of three and/or pregnant mothers. Therefore, families supported in the MYAP project changed over time. These targeting differences are controlled for based on household composition in the multivariate regression analysis below.

In order to obtain a representative sample, a random sample of recipient families was generated by stratifying participating municipalities. Villages were randomly sampled within each municipality depending on the number of recipient families in each municipality. Because the families receiving aid changed over time in the MYAP region, only those families who had received at least two rations and were still receiving food at the time of the survey were randomly selected. A total of eight villages were sampled in each department and at least 15 households were surveyed in each community, yielding a total of 120 recipient survey respondents in Baja Verapaz and 121 in Santa Rosa. The surveys were conducted in July 2011 within a two-week period. The person in charge of cooking the majority of the meals was asked to answer the survey questions.

Recipients were asked to rate several attributes of the commodities they received on a Likert scale from 1 (very unsatisfied) to 5 (very satisfied). These attributes included perceived quality, quantity, taste, storability, time to cook, texture/appearance, perceived nutritional content and cleanliness. The recipients also rated their overall satisfaction with the commodities. Recipients were also asked to rate their satisfaction with the received commodity relative to the product that most resembled the distributed good that the respondent had either purchased in the local market or produced at home. Recipients were asked how much they preferred the received commodity to its locally available equivalent commodity on a scale from much less (1) to much more (5). However, because the majority of responses responded 4 (satisfied) or (more) and 5 (very satisfied) or (much more) in both sets of questions, responses were regrouped into three categories in the analysis that follows: 1 (very unsatisfied, unsatisfied or the same) or (much less, less or the same), 2 (satisfied) or (more) and 3 (very satisfied) or (much more).

We employ an ordered logit specification to explain the differences in ordinal preferences between the commodities received as a function of the origin of the product (LRP versus transoceanic), while controlling for other factors that may affect preferences:

$$y^*_{ij} = \beta_0 + \beta_1 LRP_{ij} + \beta_2' X_{ij} + \beta_3' Z_j + \varepsilon_{ij} + \eta_j \quad (2)$$

$$y_{ij} = 1 \text{ if } y^*_{ij} \leq \mu_1$$

$$y_{ij} = 2 \text{ if } \mu_1 < y^*_{ij} \leq \mu_2$$

$$y_{ij} = 3 \text{ if } \mu_2 < y^*_{ij}$$

where y^*_{ij} represents the latent continuous response of recipient i in community j to a specific ranking question, which is grouped into one of the observed ordinal responses, y_{ij} , according to where y^*_{ij} falls relative to unobserved cut-off points μ_k (for $k = 1, 2$). The parameter β_0 is a constant, LRP is an indicator variable taking value one for the LRP project region and zero in the

control region (the MYAP region), X_{ij} is a matrix of household specific controls and Z_j is a matrix of community-level controls. Household-level controls include the age of the respondent, the education level of the respondent, the primary language spoken at home, the number of household members between 18 and 60 years old, the total number of household members, whether the respondent is the head of the household, the gender of the household head, the age of the household head, the education level of the household head and the number of monthly rations received by the recipients. The community-level controls include whether the local market occurs either two or three times a week, if access to the market requires walking, if part of the road to access the market is dirt, distance to the market (in km), the average time needed to travel to the market (in minutes), and whether any part of the path to the market is inaccessible at any time of the year. The ration sizes were constant and did not vary over time.

In equation (2), β_1 is the coefficient of interest, reflecting how receiving LRP commodities, rather than food aid commodities shipped from the United States, affects recipient satisfaction, after controlling for other factors that might influence preferences and might be correlated with inclusion in the LRP program. Since assignment to the LRP program was exogenous to recipients and selection was unrelated to recipient satisfaction with the commodities, β_1 can be interpreted as the causal effect of local sourcing on recipient satisfaction with rations. The coefficient vectors β_2 and β_3 reflect the effects of the control vectors X_{ij} and Z_j , respectively. The error term can be decomposed into two components, ε and η , which include household- and community-specific unobservable characteristics, respectively. A random effects model is estimated to capture community-specific unobserved variables and to allow them to vary between households within a cluster.

Table 5 defines the control variables more precisely and offers descriptive statistics. Generally, the population in the LRP community is older than in the MYAP region. A'chi, one of the 23 Mayan languages spoken in Guatemala, is the primary language spoken by the majority of recipients in Baja Verapaz, while it is Spanish for recipients in Santa Rosa. Respondents were all female in both regions and most often the wife of the head of the household, although 20 percent of respondents in Santa Rosa said they were the head of household compared to 6 percent in Baja Verapaz. The education level of both regions is comparable, with 40-45 percent of respondents having received no education and 17-19 percent having completed the elementary education.

Recipients in both regions consumed all or the majority of the food rations they received. Those who did not consume all of the rations received gave some to their friends and/or family. Histograms of the recipients' responses reveal that recipients in both the LRP and MYAP zones were generally satisfied with the commodities they received.⁹ LRP recipients more frequently responded that they were very satisfied than respondents in the MYAP region, as reflected in bivariate Mann Whitney test results indicating a statistically significantly higher median response from LRP recipients than from MYAP recipients across most attributes and commodities (Table 6).

A summary of the ordered logit results is shown in Table 6.¹⁰ Note that ordered logit coefficient estimates are not directly interpretable; they only make sense at specific values of variables. What can be unambiguously interpreted are the signs and statistical significance levels of coefficient estimates. The results again indicate that Guatemalan food aid recipients prefer locally sourced commodities along most criteria, especially for beans, with the exception of recipients' perceptions of the nutritional content for rice versus maize. When we do the same

⁹ These are available from the contact author by request.

¹⁰ Full regression results are found in the Appendix, tables A13-A21.

estimation using respondents' satisfaction with the food aid ration relative to the product available on the local market, the results are qualitatively identical; locally-sourced commodities are statistically significantly more preferred along most attributes (Table 7).

Recipients were also asked to assess, on a scale from 1 (much more) to 5 (much less), the preparation costs they incurred for the commodity they received from the PVO relative to the one they would otherwise purchase or produce, as described above. Table 8 reports the bivariate Mann Whitney test results, which show that LRP commodities required statistically significantly less fuel use, time, water use, cooking oil use, expense and effort than the MYAP commodities.

Again, responses were regrouped into three categories for multivariate ordered logit random effects estimation. The estimation results suggest that the locally-sourced commodities required fewer inputs to prepare than did the US-sourced commodities. More specifically, LRP beans required statistically significantly less fuel, time, water, and effort to cook and LRP maize required less preparation time. The US-sourced CSB, on the other hand, required statistically significantly less time than did the locally-sourced Incaparina. The comparison to cooking oil use is not shown for maize/rice and Incaparina/CSB because the majority of respondents from both the LRP and MYAP regions did not use oil to prepare these commodities for consumption.

7. Procurement case study

Some donors and agencies have seen LRP as an opportunity not only to source relief food faster or more cheaply, but also as a means to encourage smallholder production and market access in the country where aid is procured. Toward that end, in 2010, 14 percent of the WFP's purchases made in the 21 pilot P4P countries were made from smallholders (WFP 2011b). With the same development objective in mind, the PVO in Guatemala sought to procure from

smallholder producers by soliciting bids from local FBOs of small farmers and other smallholder-sourcing vendors, rather than throwing the competition open to agribusinesses without regard to where they sourced their products.

Survey instruments were designed to test whether PVO purchases led to a shift in smallholders' production choices and quantities and whether the purchases led to the adoption of improved management practices and/or investments to ensure better quality. However, in trying to survey farmers who the selected FBO managers claimed supplied the LRP products, the research team discovered many ghost suppliers. It turned out that the FBO heavily supplemented their smallholder sourcing with commodities produced outside of the FBO, reputedly due to the smallholders' inability to produce the quantities required. Few of the sampled farmers had in fact supplied the FBO, so the survey was halted.

Finding FBOs and vendors to invite to bid was a challenge for the PVO. Ultimately, only 24/42 (57 percent) of the invited FBOs submitted bids. From conversations with key informants and FBO leaders, likely reasons for the low response rate include the difficulty for FBOs and smaller commercial vendors to understand the content and terms in the call for bids, the difficulty in supplying relatively large quantities, the difficulty in abiding by the quality standards, the difficulty in being responsible for the transport of the goods, the high risks associated with possible rejection of the goods, and the delayed (two weeks after delivery) payment under the contract terms.

A common concern in semi-competitive tendering surrounds suppliers' capacity to satisfy quality standards with products sourced from nontraditional commercial suppliers relying on smallholder producers. Upon delivery of the commodity to the PVO warehouse, the goods were

tested to ensure they met commodity-specific quality standards.¹¹ Samples were also extracted during the delivery and sent to a lab to test for possible aflatoxin contamination. Ultimately, a total of 260 quintals of maize failed humidity tests during the May and July procurements.

Following unprecedented domestic maize price increases beginning in January 2011, the FBO maize and beans supplier from the third tender agreed only to sign a maize contract up to two months at a time despite the fact that tender specifications asked for a six month contract. It was later discovered that this FBO was supplying goods not produced by its members, breaching the terms of their contract. The right of the PVO to invoke the terms of the contract legally presented two problems: the additional costs and time needed for legal action and the financial and reputational harm it would cause to the FBO. Instead, the PVO terminated the contract amicably and procured the remaining distributions competitively. It decided to procure competitively given the difficulty of finding maize in Guatemala during June-July 2011, especially from smallholders. After the competitive tender was announced, 14-16 suppliers requested the tendering details and three prospective suppliers submitted bids.

Table 9 shows the prices and quantities by commodity offered by different bidders over the course of the LRP project. Prices rose for all three commodities between October 2010-September 2011: from 350 quetzals per quintal (Qz/Q) to 450 Qz/Q for beans, from 160 Qz/Q to 265 Qz/Q for maize, and from 5.39 Qz/bag to 6.9 Qz/Q for CSB. This presented a challenge for the PVO, which had a fixed budget to manage. Market prices far exceeded past trends for maize, where prices at the same time one year earlier reached a maximum at 141 Qz/Q (FAO 2010). However, the winners were not necessarily those that offered the lowest prices. Indeed, the PVO and its partner organization reviewed the offers and allocated points to each offer based on price,

¹¹ The quality standards for beans, maize and fortified CSB are available from the contact author in Tables A22-A23.

the suppliers' experience with supplying other PVOs and the bidders' mandate to support local smallholders.

The PVO's experience procuring from smallholders highlights some very real challenges for LRPs. Substantial time is needed to identify potential suppliers. Government or donor agencies or other PVOs may be able to provide lists of organizations working within a region. But the certified organizations will not necessarily be able to respond to the contract specifications (e.g., quality standards and procurement volumes sought). Smallholders may take additional risks by deciding to invest in technology to improve production of the commodities purchased by the PVO if they expect the demand for the good to grow or subsist in subsequent seasons. Furthermore, if PVOs purchase directly from producers, traders may be forced out of the market, diminishing their welfare. Should the buyer no longer purchase locally or directly from producers in subsequent seasons, traders would incur additional costs if they deemed it profitable to re-enter, potentially asking producers a higher price premium to account for the trader's newly acquired risk of losing their livelihood when PVOs decide to buy directly from producers. Unexpected price changes or yield shocks may make it difficult for FBOs to honor their contracts and for the PVO to purchase locally given a fixed budget. While contracts may be signed between the PVO and FBO, legal recourse may prove too time-consuming and costly to seek restitution in the event of breach of contract. These prospective complications must be weighed against the potential development gains of contracting with smallholders, especially in the context of an emergency food aid program with immediate objectives of relieving acutely food insecure households.

8. Conclusions

The nuanced results of this in-depth case study highlight the importance of carefully considering the objectives of a food assistance intervention and the context in which it might be undertaken when deciding whether to procure rations locally. LRP does appear to be preferred when time is of the essence, such as in emergency response relief situations. But in the 2010-11 Guatemala case, LRP entailed higher costs of distributing food aid. Those higher costs must also be considered with the quality and nutritional content of the commodities as well as with recipients' preferences, which clearly favored locally-sourced products. In this case – and we suspect in other contexts as well – some tradeoffs are inevitable. These should be confronted explicitly in the decision of whether to pursue local procurement and, if so, whether to source competitively or semi-competitively, with the intent of using the agency's local market demand to benefit smallholder producers and groups.

Monitoring prices is crucial to determine both when local procurement is viable and whether LRP has any effect on price levels and their volatility. The results of this study indicate that the small quantities procured had little effect on prices or price volatility in the procurement/distribution market or in other markets nationwide. Further, although the larger volumes procured by parallel LRP programs appear to have had a statistically significant correlation with price levels, the magnitude of such effect is too modest to be relevant in economic terms.

Finally, the case study of the PVO's experience procuring from smallholders highlighted several challenges. The mechanism by which a PVO decides to procure food locally and regionally, whether through competitive or semi-competitive tendering, must be carefully considered, especially with respect to the primary objectives of the intervention, the relief of

targeted food recipients. While there may well be situations in which local sourcing of food aid generates synergies between smallholder gains and recipient preferences (Upton *et al.* 2012), the Guatemala case underscores that such synergies are by no means guaranteed. The attempt to support smallholder agriculture should not be made at the expense of the food insecure in food aid programs justified on humanitarian grounds.

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10. Figures

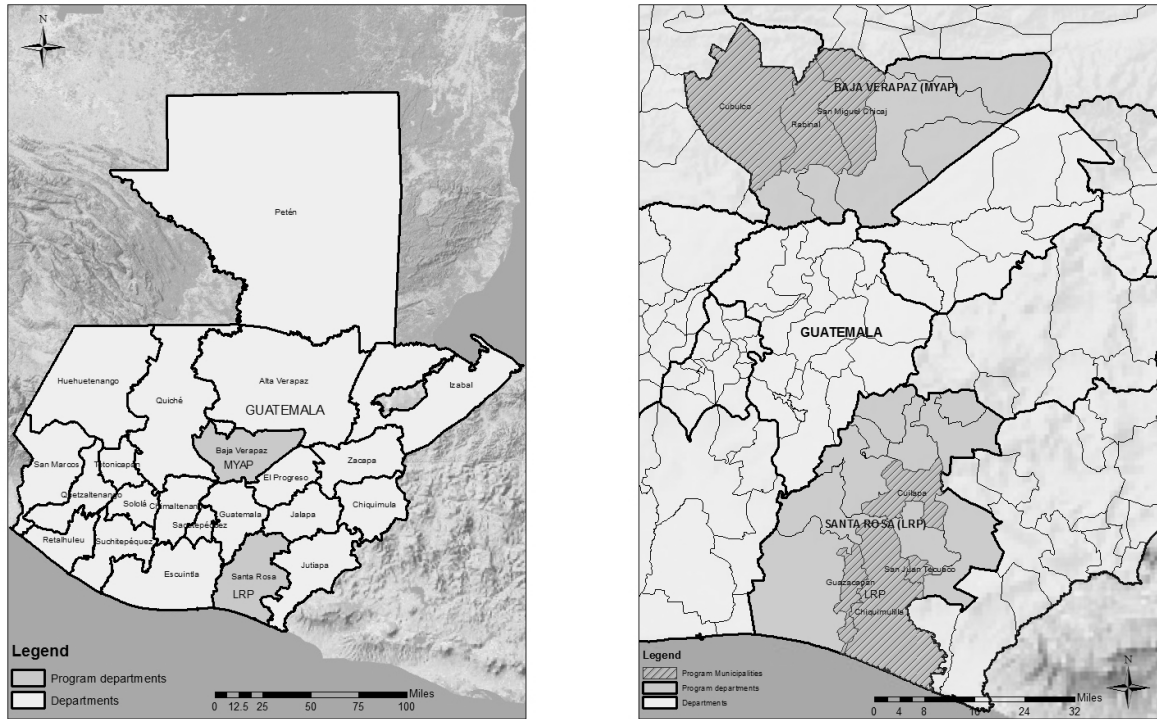


Figure 1: LRP and MYAP departments and municipalities

11. Tables

Table 1: Timeliness of Food Aid Deliveries (weeks)

	LRP	Food Shipped from US	Difference
Commodity 1	Maize (5)	Rice (3)	
Time to delivery	8.51	17.24	8.73*
Commodity 2	Black Beans (9)	Pinto Beans (4)	
Time to delivery	10.12	16.43	6.31*
Commodity 3	Incaparina (6)	CSB (3)	
Time to delivery	16.81	17.42	0.61
Commodity 4	-	Vegetable Oil (3)	
Time to delivery		23.05	
Cross Commodity average	12.72	18.37	5.65*

* indicates statistical significance of a two-tailed t-test at the 10 % level
 Numbers in parentheses are the number of observations.

Table 2: Cost of Delivered Commodities (USD/Metric Ton)

	Transoceanic		LRP	
Commodity	CSB (2)	Incaparina (9)	Pinto Beans (3)	Beans (6)
Commodity Cost	\$616.76	\$1,919.03	\$739.14	\$1,087.25
Ocean Freight Rate	\$177.06	-	\$189.56	-
ITSH	\$73.41	-	\$70.60	-
Total	\$867.23	\$1,919.03	\$999.30	\$1,087.25
Cost Savings	-121% ***		-9%	

*** indicates statistical significance of a two-tailed t-test at the 1 % level.
 Numbers in parentheses are the number of observations.

Table 3: Monthly price data, by region

No.	Region	Departments
1	Metropolitana	Guatemala
2	North	Alta Verapaz, Baja Verapaz
3	Northeast	Izabal Chiquimula, Zacapa, El Progreso
4	Southeast	Jutiapa, Jalapa, Santa Rosa
5	Central	Chimaltenango, Sacatepéquez, Escuintla
6	Southwest	San Marcos, Quetzaltenango, Totonicapán, Sololá, Retalhuleu, Suchitepéquez
7	Northwest	Huehuetenago, Quiché
8	Petén	Petén

Table 4: Estimated % Retail Price and Price Volatility Effects of LP

Commodity	Time	All Markets		Santa Rosa		Not Santa Rosa	
		Price	P Volatility	Price	P Volatility	Price	P Volatility
Beans	Immediate	1.796 (1.234)	-0.638 (0.788)	6.986* (4.019)	-0.810 (3.292)	1.083 (1.268)	-0.312 (0.794)
	1 month lag	-0.026 (1.411)	-0.035 (0.835)	-3.468 (4.637)	-0.550 (6.981)	0.523 (1.450)	-0.264 (0.837)
Incaparina	Immediate	0.542 (0.390)	-0.607 ** (0.259)	-1.061 (1.163)	1.088 (1.065)	-0.470 (0.411)	-0.892** (0.452)
	1 month lag	-0.810 (0.444)	-0.127 (0.532)	-2.033 (1.316)	-0.488 (1.911)	-0.627 (0.470)	0.610 (2.952)
White Maize	Immediate	-5.291 (5.499)	2.855 (5.900)	-3.009 (3.424)	2.152 (2.699)	-5.564 (6.257)	2.613 (6.744)
	1 month lag	-8.971 (6.080)	0.677 (6.708)	-4.456 (3.680)	-1.544 (2.763)	-9.544 (6.927)	0.469 (7.680)
Yellow Maize	Immediate	-6.560 (6.573)	3.904 (7.289)	-6.049 (7.802)	4.912 (11.661)	-5.916 (7.372)	3.499 (8.080)
	1 month lag	-8.403 (7.328)	1.132 (8.325)	-8.405 (8.889)	-0.172 (21.15)	-7.637 (8.190)	2.202 (9.242)

NOTES: (1) ***,** and * indicate statistical significance at the 1%, 5% and 10% levels, respectively. Standard errors are reported in parentheses. (2) Percent change are calculated based on equations (2) and (5) in Garg et al (2012) and are calculated at the PVO's average procurement volume. (3) We instrument lagged prices using twice-lagged prices.

Table 5: Control Variable Definitions and Means

Variable Description	Variable Definition	LRP (Santa Rosa)		MYAP (Baja Verapaz)	
		Mean	Std. Dev.	Mean	Std. Dev.
Program (LRP or MYAP)	=1 if LRP, else 0				
Market frequency 2/week	=1 if market occurs 2 times/week, else 0	0.38	0.487	0.625	0.486
Market frequency 3/week	=1 if market occurs 3 times/week, else 0	0	0	0.125	0.332
Market access by foot	=1 if part of the transportation to the mkt is done by foot, else 0	0.124	0.331	0.625	0.486
Market access by dirt road	=1 if part of the road to access the mkt is dirt, else 0	0.496	0.502	0.875	0.332
Distance to market	in kilometers	25.579	15.859	9.25	5.719
Distance to market	in minutes	70.165	31.675	68.125	49.828
Market accessibility	=1 if any part of the way to the market is inaccessible at any time of the year	0.248	0.434	0.25	0.435
Age of respondent	in years	42.421	16.318	27.683	7.038
Education	in years	2.438	2.614	2.342	2.649
Language	=1 if A'chi, else 0	0	0	0.908	0.29
HH members b/w 19-60	number of household members between ages 19-60	2	1.132	2.325	1.21
Total HH members	total number of hh members	5.124	2.234	6.092	2.227
Respondent is the head of HH	=1 if respondent is the household head	0.19	0.394	0.058	0.235
Female head of HH	=1 if head of hh is female	0.223	0.418	0.075	0.264
Age of head of HH	in years	47.934	16.431	34.333	11.578
Education of head of HH	in years	2.372	2.53	3.042	2.686

Table 6: General Satisfaction

	Beans	Maize/Rice	Fortified CSB/CSB
<i>Mann Whitney Results:</i>			
Quality	LRP***	LRP ***	LRP ***
Quantity	LRP***	LRP **	LRP ***
Taste	LRP***	LRP **	LRP ***
Storability	LRP***	LRP *	LRP
Time to cook	LRP***	LRP **	LRP
Texture/Appearance	LRP***	LRP ***	LRP **
Nutritional content	LRP	LRP ***	LRP ***
Cleanliness	LRP***	LRP ***	LRP *
General Satisfaction	LRP***	LRP **	LRP **
<i>Multivariate Ordered Logit Results:</i>			
Quality	LRP	LRP	LRP***
Quantity	LRP*	MYAP	LRP
Taste	LRP***	LRP	LRP
Storability	LRP***	LRP***	LRP**
Cooking Time	LRP***	LRP	LRP
Appearance	LRP**	LRP***	LRP
Nutritional content	LRP	MYAP	LRP
Cleanliness	LRP*	MYAP **	MYAP
General Satisfaction	LRP***	LRP	LRP

NOTES: (1) ***,** and * indicate statistical significance at the 1%, 5% and 10% levels, respectively. (2) The *multivariate ordered logit results* include the following controls: age, education, total household members, distance to market (km), distance to the market (minutes), monthly rations received, language, household members aged between 19-60, female head of household and market accessibility, market frequency 2/week, market frequency 3/week, market accessed by foot and market access by dirt road.

Table 7: Relative Satisfaction

	Beans	Maize/Rice	Fortified CSB/CSB
<i>Mann Whitney Results:</i>			
Quality	LRP***	LRP ***	LRP ***
Taste	LRP***	LRP ***	LRP ***
Storability	LRP***	LRP ***	LRP***
Texture/Appearance	LRP***	LRP ***	LRP ***
Nutritional content	LRP***	LRP ***	LRP **
Cleanliness	LRP***	LRP ***	LRP ***
General Satisfaction	LRP***	LRP ***	LRP ***
<i>Multivariate Ordered Logit Results:</i>			
Quality	LRP	LRP***	MYAP*
Taste	LRP**	LRP	MYAP
Storability	LRP	LRP*	MYAP
Appearance	MYAP	LRP	MYAP
Nutritional content	MYAP	MYAP ***	MYAP
Cleanliness	LRP	LRP	MYAP
General Satisfaction	MYAP	MYAP	MYAP

NOTES: (1) ***, ** and * indicate statistical significance at the 1%, 5% and 10% levels, respectively. (2) The *multivariate ordered logit results* include the following controls: age, education, total household members, distance to market (km), distance to the market (minutes), monthly rations received, language, household members aged between 19-60, female head of household and market accessibility, market frequency 2/week, market frequency 3/week, market accessed by foot and market access by dirt road.

Table 8: Preparation Costs

	Beans	Maize/Rice	Fortified CSB/CSB
<i>Mann Whitney Results:</i>			
Fuel Use	LRP***	LRP ***	LRP ***
Time	LRP***	LRP ***	LRP ***
Water Use	LRP***	LRP **	LRP***
Cooking Oil Use	LRP***	-	-
Cost	LRP***	LRP ***	LRP ***
Effort	LRP***	LRP ***	LRP ***
<i>Multivariate Ordered Logit Results:</i>			
Fuel Use	LRP***	LRP*	MYAP
Time	LRP***	LRP	MYAP
Water Use	LRP	MYAP	LRP
Cost	-	MYAP	MYAP
Effort	MYAP	LRP	MYAP*

NOTES: (1) ***,** and * indicate statistical significance at the 1%, 5% and 10% levels, respectively. (2) The *multivariate ordered logit results* include the following controls: age, education, total household members, distance to market (km), distance to the market (minutes), monthly rations received, language, household members aged between 19-60, female head of household and market accessibility, market frequency 2/week, market frequency 3/week, market accessed by foot and market access by dirt road.

Table 9: Offers (prices and quantities)

Winner	Date	Year	Org type	Qty (1Q = 100 lbs)	Price	Total Bid (Qz)
<i>Beans:</i>						
*	October-November	2010	Commercial	720 Q	350 Qz/Q	252,000
	October-November	2010	Association	720 Q	475 Qz/Q	342,000
	December	2010	Association	360 Q	400 Qz/Q	144,000
*	December	2010	Commercial	360 Q	400 Qz/Q	144,000
*	April-September	2011	Association	2,160 Q	400 Qz/Q	864,000
	April-September	2011	Association	2,160 Q	420 Qz/Q	907,200
	April-September	2011	Commercial	2,160 Q	450 Qz/Q	972,000
	July-September	2011	Association	1,080 Q	420 Qz/Q	453,600
*	July-September	2011	Commercial	1,080 Q	390 Qz/Q	421,200
	July-September	2011	Commercial	1,080 Q	415 Qz/Q	448,200
<i>Maize:</i>						
*	October-November	2010	Commercial	6,000 Q	160 Qz/Q	960,000
	October-November	2010	Association	6,000 Q	196 Qz/Q	245,784
*	October-November	2010	Association	6000 Q	162 Qz/Q	972,000
*	December	2010	Association	3000 Q	158 Qz/Q	474,000
	December	2010	Commercial	3000 Q	160 Qz/Q	480,000
*	April-September	2011	Association	18,000 Q	162 Qz/Q	2,916,000
	April-September	2011	Association	18,000 Q	164 Qz/Q	2,952,000
	April-September	2011	Commercial	18,000 Q	170 Qz/Q	3,060,000
	April-September	2011	Commercial	18,000 Q	180 Qz/Q	3,240,000
*	June	2011	Association	3,000 Q	185 Qz/Q	555,000
	July-September	2011	Association	9,000 Q	250 Qz/Q	2,250,000
*	July-September	2011	Commercial	9,000 Q	265 Qz/Q	2,385,000
	July-September	2011	Commercial	9,000 Q	250 Qz/Q	2,250,000
<i>CSB:</i>						
	October-November	2010	Commercial	78,622 bags	5.39 Qz/bag	423,773
*	October-November	2010	Commercial	78,622 bags	6.50 Qz/bag	511,043
	October-November	2010	Association	78,622 bags	6.75 Qz/bag	530,699
*	December	2010	Commercial	39,000 bags	6.50 Qz/bag	253,500
*	April-September	2011	Commercial	234,000 bags	6.90 Qz/bag	1,614,600
	April-September	2011	Commercial	234,000 bags	6.29 Qz/bag	1,471,860

NOTES: * indicates the winner of the bid.

12. Appendices

Table A-1: All Market Effects: Beans (Regression Output)

VARIABLES	(1) Log Price	(2) Price Volatility
Log prices lag 1	0.950*** (0.0326)	
Log prices lag 2	-0.0686** (0.0321)	
Procurement current	0.000765 (0.000573)	-0.000237 (0.000362)
Procurement lag 1	-0.000742 (0.000630)	-2.41e-05 (0.000399)
Procurement lag 2	0.000892 (0.000611)	0.000176 (0.000387)
Log world prices current	0.0569** (0.0287)	0.0170 (0.0188)
Log world prices lag 1	-0.00776 (0.0461)	-0.0416 (0.0300)
Log world prices lag 2	-0.0244 (0.0283)	0.0209 (0.0181)
Precipitation 6month MA	-0.00500 (0.00474)	0.00244 (0.00297)
Temperature 6month MA	-0.00230 (0.00381)	0.000486 (0.00245)
Lean Season	0.00873* (0.00475)	0.00284 (0.00304)
WFP procurements current	-2.96e-05** (1.45e-05)	-1.87e-07 (9.17e-06)
WFP (neighbors) current	5.22e-06 (4.28e-06)	2.18e-06 (2.71e-06)
Surplus Season	-0.00357 (0.00430)	0.00460* (0.00275)
National CPI	0.00418*** (0.000748)	0.00171*** (0.000461)
Transportation CPI	0.00131*** (0.000217)	-0.000115 (0.000127)
Residual lag 1		0.136*** (0.0311)
Residual lag 2		0.00583 (0.0312)
Constant	0.378*** (0.0593)	0.0449 (0.0274)
Observations	952	936
R-squared	0.961	0.110

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

Table A-2: Non-procurement/distribution Market Effects: Beans (Regression Output)

VARIABLES	(1) Log Price	(2) Price Volatility
Log prices lag 1	0.965*** (0.0350)	
Log prices lag 2	-0.0817** (0.0342)	
Procurement current	0.000424 (0.000589)	-7.86e-05 (0.000370)
Procurement lag 1	-0.000182 (0.000648)	-0.000137 (0.000408)
Procurement lag 2	0.000443 (0.000628)	-0.000148 (0.000396)
Log world prices current	0.0357 (0.0294)	0.0292 (0.0192)
Log world prices lag 1	0.0343 (0.0474)	-0.0643** (0.0306)
Log world prices lag 2	-0.0410 (0.0291)	0.0344* (0.0185)
Precipitation 6month MA	-0.00295 (0.00486)	0.00114 (0.00303)
Temperature 6month MA	-0.00278 (0.00391)	0.000389 (0.00251)
Lean Season	0.00505 (0.00486)	0.00360 (0.00310)
WFP procurements current	-1.94e-05 (1.49e-05)	-8.82e-07 (9.38e-06)
WFP (neighbors) current	6.24e-06 (4.40e-06)	2.10e-06 (2.77e-06)
Surplus Season	-0.00400 (0.00441)	0.00396 (0.00281)
National CPI	0.00393*** (0.000771)	0.00174*** (0.000472)
Transportation CPI	0.00121*** (0.000224)	-0.000121 (0.000130)
Residual lag 1		0.147*** (0.0334)
Residual lag 2		0.0162 (0.0333)
Constant	0.360*** (0.0613)	0.0299 (0.0280)
Observations	833	819
R-squared	0.964	0.121

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

Table A-3: Procurement/distribution Market Effects: Beans (Regression Output)

VARIABLES	(1) Log Price	(2) Price Volatility
Log prices lag 1	0.903*** (0.0926)	
Log prices lag 2	-0.0168 (0.0935)	
Procurement current	0.00320 (0.00200)	-0.000264 (0.00121)
Procurement lag 1	-0.00446** (0.00220)	-0.000459 (0.00133)
Procurement lag 2	0.00411* (0.00215)	-0.000967 (0.00130)
Log world prices current	0.196* (0.101)	-0.0129 (0.0653)
Log world prices lag 1	-0.311* (0.160)	0.0560 (0.101)
Log world prices lag 2	0.0996 (0.0974)	-0.0594 (0.0607)
Precipitation 6month MA	-0.0219 (0.0169)	0.00886 (0.0101)
Temperature 6month MA	0.00201 (0.0133)	-0.00205 (0.00818)
Lean Season	0.0414** (0.0176)	0.000787 (0.0110)
WFP procurements current	-0.000101** (5.09e-05)	1.26e-05 (3.20e-05)
WFP (neighbors) current	-2.93e-06 (1.50e-05)	7.88e-06 (9.05e-06)
Surplus Season	-0.00538 (0.0155)	0.00365 (0.00959)
National CPI	0.00614** (0.00259)	0.00138 (0.00155)
Transportation CPI	0.00201*** (0.000736)	-0.000133 (0.000431)
Residual lag 1		0.153 (0.0948)
Residual lag 2		-0.00563 (0.0941)
Constant	0.461** (0.195)	0.116 (0.0912)
Observations	119	117
R-squared	0.943	0.128
Standard errors in parentheses		
*** p<0.01, ** p<0.05, * p<0.1		

Table A-4: All Market Effects: Incaparina (Regression Output)

VARIABLES	(1) Log Price	(2) Price Volatility
Log prices lag 1	1.005*** (0.0333)	
Log prices lag 2	-0.0844*** (0.0321)	
Procurement current	-0.000224 (0.000167)	-0.000258** (0.000112)
Procurement lag 1	-0.000134 (0.000176)	-3.34e-05 (0.000118)
Procurement lag 2	-0.000169 (0.000175)	-0.000210* (0.000117)
Log world prices current	-0.00412 (0.00870)	0.0138** (0.00586)
Log world prices lag 1	0.0608*** (0.0134)	-0.00892 (0.00913)
Log world prices lag 2	-0.0366*** (0.00930)	0.00352 (0.00624)
Precipitation 6month MA	-0.00273** (0.00130)	-1.21e-05 (0.000876)
Temperature 6month MA	7.74e-05 (0.00116)	0.000431 (0.000782)
Lean Season	-0.00477*** (0.00154)	0.000583 (0.00104)
WFP procurements current	-1.37e-06 (1.32e-06)	-1.02e-06 (8.84e-07)
WFP (neighbors) current	-2.40e-06* (1.27e-06)	-1.52e-06* (8.48e-07)
Surplus Season	-0.00252* (0.00141)	0.00202** (0.000949)
National CPI	0.000804*** (0.000225)	0.000275* (0.000150)
Transportation CPI	0.000702*** (0.000127)	-7.24e-05 (4.57e-05)
Residual lag 1		0.0183 (0.0334)
Residual lag 2		0.00439 (0.0338)
Constant	0.301*** (0.0502)	-0.0268*** (0.00953)
Observations	952	936
R-squared	0.995	0.080

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

Table A-5: Non-procurement/distribution Market Effects: Incaparina (Regression Output)

VARIABLES	(1) lprice	(2) e_a
Log prices lag 1	1.012*** (0.0354)	
Log prices lag 2	-0.0899*** (0.0342)	
Procurement current	-0.000185 (0.000176)	-0.000371*** (0.000118)
Procurement lag 1	-8.29e-05 (0.000186)	1.12e-05 (0.000125)
Procurement lag 2	-0.000261 (0.000185)	-0.000337*** (0.000124)
Log world prices current	-0.000508 (0.00918)	0.0146** (0.00620)
Log world prices lag 1	0.0546*** (0.0142)	-0.00746 (0.00967)
Log world prices lag 2	-0.0350*** (0.00981)	0.000985 (0.00662)
Precipitation 6month MA	-0.00281** (0.00137)	0.000483 (0.000928)
Temperature 6month MA	0.000146 (0.00123)	0.000126 (0.000827)
Lean Season	-0.00457*** (0.00159)	0.000656 (0.00108)
WFP procurements current	-1.98e-06 (1.40e-06)	-9.52e-07 (9.36e-07)
WFP (neighbors) current	-2.22e-06* (1.35e-06)	-1.92e-06** (8.98e-07)
Surplus Season	-0.00283* (0.00145)	0.00191* (0.000975)
National CPI	0.000826*** (0.000238)	0.000278* (0.000159)
Transportation CPI	0.000698*** (0.000133)	-6.32e-05 (4.83e-05)
Residual lag 1		-0.00252 (0.0354)
Residual lag 2		-0.0131 (0.0355)
Constant	0.298*** (0.0524)	-0.0258** (0.0101)
Observations	833	819
R-squared	0.995	0.090

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

Table A-6: Procurement/distribution Market Effects: Incaparina (Regression Output)

VARIABLES	(1) Log Price	(2) Price Volatility
Log prices lag 1	0.994*** (0.106)	
Log prices lag 2	-0.0816 (0.102)	
Procurement current	-0.000501 (0.000534)	0.000439 (0.000315)
Procurement lag 1	-0.000459 (0.000560)	-6.21e-05 (0.000336)
Procurement lag 2	0.000526 (0.000562)	-0.000116 (0.000332)
Log world prices current	-0.0306 (0.0280)	0.00169 (0.0171)
Log world prices lag 1	0.104** (0.0429)	-0.00478 (0.0263)
Log world prices lag 2	-0.0473 (0.0302)	0.0151 (0.0176)
Precipitation 6month MA	-0.00219 (0.00415)	-0.00277 (0.00248)
Temperature 6month MA	-0.000462 (0.00365)	0.00279 (0.00224)
Lean Season	-0.00533 (0.00692)	0.00186 (0.00417)
WFP procurements current	2.97e-06 (4.25e-06)	-4.25e-06* (2.49e-06)
WFP (neighbors) current	-3.79e-06 (4.04e-06)	1.80e-07 (2.38e-06)
Surplus Season	9.77e-05 (0.00665)	0.00419 (0.00395)
National CPI	0.000577 (0.000726)	0.000442 (0.000425)
Transportation CPI	0.000710 (0.000453)	-0.000131 (0.000129)
Residual lag 1		0.133 (0.102)
Residual lag 2		0.00120 (0.111)
Constant	0.321* (0.185)	-0.0421 (0.0267)
Observations	119	117
R-squared	0.994	0.165

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

Table A-7: All Market Effects: White Maize (Regression Output)

VARIABLES	(1) Log Price	(2) Price Volatility
Log prices lag 1	0.915*** (0.0327)	
Log prices lag 2	-0.106*** (0.0327)	
Procurement current	-0.000299 (0.000304)	0.000187 (0.000278)
Procurement lag 1	-0.000217 (0.000327)	-9.22e-05 (0.000299)
Procurement lag 2	-1.89e-06 (0.000325)	2.38e-05 (0.000298)
Log world prices current	0.0449 (0.123)	0.0313 (0.114)
Log world prices lag 1	0.00586 (0.188)	-0.137 (0.174)
Log world prices lag 2	0.0940 (0.130)	0.165 (0.119)
Precipitation 6month MA	0.0301* (0.0182)	-0.00454 (0.0167)
Temperature 6month MA	-0.0188 (0.0161)	0.00404 (0.0150)
Lean Season	-0.0171 (0.0220)	0.0110 (0.0203)
WFP procurements current	-9.88e-07 (1.02e-05)	-2.05e-06 (9.43e-06)
WFP (neighbors) current	-2.80e-06 (8.83e-06)	1.52e-06 (8.15e-06)
Surplus Season	-0.0216 (0.0201)	-0.00779 (0.0184)
National CPI	-0.00483 (0.00311)	-0.000446 (0.00286)
Transportation CPI	-0.000377 (0.00103)	-0.00151 (0.000929)
Residual lag 1		0.149*** (0.0327)
Residual lag 2		0.153*** (0.0327)
Constant	0.153 (0.216)	-0.111 (0.190)
Observations	952	936
R-squared	0.759	0.097

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

Table A-8: Non-procurement/distribution Market Effects: White Maize (Regression Output)

VARIABLES	(1) Log Price	(2) Price Volatility
Log prices lag 1	0.914*** (0.0350)	
Log prices lag 2	-0.105*** (0.0350)	
Procurement current	-0.000314 (0.000347)	0.000193 (0.000317)
Procurement lag 1	-0.000239 (0.000372)	-9.50e-05 (0.000341)
Procurement lag 2	4.35e-06 (0.000371)	2.55e-05 (0.000340)
Log world prices current	0.0534 (0.141)	0.0349 (0.130)
Log world prices lag 1	0.00718 (0.214)	-0.157 (0.198)
Log world prices lag 2	0.0966 (0.148)	0.183 (0.136)
Precipitation 6month MA	0.0335 (0.0207)	-0.00449 (0.0191)
Temperature 6month MA	-0.0207 (0.0184)	0.00427 (0.0171)
Lean Season	-0.0193 (0.0245)	0.0110 (0.0227)
WFP procurements current	-5.73e-07 (1.16e-05)	-1.58e-06 (1.08e-05)
WFP (neighbors) current	-3.26e-06 (1.01e-05)	1.74e-06 (9.30e-06)
Surplus Season	-0.0252 (0.0222)	-0.00916 (0.0204)
National CPI	-0.00545 (0.00355)	-0.000607 (0.00327)
Transportation CPI	-0.000637 (0.00117)	-0.00165 (0.00106)
Residual lag 1		0.149*** (0.0350)
Residual lag 2		0.153*** (0.0350)
Constant	0.121 (0.245)	-0.109 (0.216)
Observations	833	819
R-squared	0.753	0.096

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

Table A-9: Procurement/distribution Market Effects: White Maize (Regression Output)

VARIABLES	(1)	(2)
	Log Price	Price Volatility
Log prices lag 1	0.929*** (0.0984)	
Log prices lag 2	-0.146 (0.102)	
Procurement current	-0.000180 (0.000200)	0.000154 (0.000122)
Procurement lag 1	-4.89e-05 (0.000215)	-7.18e-05 (0.000131)
Procurement lag 2	-4.77e-05 (0.000212)	-8.68e-05 (0.000130)
Log world prices current	0.00741 (0.0802)	0.0462 (0.0525)
Log world prices lag 1	-0.0457 (0.123)	-0.0416 (0.0771)
Log world prices lag 2	0.0892 (0.0842)	0.0532 (0.0518)
Precipitation 6month MA	0.00379 (0.0120)	-0.00796 (0.00741)
Temperature 6month MA	-0.00827 (0.0118)	0.00922 (0.00673)
Lean Season	0.0383* (0.0208)	0.0180 (0.0125)
WFP procurements current	-5.55e-06 (6.61e-06)	-4.71e-06 (4.17e-06)
WFP (neighbors) current	2.28e-06 (5.73e-06)	-3.47e-06 (3.57e-06)
Surplus Season	0.0413** (0.0196)	0.00469 (0.0118)
National CPI	-0.000335 (0.00200)	0.00178 (0.00134)
Transportation CPI	0.00176* (0.000975)	-0.000509 (0.000405)
Residual lag 1		0.0257 (0.0969)
Residual lag 2		-0.0835 (0.101)
Constant	0.457* (0.260)	-0.224*** (0.0852)
Observations	119	117
R-squared	0.951	0.187

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

Table A-10: All Market Effects: Yellow Maize (Regression Output)

VARIABLES	(1) Log Price	(2) Price Volatility
Log prices lag 1	0.910*** (0.0362)	
Log prices lag 2	-0.0817** (0.0362)	
Procurement current	-0.000374 (0.000366)	0.000199 (0.000338)
Procurement lag 1	-0.000135 (0.000391)	-8.84e-05 (0.000361)
Procurement lag 2	1.99e-05 (0.000391)	-7.87e-05 (0.000361)
Log world prices current	0.0265 (0.150)	0.0160 (0.139)
Log world prices lag 1	0.117 (0.229)	-0.132 (0.213)
Log world prices lag 2	-0.0128 (0.158)	0.178 (0.147)
Precipitation 6month MA	0.0325 (0.0222)	0.00109 (0.0207)
Temperature 6month MA	-0.0155 (0.0197)	0.000937 (0.0184)
Lean Season	-0.0493* (0.0275)	0.00508 (0.0258)
WFP procurements current	4.99e-06 (1.25e-05)	-5.59e-07 (1.17e-05)
WFP (neighbors) current	-5.23e-06 (1.06e-05)	-2.26e-06 (9.88e-06)
Surplus Season	-0.0290 (0.0249)	-0.0267 (0.0232)
National CPI	-0.00444 (0.00379)	-0.00186 (0.00353)
Transportation CPI	-0.000609 (0.00127)	-0.00178 (0.00117)
Residual lag 1		0.127*** (0.0363)
Residual lag 2		0.135*** (0.0364)
Constant	0.191 (0.261)	-0.0701 (0.234)
Observations	780	762
R-squared	0.760	0.083

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

Table A-11: Non-procurement/distribution Market Effects: Yellow Maize (Regression Output)

VARIABLES	(1) Log Price	(2) Price Volatility
Log prices lag 1	0.903*** (0.0384)	
Log prices lag 2	-0.0857** (0.0384)	
Procurement current	-0.000342 (0.000410)	0.000174 (0.000378)
Procurement lag 1	-0.000124 (0.000440)	-3.74e-05 (0.000405)
Procurement lag 2	-1.26e-05 (0.000439)	-7.87e-05 (0.000405)
Log world prices current	0.0759 (0.168)	-0.00581 (0.156)
Log world prices lag 1	0.0266 (0.255)	-0.108 (0.238)
Log world prices lag 2	0.0721 (0.176)	0.181 (0.163)
Precipitation 6month MA	0.0296 (0.0246)	-0.00276 (0.0229)
Temperature 6month MA	-0.0211 (0.0219)	0.000561 (0.0205)
Lean Season	-0.0535* (0.0297)	0.0128 (0.0278)
WFP procurements current	5.93e-06 (1.38e-05)	2.23e-07 (1.30e-05)
WFP (neighbors) current	-7.35e-06 (1.19e-05)	1.20e-06 (1.11e-05)
Surplus Season	-0.0399 (0.0268)	-0.0270 (0.0248)
National CPI	-0.00581 (0.00422)	-0.00160 (0.00392)
Transportation CPI	-0.000943 (0.00140)	-0.00186 (0.00128)
Residual lag 1		0.142*** (0.0385)
Residual lag 2		0.148*** (0.0385)
Constant	0.0631 (0.288)	-0.0942 (0.259)
Observations	695	679
R-squared	0.748	0.093

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

Table A-12: Procurement/distribution Market Effects: Yellow Maize (Regression Output)

VARIABLES	(1) Log Price	(2) Price Volatility
Log prices lag 1	0.865*** (0.115)	
Log prices lag 2	0.0317 (0.112)	
Procurement current	-0.000330 (0.000481)	9.25e-05 (0.000303)
Procurement lag 1	-0.000173 (0.000505)	-0.000202 (0.000321)
Procurement lag 2	0.000517 (0.000515)	-4.75e-05 (0.000325)
Log world prices current	-0.302 (0.202)	-0.109 (0.129)
Log world prices lag 1	0.606* (0.310)	0.113 (0.198)
Log world prices lag 2	-0.429* (0.219)	0.0796 (0.138)
Precipitation 6month MA	0.0188 (0.0333)	0.0114 (0.0201)
Temperature 6month MA	0.0244 (0.0287)	0.0165 (0.0181)
Lean Season	0.101* (0.0558)	-0.145*** (0.0375)
WFP procurements current	-8.27e-06 (1.82e-05)	-5.28e-06 (1.13e-05)
WFP (neighbors) current	8.38e-06 (1.40e-05)	-1.26e-05 (9.31e-06)
Surplus Season	0.169*** (0.0521)	-0.130*** (0.0361)
National CPI	0.00626 (0.00541)	-0.000688 (0.00342)
Transportation CPI	0.00117 (0.00212)	-0.00140 (0.00143)
Residual lag 1		-0.0951 (0.114)
Residual lag 2		-0.219* (0.112)
Constant	0.815* (0.434)	-0.0462 (0.224)
Observations	85	83
R-squared	0.890	0.269

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

Table A-13: General Satisfaction, Maize and Rice (ordered logit random effects)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Quality	Quantity	Taste	Storability	Cooking Time	Appearance	Nutritional Content	Non-contamination	General satisfaction
LRP (D)	1.04 (.942)	- .738 (.579)	.427 (.686)	2.94*** (.609)	.619 (.689)	1.62*** (.501)	- .577 (.59)	-1.07** (.449)	1.23 (2.25)
Age	6.5e-04 (.024)	.025 (.032)	- .044** (.022)	.021 (.037)	7.5e-03 (.022)	- .016 (.022)	5.6e-03 (.031)	.019 (.016)	.011 (.024)
Education	.238** (.103)	.204* (.115)	.095 (.123)	.03 (.146)	.156 (.118)	.019 (.111)	.052 (.082)	- .019 (.094)	- .021 (.048)
Language (D)	- .8 (.748)	-1.94** (.792)	- .71 (.713)	1.14** (.497)	-1.24 (1.05)	-1.87** (.861)	-2.58*** (.669)	-2.09*** (.443)	.765 (2.4)
HH Members b/w 19-60	- .267 (.294)	- .25* (.147)	- .204 (.326)	.139 (.19)	- .102 (.12)	- .147 (.128)	- .379** (.173)	- .288* (.174)	- .162 (.132)
Total HH Members	- .069 (.103)	- .135*** (.048)	5.5e-03 (.148)	8.0e-03 (.153)	- .56e-03 (.078)	.147*** (.052)	.119 (.074)	- .077 (.098)	- .111* (.066)
Female head of HH (D)	- .899 (1.08)	- .223 (.84)	.633 (.649)	- .831 (.746)	- .952 (.593)	- .277 (.383)	-1.03*** (.371)	-1.81*** (.549)	- .753 (.784)
Mkt frequency 2/week (D)	7.5e-03 (.246)	.303 (.318)	.359 (.373)	- .306 (.422)	.713** (.356)	.613** (.281)	.339 (.341)	- .168 (.302)	- .557** (.223)
Mkt frequency 3/week (D)	- .442 (.425)	.406 (.506)	.622 (.526)	.266 (.356)	2.11*** (.672)	- .126 (.637)	- .021 (.378)	- .997** (.472)	-1.47*** (.341)
Mkt access by foot (D)	- .254 (.239)	- .657 (.476)	- .276 (.252)	.108 (.344)	- .108** (.534)	.795** (.329)	.146 (.22)	-1.8*** (.506)	.877*** (.308)
Mkt access by dirt road (D)	- .324 (.247)	.041 (.489)	- .016 (.316)	- .076 (.291)	.452 (.329)	-1.07*** (.337)	.252 (.272)	1.94*** (.637)	.052 (.334)
Distance to mkt (km)	- .051*** (.012)	- .031 (.019)	- .02* (.011)	- .039** (.016)	- .7.0e-03 (.01)	- .071*** (.025)	- .01 (8.5e-03)	-1.4e-03 (8.8e-03)	- .034*** (9.5e-03)
Distance to kt (minutes)	2.5e-03 (1.8e-03)	.024*** (7.2e-03)	2.2e-03 (2.1e-03)	8.6e-03*** (3.2e-03)	3.0e-03 (2.6e-03)	.015*** (4.2e-03)	.01** (4.7e-03)	-5.7e-03 (3.9e-03)	1.1e-03 (2.3e-03)
Mkt accessibility (D)	.495*** (.176)	- .47 (.301)	.262 (.275)	- .13 (.365)	- .828*** (.231)	- .872*** (.174)	-1*** (.337)	.568*** (.211)	- .08 (.172)
Monthly rations received	- .013 (.024)	-8.6e-03 (.012)	- .024 (.021)	1.0e-02 (.016)	8.2e-04 (6.4e-03)	1.1e-04 (8.0e-03)	2.7e-03 (.016)	- .017 (.012)	- .027 (.024)
Observations	238	238	236	209	237	237	238	237	237

Standard errors in parentheses
 * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$
 D denotes dummy variable

Table A-14: General Satisfaction, Beans (ordered logit random effects)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Quality	Quantity	Taste	Storability	Cooking Time	Appearance	Nutritional Content	Non-contamination	General satisfaction
LRP (D)	.219 (.465)	4.28* (2.33)	1.44*** (.484)	3.63*** (1.26)	3.08*** (.85)	3.68** (1.73)	1.46 (1.1)	1.7* (.997)	2.79*** (1.04)
Age	7.6e-03 (.015)	-0.18 (.011)	-0.21 (.016)	-2.3e-03 (.013)	-5.8e-03 (.014)	.027 (.019)	6.6e-03 (.019)	-1.4e-03 (.016)	4.5e-03 (.013)
Education	.153** (.071)	.022 (.078)	.121 (.083)	.08 (.105)	-.041 (.095)	.01 (.062)	.082 (.104)	-.015 (.14)	.041 (.054)
Language (D)	-1.95*** (.615)	.949 (2.66)	-1.37 (.888)	1.08 (1.19)	.632 (.406)	2.82 (1.78)	.359 (1.22)	-1.62 (1.5)	.822 (1.07)
HH Members b/w 19-60	-.203 (.133)	-.168 (.198)	-.032 (.157)	-.368 (.293)	-.128 (.141)	-.449** (.229)	-.349 (.285)	-.249 (.288)	-.178 (.161)
Total HH Members	.085 (.056)	-5.9e-03 (.089)	-.049 (.101)	.103 (.156)	.079 (.056)	.073 (.098)	.128 (.131)	2.6e-03 (.115)	.035 (.07)
Female head of HH (D)	-1.75* (.999)	3.2e-03 (.555)	-1.85 (1.35)	-6.19 (.83)	-.867 (.815)	-.681* (.396)	-.779* (.462)	-.644 (.452)	.042 (.53)
Mkt frequency 2/week (D)	.294* (.175)	.368 (.325)	.815*** (.275)	.59 (.406)	.589* (.319)	-.199 (.217)	.233 (.294)	.991*** (.365)	.203 (.214)
Mkt frequency 3/week (D)	-.245 (.283)	.619 (.512)	1.64** (.658)	1.16** (.505)	.954*** (.333)	.478 (.519)	2.02*** (.455)	-.511 (.338)	.495* (.297)
Mkt access by foot (D)	-.327 (.23)	.488 (.763)	-1.01** (.476)	-1.75*** (.356)	-.83*** (.143)	-1.14** (.453)	-2.96*** (.843)	-1.83** (.839)	-.043 (.314)
Mkt access by dirt road (D)	.274 (.238)	-.16 (.577)	.633 (.592)	-.462 (.438)	-.438 (.43)	.129 (.504)	.887* (.505)	1.17 (.85)	.06 (.45)
Distance to mkt (km)	-5.6e-03 (9.6e-03)	-.053** (.025)	4.1e-03 (.018)	-.038** (.016)	-.014 (9.7e-03)	-.024* (.012)	.011 (8.4e-03)	-.013 (.015)	-.025** (.012)
Distance to kt (minutes)	2.3e-03 (1.5e-03)	.025*** (5.4e-03)	2.8e-03 (2.4e-03)	-.015*** (4.4e-03)	-3.1e-03 (2.4e-03)	2.1e-03 (2.6e-03)	-.018** (7.0e-03)	-8.9e-03 (5.5e-03)	1.6e-03 (1.9e-03)
Mkt accessibility (D)	-.213 (.179)	-1.12*** (.357)	-.19 (.18)	1.45*** (.343)	-.043 (.083)	.414 (.356)	1.3*** (.36)	.262 (.261)	-.532*** (.092)
Monthly rations received	-.028 (.02)	-.027 (.022)	-.02 (.029)	-.016 (.027)	-.011 (.015)	-.041*** (.014)	-.014 (.013)	-.024 (.026)	-.018 (.025)
Observations	238	238	235	206	236	238	237	238	236

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

D denotes dummy variable

Table A-15: General Satisfaction, CSB (ordered logit random effects)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	Quality	Quantity	Taste	Storability	Cooking Time	Appearance	Nutritional Content	Non-contamination	General satisfaction
LRP (D)	4.55** (1.85)	1.09 (1.07)	1.18 (.984)	1.29** (.536)	.455 (1.66)	4 (2.79)	.905 (.694)	-.102 (.846)	1.21 (.815)
Age	.028 (.025)	3.9e-03 (.026)	2.4e-03 (.015)	-3.4e-03 (.027)	.02 (.042)	.011 (.042)	.018 (.025)	.039 (.028)	5.2e-03 (.023)
Education	.284* (.146)	.232* (.131)	.143 (.092)	.214** (.108)	.205*** (.078)	.232 (.181)	.112** (.057)	.134 (.098)	.027 (.086)
Language (D)	1.55* (.86)	-1.04 (1.27)	.428 (.892)	.45** (.175)	-.738 (.936)	3.02 (3.35)	-.802 (.885)	-1.81** (.817)	-1.39 (.972)
HH Members b/w 19-60	-.174 (.185)	-.032 (.213)	-.312 (.244)	-.443*** (.14)	-.574*** (.198)	-.276* (.142)	-.336 (.257)	-.614*** (.226)	-.571*** (.192)
Total HH Members	-.112 (.102)	-.222*** (.07)	.087 (.116)	.133 (.094)	.129* (.075)	-.04 (.117)	.029 (.081)	.026 (.077)	.048 (.072)
Female head of HH (D)	-2.07** (.822)	-1.65** (.763)	-1.25** (.511)	-1.57* (.875)	-2.14** (.965)	-2.02*** (.775)	-1.82** (.778)	-4.89*** (1.64)	-1.19 (.851)
Mkt frequency 2/week (D)	-.417 (.671)	.598* (.316)	.261 (.329)	1.09*** (.29)	-.117 (1.85)	-.502 (.309)	-.299 (.293)	.268 (.361)	-.256 (.297)
Mkt frequency 3/week (D)	3.44*** (1.02)	.489 (.759)	.121 (.328)	-2.05*** (.719)	.421 (1.84)	-.48 (.362)	.275 (.336)	-.305 (.462)	-.031 (.738)
Mkt access by foot (D)	.382 (.319)	.493 (.411)	-.4** (.19)	1.08** (.505)	.822* (.457)	.453 (.52)	.392 (.352)	.033 (.313)	.951** (.385)
Mkt access by dirt road (D)	-.553 (.359)	-.858 (.644)	.182 (.288)	-.582** (.258)	-.812 (2.34)	1.32** (.531)	-.76*** (.285)	-1.14* (.641)	-1.41 (1)
Distance to mkt (km)	-.069*** (.022)	-.027* (.015)	3.2e-03 (9.8e-03)	-.052** (.02)	-.065 (.04)	-.095*** (.018)	-.06*** (.012)	-.08*** (.017)	-.09*** (.026)
Distance to kt (minutes)	6.5e-04 (5.1e-03)	.019*** (5.7e-03)	-7.1e-03*** (2.2e-03)	3.8e-04 (2.1e-03)	7.2e-03 (.015)	.021*** (5.9e-03)	3.2e-03** (1.4e-03)	8.4e-04 (2.0e-03)	.016*** (6.0e-03)
Mkt accessibility (D)	-1.91*** (.577)	-.074 (.244)	-.643*** (.195)	.887*** (.206)	-.816** (.413)	-.948*** (.36)	-.454** (.221)	-.096 (.249)	-.846*** (.173)
Monthly rations received	-.058 (.04)	-.04 (.027)	-.024 (.025)	-.038** (.018)	-.032* (.017)	-.07*** (.024)	-.023* (.013)	-7.0e-03 (.022)	2.1e-03 (.017)
Observations	238	238	238	201	238	223	238	237	238

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

D denotes dummy variable

Table A-16: Relative Satisfaction, Maize and Rice (ordered logit random effects)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Quality	Taste	Storability	Appearance	Nutritional Content	Non-contamination	General satisfaction
LRP (D)	1.85*** (.7)	.474 (.605)	1.21* (.7)	.022 (.585)	-1.56*** (.385)	.67 (.532)	-.804 (1.16)
Age	-.059*** (9.4e-03)	-.055*** (.018)	-7.0e-03 (9.1e-03)	-.033*** (8.1e-03)	-.021** (8.5e-03)	-4.1e-03 (.016)	-.03** (.013)
Education	-.153* (.089)	-.303* (.182)	.052 (.053)	.015 (.073)	.042 (.079)	.34** (.135)	-.123 (.1)
Language (D)	.633 (.627)	-1.09 (.996)	.132 (.513)	-1.43*** (.283)	-1.53*** (.457)	-1.46*** (.373)	-1.54*** (.399)
HH Members b/w 19-60	-.167 (.155)	-.146 (.151)	-5.84** (.281)	-.354*** (.122)	-.176 (.161)	-.686** (.336)	.065 (.138)
Total HH Members	.057 (.063)	.113 (.134)	.159 (.172)	.156* (.085)	.158 (.125)	.265* (.148)	-.081 (.066)
Female head of HH (D)	-.303 (.441)	-.73 (.467)	.945 (.981)	-.069 (.627)	.739 (.723)	.503 (.535)	.945 (.702)
Mkt frequency 2/week (D)	1.04*** (.14)	-8.7e-03 (.168)	1.44*** (.394)	.362 (.225)	.326* (.189)	1.3*** (.393)	-.371** (.168)
Mkt frequency 3/week (D)	.412 (.266)	-2.05*** (.375)	1.44*** (.543)	.382 (.299)	-.609*** (.224)	1.55*** (.493)	-1.67** (.65)
Mkt access by foot (D)	-1.33*** (.262)	-.769** (.343)	-.971*** (.272)	-1.02*** (.144)	-1.66*** (.221)	-.361 (.247)	-.912*** (.342)
Mkt access by dirt road (D)	1.48*** (.441)	.691 (.529)	.214 (.259)	1.35*** (.37)	.588** (.265)	-.536** (.265)	.636 (.496)
Distance to mkt (km)	.037*** (.01)	.028** (.012)	.018* (9.4e-03)	.032*** (7.1e-03)	.031*** (6.5e-03)	.011*** (4.0e-03)	-1.4e-03 (5.9e-03)
Distance to kt (minutes)	-.013*** (3.2e-03)	-3.7e-03* (2.0e-03)	3.5e-03*** (1.2e-03)	8.4e-04 (1.8e-03)	2.8e-03** (1.4e-03)	6.5e-03** (2.7e-03)	-1.4e-03 (2.1e-03)
Mkt accessibility (D)	-.212 (.156)	.521*** (.123)	.301 (.208)	-.09 (.153)	.867*** (.157)	-.219 (.248)	.902*** (.115)
Monthly rations received	-.055*** (.019)	-.032 (.029)	-.026 (.025)	1.5e-03 (.018)	-.013 (9.3e-03)	2.6e-04 (.022)	-.03 (.038)
Observations	238	238	215	237	231	237	238

Standard errors in parentheses
 * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$
 D denotes dummy variable

Table A-17: Relative Satisfaction, Beans (ordered logit random effects)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Quality	Taste	Storability	Appearance	Nutritional Content	Non-contamination	General satisfaction
LRP (D)	.59 (.736)	1.44** (.68)	1.04 (.814)	-.072 (.871)	-.444 (1.41)	1.05 (.679)	-1.15 (1.14)
Age	-.019 (.012)	-.019* (.012)	-.011 (.013)	-.018 (.011)	-8.9e-03 (.015)	-.031*** (9.3e-03)	-.03*** (.012)
Education	-.059 (.046)	-.028 (.033)	-.096 (.078)	.067 (.061)	.091 (.09)	.03 (.058)	-.12* (.066)
Language (D)	-1.64** (.777)	-.364 (.683)	1.2e-03 (.674)	-.473 (.874)	-.387 (1.29)	-1.99*** (.361)	-2.14*** (.706)
HH Members b/w 19-60	-.285** (.13)	-.098 (.152)	.059 (.12)	.138* (.083)	-.351** (.168)	-.282*** (.103)	-.159 (.147)
Total HH Members	.059 (.146)	-.049 (.069)	-.153** (.069)	-.136 (.124)	.189 (.117)	.25** (.114)	.029 (.046)
Female head of HH (D)	-.212 (.784)	-.821 (.62)	-.594 (.382)	-.358 (.599)	-.646* (.346)	.584 (.841)	.253 (.563)
Mkt frequency 2/week (D)	.665*** (.124)	.616** (.262)	1.19*** (.16)	.495*** (.156)	.214 (.234)	-.262 (.241)	-.489*** (.128)
Mkt frequency 3/week (D)	-.453 (.445)	.199 (.216)	-.319 (.236)	.595*** (.223)	.56 (.377)	-1.29*** (.324)	-1.8*** (.44)
Mkt access by foot (D)	-.813*** (.301)	-.707*** (.197)	-1.33*** (.187)	-1.2*** (.253)	-.765*** (.204)	-1.24*** (.167)	-.875*** (.304)
Mkt access by dirt road (D)	-.074 (.232)	-.284 (.353)	-.561*** (.163)	.423 (.265)	.464** (.234)	.559 (.395)	1.05** (.469)
Distance to mkt (km)	-9.9e-03 (7.7e-03)	5.2e-03 (.026)	-.017** (6.6e-03)	.029*** (9.2e-03)	.049*** (.016)	-4.5e-03 (6.6e-03)	-2.5e-03 (.012)
Distance to kt (minutes)	-2.5e-03** (1.3e-03)	-7.8e-03** (3.3e-03)	-.015*** (3.3e-03)	-9.2e-03*** (1.8e-03)	-6.6e-03*** (2.3e-03)	-9.8e-03*** (1.6e-03)	-4.6e-03*** (1.5e-03)
Mkt accessibility (D)	.154 (.258)	.843*** (.125)	1.42*** (.18)	1.01*** (.266)	.458*** (.134)	.542** (.214)	.786*** (.106)
Monthly rations received	-.044*** (.013)	-.054*** (.021)	-.032** (.015)	-.043** (.018)	-.039 (.027)	-.012 (.018)	-.06 (.038)
Observations	237	237	221	236	232	238	237

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

D denotes dummy variable

Table A-18: Relative Satisfaction, CSB (ordered logit random effects)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Quality	Taste	Storability	Appearance	Nutritional Content	Non-contamination	General satisfaction
LRP (D)	-1.22* (.659)	-.736 (.891)	-.962 (.716)	-1.41 (1.8)	-.862 (.692)	-1.1 (1.09)	-.738 (.538)
Age	-.029*** (.01)	-5.0e-03 (.017)	-4.2e-03 (.016)	.024 (.022)	-.011 (9.6e-03)	.021 (.017)	-.023** (9.6e-03)
Education	-.118** (.055)	-.063 (.044)	.072 (.074)	.136* (.073)	-.063 (.049)	.179** (.09)	-.071** (.03)
Language (D)	-1.4*** (.53)	-.589 (.575)	-.285 (.551)	-.928 (2.05)	-1.09 (.748)	-.886 (.744)	-1.45*** (.556)
HH Members b/w 19-60	.092 (.108)	.054 (.161)	.146 (.201)	.194 (.164)	.123 (.108)	-.1 (.216)	.238* (.144)
Total HH Members	.063 (.096)	.156 (.131)	.168 (.158)	.055 (.12)	-.013 (.07)	.14 (.181)	-.073 (.055)
Female head of HH (D)	.355 (.356)	.52 (.436)	.668 (.453)	-.246 (.641)	.331 (.471)	-.229 (.533)	.148 (.444)
Mkt frequency 2/week (D)	.364** (.169)	.422** (.17)	.072 (.196)	-3.6e-03 (.157)	.442** (.196)	.396 (.311)	-.091 (.232)
Mkt frequency 3/week (D)	-.884*** (.261)	.325 (.28)	-1.81*** (.388)	-.846* (.451)	-.361** (.157)	-.876** (.384)	-.322 (.229)
Mkt access by foot (D)	.189** (.095)	.05 (.127)	-.403*** (.149)	.065 (.192)	-1.48*** (.312)	-.115 (.274)	-.85*** (.256)
Mkt access by dirt road (D)	.68** (.279)	.234 (.254)	.653 (.429)	-.519* (.283)	.295 (.311)	-.115 (.47)	.712** (.316)
Distance to mkt (km)	.037*** (.011)	.035*** (.011)	.071*** (.018)	.029* (.015)	.025*** (9.4e-03)	.034** (.015)	1.6e-03 (9.5e-03)
Distance to kt (minutes)	-.014*** (2.3e-03)	-9.7e-03*** (1.9e-03)	-.02*** (2.3e-03)	-9.8e-03*** (1.2e-03)	-.013*** (2.5e-03)	-9.1e-03*** (3.0e-03)	-2.4e-03 (1.5e-03)
Mkt accessibility (D)	.283* (.149)	-.096 (.253)	2.14*** (.399)	1.28*** (.158)	1.78*** (.221)	1.01*** (.269)	.862*** (.11)
Monthly rations received	-.044** (.021)	-.042* (.023)	-.018 (.033)	-3.4e-03 (9.8e-03)	.026 (.019)	-.025 (.021)	-.026 (.022)
Observations	238	238	203	226	233	228	238

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

D denotes dummy variable

Table A-19: Preparation, Maize and Rice (ordered logit random effects)

	(1) Fuel Use	(2) Time	(3) Water Use	(4) Costs	(5) Effort
LRP (D)	1.09* (.636)	.482 (.651)	-1.15 (.704)	-1.22 (1.01)	.402 (.826)
Age	-.015 (.011)	-.014 (.011)	-.016 (.017)	4.0e-03 (.021)	-.027* (.016)
Education	.036 (.049)	.027 (.042)	.109 (.095)	.283*** (.106)	.062 (.063)
Language (D)	-.918 (.861)	-1.08** (.506)	-.546 (.606)	-3.06*** (.792)	-1.67* (.927)
HH Members b/w 19-60	-.063 (.187)	-.109 (.203)	-.049 (.221)	-.011 (.227)	-.065 (.171)
Total HH Members	-.067 (.099)	.012 (.076)	-.034 (.136)	-.152 (.109)	.058 (.07)
Female head of HH (D)	.706 (.482)	-.206 (.512)	.81 (.549)	-.952 (.714)	.336 (.5)
Mkt frequency 2/week (D)	.311 (.322)	.556*** (.137)	2.55*** (.306)	1.17*** (.287)	.699** (.273)
Mkt frequency 3/week (D)	.728* (.388)	.625*** (.171)	4.89*** (.51)	.497 (1.08)	1.54*** (.37)
Mkt access by foot (D)	-7.716*** (.221)	-6.601*** (.111)	-1.98*** (.304)	-3.39*** (.853)	-.465 (.469)
Mkt access by dirt road (D)	-.808 (.563)	.261* (.15)	-.922*** (.334)	.26 (.22)	-.52 (.333)
Distance to mkt (km)	-.012 (.016)	.025*** (4.7e-03)	.041*** (7.2e-03)	.089*** (.014)	.03*** (.011)
Distance to mkt (minutes)	-7.6e-03*** (2.2e-03)	-6.3e-03*** (8.6e-04)	-.015*** (2.2e-03)	-.016*** (3.1e-03)	4.9e-03** (2.2e-03)
Mkt accessibility (D)	1.2*** (.244)	.928*** (.142)	2.63*** (.387)	3.72*** (.705)	-.027 (.355)
Monthly rations received	3.4e-03 (.022)	-4.8e-03 (.016)	-.024 (.02)	-.015 (.03)	-.034 (.028)
Observations	236	237	238	227	238

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

D denotes dummy variable

Table A-20: Preparation, Beans (ordered logit random effects)

	(1)	(2)	(3)	(4)
	Fuel Use	Time	Water Use	Effort
LRP (D)	3.61*** (1.25)	2.12*** (.818)	.615 (1.13)	-.019 (1.27)
Age	-.015 (.02)	.013 (.02)	.011 (.025)	.016 (.032)
Education	.027 (.078)	.32* (.167)	.207 (.151)	.448* (.243)
Language (D)	-1.18 (1.44)	-1.41 (1.21)	-1.93 (1.41)	-3.28** (1.66)
HH Members b/w 19-60	-.069 (.284)	.314* (.185)	.025 (.166)	.076 (.244)
Total HH Members	-8.5e-03 (.094)	-.114 (.182)	-6.5e-04 (.119)	-.011 (.113)
Female head of HH (D)	-.397 (.745)	-.273 (.537)	.352 (.63)	-.285 (.364)
Mkt frequency 2/week (D)	-.176 (.301)	.293 (.332)	-.664* (.37)	.037 (.492)
Mkt frequency 3/week (D)	.7* (.409)	2.54*** (.416)	.065 (.483)	-.947 (1.45)
Mkt access by foot (D)	-1.1*** (.26)	-2.21*** (.571)	-.827*** (.317)	-2.1** (.938)
Mkt access by dirt road (D)	-.29 (.354)	.277 (.336)	.462 (.405)	-.731 (.612)
Distance to mkt (km)	.01 (.011)	.071*** (.022)	.04** (.018)	.037 (.024)
Distance to mkt (minutes)	-.027*** (4.1e-03)	-.033*** (7.1e-03)	-.031*** (6.1e-03)	-.02*** (3.6e-03)
Mkt accessibility (D)	.73** (.31)	1.32* (.736)	2.53*** (.72)	1.71** (.69)
Monthly rations received	-.03 (.019)	-.02 (.022)	-.059** (.028)	-.12** (.053)
Observations	238	237	238	237

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

D denotes dummy variable

Table A-21: Preparation, CSB (ordered logit random effects)

	(1) Fuel Use	(2) Time	(3) Water Use	(4) Costs	(5) Effort
LRP (D)	-.092 (.854)	-1.11 (.814)	.595 (1.64)	-1.28 (1.11)	-1.44* (.745)
Age	-.02 (.012)	.01 (.016)	-.017 (.027)	-.029 (.03)	.012 (.025)
Education	-.037 (.066)	.099 (.092)	-.036 (.216)	.147 (.128)	.17 (.16)
Language (D)	-2.94* (1.54)	-2.61*** (.912)	-2.1 (1.6)	-2.21*** (.777)	-.881*** (.216)
HH Members b/w 19-60	.12 (.135)	.032 (.09)	.261 (.22)	.063 (.215)	-.097 (.157)
Total HH Members	.033 (.122)	.061 (.052)	-2.9e-03 (.131)	-.277** (.124)	.155 (.138)
Female head of HH (D)	-.281 (.385)	-.433 (.44)	-.389 (.641)	-.453 (.813)	-.208 (.555)
Mkt frequency 2/week (D)	.134 (.27)	.364 (.23)	1.53*** (.39)	1.01* (.568)	.972 (.65)
Mkt frequency 3/week (D)	-.662 (.602)	-.267 (.193)	1.74*** (.637)	-1.73 (1.09)	-1.51*** (.373)
Mkt access by foot (D)	1.52** (.676)	1.04*** (.392)	1.32** (.53)	-1.67*** (.475)	-.221 (.211)
Mkt access by dirt road (D)	-1.6** (.673)	-1.68*** (.414)	1.05 (.753)	-.541 (.519)	-.924*** (.333)
Distance to mkt (km)	-.033 (.022)	-.032** (.013)	.052*** (.016)	.036*** (.011)	-6.3e-03 (.01)
Distance to mkt (minutes)	-3.5e-04 (3.8e-03)	-2.3e-03 (2.8e-03)	-7.8e-03 (5.0e-03)	-.018*** (2.7e-03)	-4.6e-03 (2.8e-03)
Mkt accessibility (D)	.092 (.383)	.413* (.228)	.114 (.524)	3.21*** (.649)	.97*** (.356)
Monthly rations received	.015 (.015)	-9.3e-03 (.021)	-.019 (.058)	7.4e-03 (.027)	-.039 (.029)
Observations	237	237	237	227	237

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

D denotes dummy variable

Table A-22: Maize and Bean Quality Requirements

Characteristic	Max % (per 5 lb sample)
Humidity	14 %
Burnt grains	3 %
Impurities	3 %
Stained	2 %
Descalentado ???	2 %
Grains with fungi growth	2 %
Broken grains	1 %
Plagued grains	0 %
Residual or trash	1 %
Aflatoxins	20g/Kg
Free of insects	Recommended use of aluminum phosphide (not to exceed 0.01 ppm)

Table A-23: CSB Quality Requirements

Characteristic	Standard
Humidity	Max 10%
Protein content	Min 18 %
Color	Beige/yellow
Microorganism content	Max 100,000 UFC/g
Mold and yeast content	10,000 UFC/g
Fecal coliform bacteria	Max 6 NMP/g
Salmonella	Max 0/25gr
Aflatoxins	Max 20 ppb
Energy	340 kcal/100 gr
Vit A	3000 UI/100 gr
Thiamine	2 mg/100 gr
Riboflavin	1.3 mg/100 gr
Folic Acid	357 mcg/100 gr
Vit B12	3.21 mcg/100 gr
Calcium	350 mg/100 gr
Niacine	20 mg/100 gr
Iron	25 mg/100 gr

CHAPTER 3

IS LATE REALLY BETTER THAN NEVER? THE FARMER WELFARE EFFECTS OF PINEAPPLE ADOPTION IN GHANA¹

1. Introduction

There has been much optimism about the prospects for development through agricultural exports in low-income countries (World Bank 2008). Since the majority of the poor in developing countries are farmers, sustained growth in agriculture has the potential to substantially reduce poverty. Several studies examine the increased opportunities of smallholders due to the proliferation of supermarkets in low- to middle-income countries as well as the increase in exports due to liberalized rules of trade and foreign direct investment and improvements in logistics and infrastructure (Reardon *et al.* 2009). Most careful evidence to date finds that, even controlling for the initial advantages often enjoyed by those who participate in modern agrifood value chains, smallholder suppliers tend to enjoy higher net earnings per hectare or per unit of output marketed, although this is by no means universal or uniform (Michelson 2013, Barrett *et al.* 2012). For example, Udry and Goldstein (1999) estimate that farmers in Ghana could achieve returns ten times higher for pineapple than for maize or cassava.

In response to these generally positive effects for smallholders, aid agencies have invested heavily in efforts to train and equip farmers in developing countries to grow cash crops such as pineapple for export. They have recognized and attempted to alleviate some of the various constraints on farmers entering these markets by providing access to credit, technical and institutional training, and appropriate certification.

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Crucial questions remain, however, about the ability of smallholders to succeed or even survive in export agricultural markets. Indeed, supplying modern value chains exposes producers to significant risks, especially if farmers reallocate land and other scarce inputs to the export crop, becoming vulnerable to disruptions outside local market control, such as changing foreign consumer preferences, exchange rates, or trade barriers (Maertens and Swinnen 2009). For example, the epilogue in Ashraf *et al.* (2009) studying the effects of Kenyan smallholders growing baby corn and French beans describes the catastrophic effect that farmers faced when their crop no longer met the revised Euro-Retailer Produce Working Group Good Agricultural Practices (EurepGAP) 2005 requirements.

The case we study is similarly cautionary. European demand for fresh pineapple grew rapidly over the course of the 1990s and early 2000s as a result of expanded sea freight capacity from Ghana to Europe and increased demand for pineapple in Europe (FAOStat 2013, Fold and Gough 2008). From 2005, after almost a decade of rapid growth in pineapple production and exports, demand for Ghana's pineapples suddenly fell sharply (Figure 1). The main explanation for the drop in demand was a sudden taste shift among European consumers from the variety of pineapple most commonly grown in Ghana, Smooth Cayenne, to a new variety called MD2 (Fold and Gough 2008). This paper studies the resulting welfare consequences of this exogenous market shock for farmers growing pineapple in four communities in the Akwapim South district of Southern Ghana, where the returns to pineapple adoption initially appeared extremely high (Conley and Udry 2010, Udry and Goldstein 1999). Because the onset and effects of

the shock were truly exogenous to the farmers in this study, we can treat the demand shock as a natural experiment.

More specifically, this study compares the implications for smallholder farm household welfare of the timing of a farmer's decisions to grow pineapple – early vs. late vs. non-adopters – and to discontinue pineapple cultivation following an adverse market shock. In the canonical model of the farmer welfare effects of technology adoption (Cochrane 1958), early adopters systematically benefit most from the introduction of a new and lower-cost farm technology, non-adopters lose, and late adopters fall somewhere in between, perhaps benefitting, perhaps suffering some losses, but never as large as non-adopters who face lower prices without enjoying lower costs. But that theory relies on a strong assumption that the new technology is unambiguously and permanently superior for the farmer. Although analysts commonly use technology adoption models to explain patterns of uptake of new products – such as pineapple in Ghana (Conley and Udry 2010, Udry and Goldstein 1999), sunflower in Mozambique (Bandiera and Rasul 2006), or horticultural crops in Kenya (Ashraf *et al.* 2009) – a new crop is more profitable only conditional on consumer demand. If market demand for the new crop suddenly collapses, due to shifting standards (Ashraf *et al.* 2009), consumer tastes (Fold and Gough 2008), or if the market price collapses due to excessive aggregate supply expansion in the face of price inelastic demand (McKay *et al.* 1997), then adoption no longer unambiguously dominates non-adoption. In that case, timing of entry into and exit from the market matters. And in the case of perennial crops, like pineapple, non-trivial sunk costs to market entry or exit create frictions that can cause predictable delays in entry and/or exit that can then prove costly. This basic insight has been overlooked to date in the literature

on smallholder crop choice and technology adoption. In this paper, we explore whether those southern Ghanaian farmers who never cultivated pineapple are better or worse off than farmers who decided to adopt the technology earlier or later.

The remainder of this paper is structured as follows. Section 2 reviews the relevant literature and section 3 provides some background on pineapple in Ghana. Section 4 then explains the data. Section 5 describes the empirical strategy and section 6 discusses the results while section 7 concludes.

2. Literature Review

Considerable research in agricultural and development economics has been dedicated to the issue of technology adoption in an attempt to help increase production and incomes, and to reduce consumer prices. Different strands of the technology adoption literature examine the drivers of adoption, including education, availability of the technology, labor and input use, costs, climatic conditions and access to credit (Feder *et al.* 1985). More recently, the literature has focused on the role of learning externalities and social learning from neighbors, agents and/or social networks (Bandiera and Rasul 2006, Moser and Barrett 2006, Foster and Rosenzweig 1996). Using the early rounds of the data used in this study, Conley and Udry (2010) show how farmers in Akwapim South district learned from their friends and relatives how to cultivate pineapple and gained significant returns from doing so. A host of other studies examine and seek to explain the low observed adoption rates of certain technologies (Foltz *et al.* 2011).

Far fewer studies examine the causes and/or effects of farmers who had adopted a technology but subsequently stop using, or “disadopt”, the technology. Suri (2011)

studies the dynamics of adoption of maize hybrid seeds by Kenyan farmers by categorizing three types of farmers. A small group of farmers have high expected returns to adopting the improved hybrid seed variety yet do not due to the higher costs of supply and infrastructure constraints. A second group faces lower but still high returns and do adopt hybrid seeds in every period. Finally, a third group of farmers who have essentially zero net returns switch in and out of using hybrid seeds from period to period. This last group of marginal farmers switch into and out of adoption in response to exogenous changes in costs of and access to inputs and seeds they face in a season. Farmers with high net returns typically adopt a technology while those with low returns do not, but because expected net returns can vary seasonally, the same farmer may fall in either group at different times.

Moser and Barrett (2006) study the dynamics of technology adoption – adoption, expansion and disadoption -- of a low input rice production method, the system of rice intensification (SRI), in Madagascar. They seek to understand the low adoption rates and high disadoption rates of SRI despite the considerable crop yield increases the method allows without any new purchased inputs. They find that farmer education and liquidity and labor availability affect the farmers' likelihood of trying the new technology. They also find that learning effects and unobserved farmer fixed effects such as skill and motivation play a major role in the farmers' decisions to try and to continue with the new technology. Labor requirements, in particular, are a large obstacle to SRI adoption as many of the poorer households have highly seasonal labor and income patterns.

Neill and Lee (2001) study the adoption and subsequent disadoption of the sustainable agricultural practice, 'slash and mulch', which allows Honduran farmers to

produce more maize on less land. After the spontaneous diffusion of the practice, a widespread decline was observed roughly five years later. Cameron (1999) examines the dynamics of seed adoption in Maharashtra, India, also highlighting the importance of learning and unobserved household heterogeneity on the adoption decision. Despite the findings of these studies reviewed here, there remain many questions about the dynamics of adoption. In this paper, we examine the long-term welfare effects of adoption of a cash crop and more specifically we examine the effects of timing on welfare.

3. Pineapple in Ghana

Pineapple (*Ananas comosus*) is a unique crop for multiple reasons. Pineapple is a perennial not grown from seed, but rather from vegetative propagation called ‘suckers’, produced as side shoots from the plant’s main stem. Each plant bears a single fruit and multiple suckers, which then subsequently generate fruit themselves. It takes some time before a farmer can harvest, typically 10-20 months after suckers are planted. And if a farmer decides to discontinue pineapple, s/he must dig up and remove the plants. Pineapple cultivation also does not follow a seasonal calendar. In Akwapim South, pineapples can be grown at any time of the year. Entry into the pineapple market thus involves a longer-term investment and greater sunk entry and exist costs than does the seasonal cultivation of grains, roots and tubers that has been customary in Akwapim South. These characteristics create frictions that impede both entry and exit (Dixit and Pindyck 1994, Chavas 1994), impeding the sort of easy and regular transition between adoption and disadoption that is feasible with respect to farmers’ seed and fertilizer

choices, for example (Suri 2011). The timing of entry and exit into an industry like pineapple can therefore matter a great deal in the face of stochastic market conditions.

Pineapples grow best in slightly more acidic soils, with an optimum pH ranging between 4.5 and 6.5, which is lower than most other crops. Maize, for example, grows best in soils with a pH of 6.0-7.0. Furthermore, pineapples can survive long dry periods, although sufficient water is important during flowering and fruiting (FAO, http://www.fao.org/nr/water/cropinfo_pineapple.html).

Smooth Cayenne, a variety that originated in Hawaii, is among one of the most common pineapple varieties. It is sweet, juicy and especially well suited to canning and processing. Coastal West Africa's climate and relative proximity to ports and to Europe gave it both cost and quality advantages in the export market for fresh Smooth Cayenne pineapple. In the 1990s, as transport bottlenecks that had limited fresh fruit export volumes relaxed, Ghana's pineapple production increased significantly. Farmers who entered the pineapple market in the 1990s enjoyed significant increases in farm profits relative to the maize-cassava intercropping that had prevailed for many years (Conley and Udry 2010, 2001). The strong reported profits and abundant technical assistance available to southern Ghanaian smallholders from the late 1990s through the mid-2000s attracted many new entrants into pineapple production.

A competing variety, MD2, was aggressively propagated by Del Monte in Costa Rica and marketed in Europe in the early 2000s to meet consumer demand for sweet, juicy and yellow pineapples (Fold and Gough 2008). MD2 are slightly smaller and have a more square shape than Smooth Cayenne, thereby lending themselves better to packing and stacking on supermarket and refrigerator shelves. Enjoying ideal growing conditions

and significant economies of scale, from the early 2000s Costa Rica's lower cost of MD2 production began significantly undercutting Smooth Cayenne in the competition for European retail markets, gutting Côte d'Ivoire's once-dominant market share and significantly diverting demand from Ghana too (Fold and Gough 2008, <http://developeconomies.com/development-economics/a-brief-history-of-fresh-pineapple-exports-in-ghana/>).²

The demand for the primary pineapple variety grown in Ghana decreased as early as the end of 2003, and was noticed by major players in the industry in Ghana at that time (Ghanaian Chronicle 2004). When describing the market shock to us, farmers recounted having to leave their entire crop to rot in the fields when the buyers stopped coming. Some reported losing thousands of dollars in revenue, more than the total assets of the median household in the survey communities. While farmers previously had informal agreements to sell to certain buyers, they quickly learned to demand written contracts from buyers and formed cooperatives to provide legal support in the event that the contracts were not honored. While there were initiatives to equip farmers to shift to the new variety, MD2, involving partnerships between government, aid donors and large pineapple processing companies (GNA 2004), many smallholder farmers left the pineapple industry in the wake of this market shock.

The industry consolidated in the wake of the collapse of the European export market for Smooth Cayenne, with large firms supplying the bulk of Ghana's MD2 for

² Ghanaian farmers might also have lost their ability to export to Europe because of the widespread adoption of a new and demanding certification standard, EurepGAP, in Europe around the same time. However, discussions with focus group participants suggest the new certification standards were of minor concern. Farmers reported being offered timely support from NGOs to adopt the standards and pass the audits.

export. Smallholder farmers who continued to farm as of 2009-10 concentrated mainly on supplying Smooth Cayenne to local factories for canning and juicing, with only a limited amount of Smooth Cayenne being exported from Ghana. The change of fortunes for southern Ghana's pineapple producers over the course of a decade or less was striking. Ghana's pineapple producers' experience with the rise and fall of an export market offers uncommon insights into the welfare impacts of the timing of market entry and exit when producers face significant sunk costs that create frictions in these transitions.

4. Data

The data come from two surveys of four communities in the Akwapim South district in southern Ghana. The first survey, conducted in 1997 and 1998, interviewed 240 individuals (spouses in 120 households), collecting extensive data on respondents' farming practices, social networks and household characteristics, including a 15-month panel of data on household consumption and wealth³. Soil samples were also collected during the 1998 survey from each plot owned by a respondent. In 2009, 70 households in each of those same four villages were resurveyed using a nearly identical questionnaire to the 1997-98 survey instrument. Approximately half of the households surveyed in 2009 were part of the initial 1997-98 sample.⁴ Five survey rounds were conducted (i.e., a round every two months), covering a wide range of subjects, including personal income, farming and non-farm business activities, gifts, transfers and loans, and household

³ Further details can be found in Udry and Goldstein (1999).

⁴ In the original sample, and in the 2009 re-sampling, we selected only from the pool of households headed by a resident married couple. However, we retained households from the 1997-98 sample even if only one of the spouses remained. These 'single-headed households' account for between 7 and 15 of the sample households in each community.

consumption expenditures and respondents' in-sample social networks. These data were supplemented with focus group discussions conducted in September 2009 and July 2010 in the two main pineapple farming villages, Pokrom and Oboadaka.

5. Econometric strategy

We are interested in measuring and comparing the change in welfare experienced by different categories of farmers: those who never take up pineapple ('nonadopters') and those who enter ('adopt') the market early or late, as well as those entrants who exit the market ('disadopt') early or late. The central prediction of the canonical farm technology adoption model (Cochrane 1958) is that early adopters gain relative to late adopters, who in turn fare better than nonadopters. The adage 'better late than never' follows directly. Allowing for the possibility that the new 'technology' subsequently becomes relatively unprofitable, the same logic holds that early disadopters would fare better than late disadopters. This logic yields a clear prediction of the ordering of the welfare effects between early adopters/early disadopters and late adopters/late disadopters. But for new crop adoption – as distinct from the adoption of a new production technology that is unambiguously and permanently superior if replaced (Foster and Rosenzweig 1996, Cochrane 1958) – it becomes ambiguous whether the 'better late than never' prediction holds. This requires empirical exploration that, to the best of our knowledge, has not previously been undertaken.

Our key explanatory variable of interest is therefore the length of time (months) a farmer cultivated pineapple before and after the exogenous demand shock. Because the decision and timing of adoption is a choice variable that cannot be randomly assigned,

observed outcomes are likely correlated with both time-invariant and time-varying unobserved variables causing the point estimates of duration to be biased in a standard ordinary least squares framework. We therefore employ an instrumental variables strategy to account for the prospective selection bias in the timing of pineapple cultivation. In the first stage, we estimate a bivariate tobit model to predict how many months a household cultivates pineapple relative to the shock, using exogenous soil conditions as instruments. Using the household panel data, we then use a fixed effects framework in the second stage to eliminate time-invariant unobservables and estimate the effect of instrumented pineapple cultivation duration, pre- and post-shock, on household welfare, proxied by an asset index. Finally, given mean pre- and post-duration dates for different categories of farmers and the second stage estimation results, we estimate the mean welfare changes of distinct farmer groups: nonadopters, early adopters/early disadopters, early adopters/late disadopters, late adopters/early disadopters, and late adopters/late disadopters. The prospective differences among these distinct groups are the central topic of interest in this paper.

More specifically, in the first stage, we estimate the duration (months) that a farmer cultivated pineapple before and after the export market shock. A bivariate tobit model accounts for the left censoring that occurs at zero for both pre- and post-duration variables for farmers who never farmed pineapple⁵. Therefore, we have,

$$\begin{aligned}
 y_{ip}^* &= \mathbf{X}'_{ip}\beta + \varepsilon_{ip} \\
 y_{ip} &= 0 \text{ if } y_{ip}^* \leq 0
 \end{aligned}
 \tag{1}$$

⁵ 55 percent of farmers never cultivated pineapple.

$$y_{ip} = y_{ip}^* \text{ if } y_{ip}^* > 0$$

where the variable y represents the observed duration measured in months and indexed by i for individuals and $p = \{\text{pre, post}\}$ indicating whether duration is pre- or post-shock. The latent variable is $y^* \sim N(\mu, \sigma^2)$ and the $\text{Prob}(y^* \leq 0) = \Phi(-\mu/\sigma)$ where $\Phi(\cdot)$ is the normal cumulative distribution function. The matrix \mathbf{X}' contains individual- and community-level explanatory variables. The bivariate model allows for correlation in the error terms for both duration variables, pre- and post-shock. Furthermore, we cluster errors to allow for correlation at the village level.

As shown in Figure 1, the value and quantity of pineapples exported from Ghana decreased significantly from 2004 to 2005. We therefore use January 1, 2005 as the “shock date”, measuring the months before and after this date to determine the duration a farmer cultivated pineapple pre- and post-shock. The duration variables were constructed using data collected in the 2009 survey, asking farmers whether they farmed pineapple and the dates they started and ended farming it. The results described further below do not differ significantly when changing the shock date 6 months prior or 6 months post January 1, 2005. The median adoption date conditional on adoption pre-shock was January 1999 and the median disadoption date conditional on adoption post-shock date was March 2007.

The first stage explanatory variables were taken from the 1998 surveys and include age and age squared to control for life cycle effects, gender, dummy variables for whether the respondent attended primary, secondary or high school, number of household members, number of household members likely to contribute household labor (ages 18-

60), number of years having resided in the village, and a social network variable indicating the number of people a person knows⁶. Table 1 shows summary statistics for the variables used in the first stage estimation. Half of the sample is female with a mean age of 40, a mean household size of 8 of which on average 3.5 are of working age. Half of the respondents received schooling through middle school.

Our ability to identify the welfare effects of the timing of pineapple adoption and disadoption rests on the challenging task of finding an instrument, z , that is correlated with the decision and duration of cultivating pineapple, but not with changes in farmers' welfare status. We use two instruments, the lowest 1998 soil organic matter (SOM) and acidity (pH) levels observed among a farmer's cultivated plots. Pineapple thrives in low pH and high SOM soils, so the likelihood that a farmer adopts and the duration s/he cultivates pineapple should be related to one or both of these variables. Meanwhile, high acidity (i.e., low pH) lowers the productivity of virtually all other crops grown in Akwapim South, while high SOM has the opposite effect. We would therefore not expect these variables to jointly affect change in farmer asset holdings independently of their effect on pineapple cultivation. But we also test the exclusionary restriction necessary for these to serve as suitable instruments for pineapple cultivation and confirm the statistical defensibility of this instrumental variables estimation strategy. The most acidic soil recorded had a pH of 4.3 with a mean pH of 6. The mean soil organic matter was 2.46 percent.

⁶ Respondents were asked about their relationship with other villagers, including how well they knew the other villagers, how long they had known them and how often they had spoken to them. Here we simply control for the number of villagers a respondent knows.

Given the first stage bivariate tobit estimates, we predict the number of months that a household cultivated pineapple pre- and post-shock. For households from the 1997-1998 survey the duration pre-shock is the number of months a farmer cultivated pineapple until 1998, the time of the survey. The post-shock duration for households surveyed in 1998 is always 0. We use these predicted values to estimate the effect of duration on welfare using a fixed effects model. Specifically, we estimate

$$w_{it} = \hat{y}_{it} + \mathbf{X}'_{it}\beta + \varepsilon_i + u_{it} \quad (2)$$

where w_{it} is a measure of welfare for individual i at time t , \hat{y}_{it} is the predicted duration pre- and post-shock from the first stage, \mathbf{X}' is a matrix of time-varying control variables, ε_i is the individual-specific fixed effect and u_{it} is the error term, which captures any remaining individual- and time-specific unobservables that we assume to be i.i.d and mean zero. Table 2 includes summary statistics for the controls included in the second stage regression.

We proxy welfare with an asset index. The use of assets and asset indices to measure household welfare has become more common over the last decade providing some advantages over other more common welfare measures, e.g., consumption, income and expenditures. Because assets are accumulated over time and last longer, they tend to better reflect a household's permanent income or longer-term living standard than income, for example, which often suffers from seasonal variation and/or a large share of non-remunerated self-employment (Moser and Felton 2007, Sahn and Stifel 2000) or even expenditures, which are subject to liquidity constraints and greater measurement

error than easily-observed assets (Carter and Barrett 2006, Filmer and Pritchett 2001, Sahn and Stifel 2000). Several studies have indeed shown a strong link between household productive assets and subsequent poverty rates (Adato *et al.* 2006, Barrett *et al.* 2006).

In constructing an asset index, one must choose a set of weights, w , to assign to each asset within an asset category. The weights are multiplied to the asset and summed over the different assets within a category to create the index. Commonly used weights include prices, unit values, principal components analysis, factor analysis, multiple correspondence analysis or polychoric principle components analysis (Moser and Felton 2007). Obtaining asset prices can be difficult in the context of low-income rural communities where secondary markets for assets are thin and market prices may not accurately reflect the quality of an asset. Another method involves assigning each asset a binary value of 1 or 0 if it is owned or not and summing the number of assets within a category. While such a method is simple, it does not differentiate among assets with radically different values. Filmer and Pritchett (2001) recommend using principle components analysis (PCA) to aggregate several binary asset ownership variables into a single dimension. Sahn and Stifel (2000) use factor analysis (FA) instead of PCA to construct their asset index, arguing that FA offers more flexibility because it does not force all the components to explain the correlation structure between the assets. We follow the methodology of Sahn and Stifel (2000) and use factor analysis to create an asset index.

We generate four asset indices, an asset index representing durable goods (e.g. bicycle, car, fan generator, radio, television, etc.), an asset representing livestock (e.g.,

goats, lambs, sheep, ducks by gender, etc.), an index representing productive goods (e.g., barrel, chain saw, pick axe, pump, etc.) and finally an overall asset index encompassing all durable, livestock and productive goods. Summary statistics for each good owned by respondents comprising the asset indices are reported in Appendix A. Results of the factor analysis are reported in Appendix B.

Summary statistics for the asset indices are reported in Table 3 by percentile and by year. Respondents were categorized into wealth percentiles. As expected, the mean value of the asset index increases by percentile group across all asset indices for both years.

There are two additional sources of bias that may exist and that have not yet been addressed. The first source of potential bias is supplier-side bias whereby suppliers might select to purchase pineapples from farmers who have certain skills, access to resources or have plots closer to roads. In our discussions with pineapple grower groups, they explained that buyers would visit their village, often unannounced, and would purchase pineapples from any farmer whose pineapples were ready for harvest. We therefore assume no supplier-side selection effects exist in this particular setting. Finally, there is attrition from the 1998 to 2009 survey, which will also cause our estimates to be biased. We have not yet accounted for this bias but will do so in a future iteration of this paper.

6. Results & Discussion

Results from the first stage estimation of the bivariate tobit model are reported in Table 4. As expected, age has a positive effect on duration both pre- and post-shock with a decreasing marginal effect as age increases up to age 40-45 years, after which point

months of pineapple cultivation begins decreasing. Those with at least middle school level education are statistically significantly more likely to have adopted pineapple earlier (i.e., longer duration of pre-shock cultivation). Women are strongly and significantly less likely to have adopted pineapple, and much less early. Households with more working age members and those that have resided in the village longer exit pineapple cultivation statistically significantly sooner post-shock. This may reflect the limiting role of labor – from one’s own household or reciprocal work parties organized with neighbors – in disadopting pineapple by uprooting and removing the plants.

Crucial to our identification strategy, an increase in soil pH level has a strong negative and statistically significant effect on the duration of pineapple cultivation pre-shock. This is exactly as expected given that pineapples grow better on more acidic soils and thus when they are profitable, those with suitable soils were more likely to enter the subsector. SOM does not have a statistically significant independent effect on pineapple cultivation duration, either pre- or post-shock.

Given the estimated bivariate tobit model, we can predict the duration a household farmed pineapple before and after January 1, 2005. Figure 2 shows the observed and predicted latent durations pre- and post- shock. However, the predicted values must be censored at 0 such that no negative duration values exist. Post-censored mean values are shown in table 5. As can be seen in the bottom left of Figure 2, the post-shock observations are right-censored at 56 months, the number of months between January 2005 and September 2009, the time of the last round of the 2009 survey, during which time some farmers were still farming pineapple. A future iteration of this paper

will try to also incorporate the right-censoring of the data in addition to the left-censoring.

We can use the predicted values to estimate the fixed effects model, equation (2) above. Results using the different asset indices as the left-hand side welfare measure are shown in Table 6. Duration before January 2005 has a low but positive effect on welfare, indicating that the earlier a farmer adopted pineapple during the period when it was profitable, the greater the household's wealth. By contrast, duration of pineapple cultivation post-January 2005 has a slight negative effect on the asset index for most asset indices and importantly for the all-encompassing asset index. However, the effects are not statistically significant, but are robust when compared to a random effects model and a fixed effect model estimated on the subset of balanced data.

Given the estimates reported in table 6, we can compare categories of farmers who farmed pineapple for different lengths of time, starting and ending at different times. We categorize four types of farmers -- early and late adopters who stop cultivating pineapple ("disadopt") early or late relative to the January 2005 shock date. We define early adopters as those who began cultivating pineapple 120 months or 10 years before January 1, 2005 (January 1, 1995) and late adopters as those who began cultivating in January 2005, at the peak of Ghana's pineapple exports and the threshold of the market collapse. We categorize early disadopters as those who stopped cultivating pineapple 10 months after the shock and late disadopters as those who continued to cultivate pineapple for 40 months after the shock. Based on these categories, we estimate the mean asset indices per percentile of the population.

Mean asset indices for the different categories of farmers are tabulated and shown in Table 8. Absolutely consistent with the predictions of theory, early adopters who disadopt early are the best off, followed by early adopters who disadopt later. Similarly, late adopters who disadopt early are better off than late adopters who disadopt late. Interestingly, early adopters who disadopt late are worse off than late adopters who disadopt early.

The most striking result, consistent across all indices, is that nonadopters are the best off. Nonadopters are only slightly better off than early adopters who disadopt early (their difference is statistically significant at the 1% level). The asset indices do not vary significantly across the initial wealth distribution within a given subgroup of farmers, indicating that these patterns are not especially sensitive to initial wealth conditions, although farmers who are initially better off do see slightly higher gains from early adoption and slightly smaller losses from late disadoption.

7. Conclusions

Our results show that there is a clear advantage for early adopters among farmers who cultivated pineapple. The magnitude of that advantage depends on the timing that growers stop cultivating if and when the new crop's market price collapses, extinguishing the profits that exist initially. Timing market entry and exit optimally is notoriously difficult; but as our results show, it matters to the welfare effects of farmer uptake of a new, currently profitable crop. Even early adopters who disadopt long after a shock may see their initial gains evaporate if they remain in the market long after it collapses. The early adopter advantage Cochrane (1958) emphasizes has an analog early disadopter

advantage in the case of adoption of crops whose prices subsequently collapse. As a result, the familiar adage ‘better late than never’ does not necessarily hold. As in the case of southern Ghanaian pineapple producers, those who never converted to the new crop were as well off as early adopters who disadopted early, missing potential gains from early adoption and missing the losses associated with continued pineapple cultivation. As a result, nonadopters proved significantly better off, several years after the market crash, than late adopters.

There are important policy implications from these results. The introduction of new cash crops, especially those that may not have a domestic market and thus are subject to added market risk associated with exchange rates, foreign market access standards and consumer tastes, must be done so with caution. Under the best of circumstances, early adopters will benefit from increased profits associated with new products. However, the adoption of new technologies may expose smallholders to new and heightened market risks. Producers and those who promote new products must remain attuned to shifting market conditions and be prepared to facilitate orderly exit from the subsector if and when demand patterns shift adversely.

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9. Figures

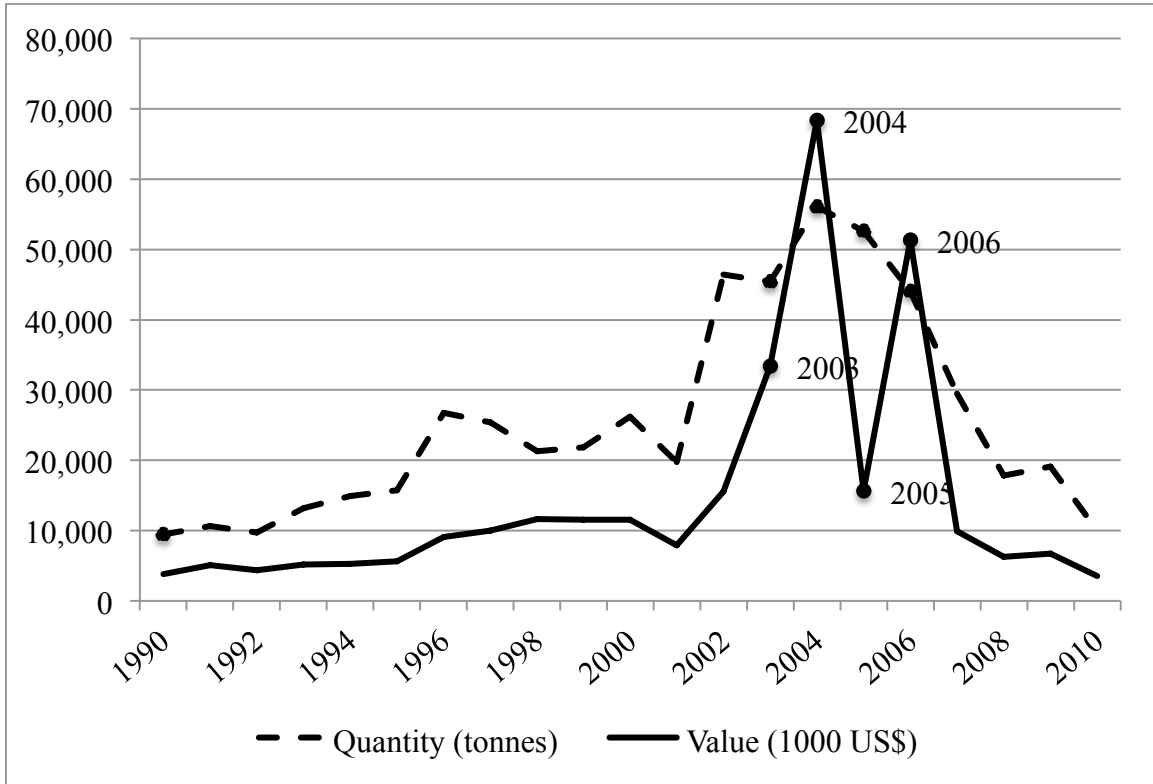


Figure 1. Pineapple quantity and value exported from Ghana (FAOSTAT, 2013)

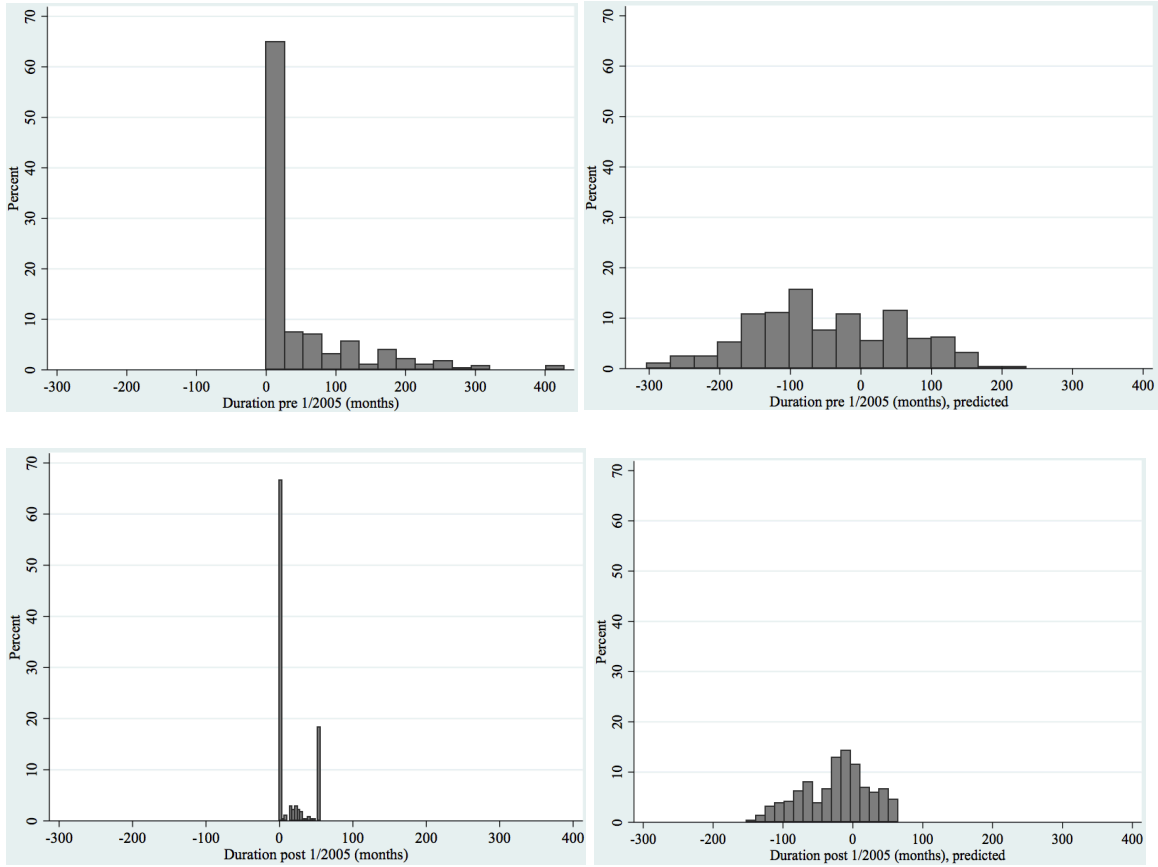


Figure 2. Observed and predicted pre- and post-2005 duration variables (months) (left to right, top to bottom: duration pre-2005 duration (months); predicted duration pre-2005 (months); duration post-2005 duration (months); predicted duration post-2005 (months))

Notes: Median start date is January 1999, median end date is March 2007, conditional on adoption.

10. Tables

Variable	Obs	Mean	Std. dev.	Min	Max
Duration (months)	280	47.10	73.11	0	327
Duration pre-2005 (months)	282	44.11	76.34	0	428
Duration post-2005 (months)	284	13.75	21.88	0	56
Social network count	226	3.79	2.23	1	11
Minimum pH	226	6.00	0.76	4.3	7.6
Minimum Organic Matter	226	2.46	0.91	0.71	5.33
Years of residence in village	242	66.96	64.69	1	400
Age	238	40.42	13.17	18	89
Female	247	0.50	0.50	0	1
Household members	247	8.07	4.27	2	24
Household Members of working age (18-50)	247	3.49	2.60	0	15
Highest level of schooling: primary	247	0.17	0.37	0	1
Highest level of schooling: middle school	247	0.52	0.50	0	1
Highest level of schooling: high school	247	0.14	0.35	0	1
Age, squared	238	1,806	1,274	324	7,921

Table 1. Summary statistics for variables used in first stage variables

		Darmang		Konkonuru		Oboadaka		Pokrom	
		1998	2009	1998	2009	1998	2009	1998	2009
Age (years)	<i>Mean</i>	39.10	47.74	41.49	49.82	42.81	49.32	37.56	44.41
	<i>Std. Dev.</i>	12.36	10.29	12.37	13.33	12.70	13.83	11.81	14.06
	<i>Min</i>	21	27	23	25	18	21	19	19
	<i>Max</i>	87	74	70	90	75	78	80	79
Age, squared	<i>Mean</i>	1679	2384	1871	2657	1991	2622	1547	2167
	<i>Std. Dev.</i>	1216	1014	1148	1437	1180	1437	1093	1369
School primary (=1 if yes)	<i>Mean</i>	0.25	0.18	0.12	0.15	0.10	0.20	0.19	0.19
	<i>Std. Dev.</i>	0.44	0.39	0.33	0.36	0.30	0.40	0.40	0.40
School middle (=1 if yes)	<i>Mean</i>	0.57	0.69	0.65	0.61	0.32	0.41	0.53	0.53
	<i>Std. Dev.</i>	0.50	0.46	0.48	0.49	0.47	0.49	0.50	0.50
School higher (=1 if yes)	<i>Mean</i>	0.11	0.08	0.12	0.08	0.17	0.09	0.16	0.11
	<i>Std. Dev.</i>	0.31	0.27	0.33	0.27	0.38	0.29	0.37	0.31
Household members	<i>Mean</i>	7.93	7.19	8.29	6.36	10.28	8.42	6.19	6.49
	<i>Std. Dev.</i>	4.39	2.55	3.93	2.87	4.92	3.46	2.75	2.95
	<i>Min</i>	3	1	3	1	4	1	2	1
	<i>Max</i>	20	14	19	13	24	19	17	14
Household members in work force	<i>Mean</i>	3.29	4.52	3.70	3.98	4.61	4.99	2.51	3.48
	<i>Std. Dev.</i>	2.74	2.30	2.44	2.35	3.03	3.06	1.77	2.08
	<i>Min</i>	1	1	1	0	2	1	0	1
	<i>Max</i>	15	9	11	11	13	13	8	10
Social network count	<i>Mean</i>	3.88	103.16	3.15	115.66	4.48	109.00	3.76	89.34
	<i>Std. Dev.</i>	2.47	28.57	1.60	21.90	2.49	28.79	2.06	29.79
	<i>Min</i>	1	39	1	59	1	47	1	19
	<i>Max</i>	10	150	7	147	11	149	10	143

Table 2. Summary statistics for controls used in the second stage (n = 529)

		1998				2009			
		mean	std. dev.	min	max	mean	std. dev.	min	max
Asset index	0-25th	-0.396	0.017	-0.481	-0.366	-0.381	0.009	-0.393	-0.366
	26-50th	-0.307	0.047	-0.366	-0.201	-0.286	0.048	-0.366	-0.201
	51-75th	-0.101	0.084	-0.201	0.121	-0.043	0.096	-0.200	0.127
	76-100th	0.294	0.145	0.206	0.588	0.756	1.808	0.129	27.886
Durables asset index	0-25th	-0.499	0.021	-0.609	-0.492	-0.492	0.000	-0.492	-0.492
	26-50th	-0.486	0.001	-0.486	-0.480	-0.466	0.008	-0.484	-0.455
	51-75th	-0.220	0.099	-0.321	0.043	-0.227	0.165	-0.451	0.112
	76-100th	0.280	0.174	0.121	0.499	1.226	1.418	0.126	14.282
Livestock asset index	0-25th	-0.474	0.018	-0.568	-0.455	-0.461	0.000	-0.461	-0.459
	26-50th	-0.376	0.056	-0.454	-0.262	-0.341	0.053	-0.454	-0.258
	51-75th	-0.099	0.100	-0.254	0.135	-0.070	0.118	-0.258	0.144
	76-100th	0.506	0.328	0.149	1.487	0.981	1.806	0.156	24.296
Productive asset index	0-25th	-0.279	0.011	-0.374	-0.276	-0.276	0.000	-0.276	-0.276
	26-50th	-0.255	0.019	-0.272	-0.232	-0.250	0.011	-0.262	-0.235
	51-75th	-0.142	0.057	-0.225	-0.023	-0.163	0.053	-0.231	-0.015
	76-100th	0.145	0.153	0.006	0.541	0.738	1.864	-0.004	27.824

Table 3. Asset index summary statistics, by percentile and year

	Duration pre 1/2005 (months)	Duration post 1/2005 (months)
Age of respondent	8.163 (8.436)	2.633** (0.619)
Age, squared	-0.091 (0.087)	-0.033** (0.004)
Gender is female	-140.867** (46.989)	-54.667** (14.540)
Highest level of schooling: primary school	32.108 (29.549)	-12.289 (14.987)
Highest level of schooling: middle school	38.206* (18.904)	-4.588 (14.962)
Highest level of schooling: high school	39.681* (16.053)	-20.352 (13.747)
Household members	4.991 (6.263)	1.687 (0.945)
Household members of working age (18-50)	-5.667 (9.081)	-3.922** (1.403)
Years of residence in village	0.201 (0.192)	-0.135** (0.046)
Social network	10.395 (5.944)	2.065 (1.524)
Pokrom	141.307** (16.098)	83.025** (8.193)
Darmang	134.675** (22.518)	31.191* (12.633)
Oboadaka	134.294** (20.541)	69.771** (5.510)
Min pH	-35.774** (9.260)	-8.707 (6.659)
Min organic matter	16.820 (11.150)	0.755 (5.017)
Constant	-176.733 (113.648)	-31.455 (42.180)
<i>N</i>	162	

Table 4. First stage - bivariate tobit with village clustered standard errors (in parentheses).

Notes: * $p < 0.05$; ** $p < 0.01$; standard errors in parenthesis

	Obs	Mean	Std. Dev.	Min	Max
Duration pre 1/2005	517	33.00	66.40	0	428
Duration pre 1/2005 (months), predicted	529	16.57	36.53	0	234
Duration post 1/2005	525	7.20	17.33	0	56
Duration post 1/2005 (months), predicted	529	4.21	12.46	0	64

Table 5. Summary statistics of observed and predicted pre- and post-2005 duration variables (months)

	Asset index	Productive asset index	Livestock asset index	Consumer durables asset index
Duration pre 1/2005 (months)	0.015 (0.032)	-0.005 (0.020)	0.016 (0.041)	0.065 (0.100)
Duration post 1/2005 (months)	-0.191 (0.449)	-0.032 (0.273)	-0.247 (0.569)	-0.635 (1.383)
Duration post 1/2005 (months), squared	0.004 (0.008)	0.001 (0.005)	0.005 (0.011)	0.012 (0.026)
Age	-0.011 (0.037)	-0.003 (0.022)	-0.010 (0.047)	-0.032 (0.114)
Highest level of schooling: primary school	-0.099 (0.344)	-0.064 (0.210)	-0.248 (0.436)	0.116 (1.060)
Highest level of schooling: middle school	-0.002 (0.378)	0.028 (0.230)	-0.087 (0.479)	0.047 (1.164)
Highest level of schooling: high school	-0.279 (0.541)	-0.177 (0.329)	-0.267 (0.685)	-0.617 (1.664)
Household members	-0.028 (0.109)	-0.013 (0.066)	-0.028 (0.138)	-0.119 (0.336)
Household members of working age (18-50)	0.027 (0.096)	-0.001 (0.058)	0.039 (0.122)	0.111 (0.295)
Number of villagers whom respondent knows personally	0.005 (0.004)	0.001 (0.002)	0.007 (0.005)	0.009 (0.012)
Constant	0.220 (1.086)	0.035 (0.661)	0.453 (1.377)	0.765 (3.345)
Sigma u	1.83	1.67	1.90	2.70
Sigma e	0.74	0.45	0.94	2.28
Rho	0.86	0.93	0.80	0.58
N	440	440	440	440

Table 6. Effect of instrumented duration on asset index

Notes: Clustered standard errors reported in parentheses. Other controls include “duration pre 1/2005 (months), squared” and “age squared” which are not statistically significantly different from 0, so are omitted from the table above. * $p < 0.05$; ** $p < 0.01$

	Asset index (IV, FE)	Asset index (IV, RE)	Asset index – IV, only data with obs in both years
Duration pre 1/2005 (months)	0.015 (0.032)	0.017 (0.019)	0.015 (0.032)
Duration post 1/2005 (months)	-0.191 (0.449)	-0.211 (0.285)	-0.191 (0.449)
Duration post 1/2005 (months), squared	0.004 (0.008)	0.004 (0.005)	0.004 (0.008)
Age	-0.011 (0.037)	-0.003 (0.028)	-0.011 (0.037)
Highest level of schooling: primary school	-0.099 (0.344)	-0.058 (0.243)	-0.099 (0.344)
Highest level of schooling: middle school	-0.002 (0.378)	0.015 (0.257)	-0.002 (0.378)
Highest level of schooling: high school	-0.279 (0.541)	-0.119 (0.331)	-0.279 (0.541)
Household members	-0.028 (0.109)	-0.037 (0.068)	-0.028 (0.109)
Household members of working age (18-50)	0.027 (0.096)	0.037 (0.065)	0.027 (0.096)
Number of villagers whom respondent knows personally	0.005 (0.004)	0.005 (0.003)	0.005 (0.004)
Female respondent		-0.072 (0.357)	
Constant	0.220 (1.086)	0.081 (0.701)	0.232 (1.098)
<i>N</i>	440	440	404

Table 7. Robustness checks

Notes: Other controls include “duration pre 1/2005 (months), squared” and “age squared” which are not statistically significantly different from 0, so are omitted from the table above output. * $p < 0.05$; ** $p < 0.01$.

	<i>Initial (1998) wealth percentile</i>	<i>n</i>	<i>Early adopter</i>		<i>Late adopter</i>		<i>Nonadopter</i>
			<i>Early disadopter</i>	<i>Late disadopter</i>	<i>Early disadopter</i>	<i>Late disadopter</i>	
Asset index	0-25th	99	-0.289	-5.775	-2.090	-7.577	-0.261
	26-50th	105	-0.166	-5.653	-1.968	-7.454	-0.139
	51-75th	123	0.065	-5.421	-1.736	-7.223	0.093
	76-100th	127	0.143	-5.343	-1.658	-7.144	0.171
Durables asset index	0-25th	179	0.884	-17.429	-6.816	-25.129	-0.712
	26-50th	42	1.056	-17.257	-6.644	-24.957	-0.540
	51-75th	122	1.602	-16.711	-6.098	-24.411	0.006
	76-100th	111	1.630	-16.683	-6.070	-24.383	0.034
Livestock asset index	0-25th	81	-0.421	-7.556	-2.343	-9.478	0.036
	26-50th	97	-0.392	-7.527	-2.313	-9.448	0.065
	51-75th	133	-0.172	-7.307	-2.094	-9.229	0.285
	76-100th	143	-0.091	-7.226	-2.013	-9.148	0.366
Productive asset index	0-25th	188	-1.005	-1.899	-0.437	-1.330	-0.139
	26-50th	33	-0.955	-1.848	-0.386	-1.280	-0.088
	51-75th	106	-0.887	-1.781	-0.319	-1.213	-0.021
	76-100th	127	-0.874	-1.768	-0.306	-1.200	-0.008

Table 8. Average welfare for categories of farmers, by wealth percentile.

Notes: Early adoption is defined as farmers adopting ten years prior to the shock (1/2005). Late adoption is defined as farmers adopting the year of the shock (1/2005). Early disadoption is defined as farmers disadopting 10 months after the shock; late disadoption is defined as farmers disadopting 40 months after the shock. *** Differences between early adopters/early disadopters and nonadopters are statistically significant at the 1 % level for all indices and percentile groups. Differences between early adopters/late disadopters and late adopters/early disadopters are statistically significant at the 1 % level for all indices and percentile groups. Differences between early adopters/late disadopters and late adopters/late disadopters are statistically significant at the 1 % level for all indices and percentile groups.

11. Appendices

A. Factor summary statistics

<i>Productive Assets:</i>	<i>mean</i>	<i>std. dev.</i>	<i>min</i>	<i>max</i>
Barrel	0.309	1.086	0	19
Chain saw	0.015	0.160	0	3
Corn mill	0.004	0.071	0	2
Cutlass	0.975	3.833	0	118
Gallon container	0.004	0.098	0	3
Hammer	0.195	0.506	0	4
Hoe	0.245	1.011	0	26
Knapsack	0.029	0.236	0	4
Mattock	0.018	0.161	0	2
Mist blower	0.226	1.740	0	53
Pick axe	0.032	0.935	0	30
Pump	0.012	0.206	0	6
Rake	0.005	0.082	0	2
Saw	0.016	0.224	0	4
Shovel	0.005	0.082	0	2
Sprayer	0.070	0.345	0	5
<i>Livestock assets:</i>				
Cows (f)	0.101	2.675	0	85
Goats, kids (f)	0.492	1.251	0	14
Goats, kids (m)	0.370	0.918	0	9
Goats, adults (f)	1.547	2.867	0	35
Goats, adults (m)	0.501	1.871	0	50
Lambs (f)	0.240	0.874	0	12
Lambs (m)	0.204	0.678	0	6
Sheep (f)	0.955	2.517	0	28
Sheep (m)	0.295	0.990	0	13
Chickens, broilers)	0.577	1.469	0	11
Chickens, broilers)	1.063	11.067	0	250
Chickens, layers (f)	1.184	2.903	0	24
Chickens, layers (m)	1.092	2.754	0	24
Chickens, local (f)	2.576	5.100	0	68
Chickens, local (m)	1.405	2.576	0	27
Cows (m)	0.018	0.423	0	13
Ducks (f)	0.245	1.561	0	24
Ducks (m)	0.180	1.210	0	23
Guinea pigs (f)	0.091	0.966	0	25
Guinea pigs (m)	0.054	0.503	0	11
Pigs adults (f)	0.072	0.623	0	15
Pigs adults (m)	0.041	0.628	0	18
Piglets (f)	0.010	0.130	0	2
Piglets (m)	0.010	0.144	0	3
Rabbits (f)	0.055	0.603	0	10
Rabbits (m)	0.032	0.396	0	8
<i>Durable assets:</i>				
Bicycle	0.065	0.260	0	2
Car	0.044	0.252	0	4
Fan	0.126	0.459	0	5
Generator	0.261	5.201	0	167

Gun	0.043	0.227	0	2
Radio	0.442	0.657	0	4
Refrigerator	0.109	0.338	0	3
Sewing machine	0.282	0.478	0	3
Television	0.225	0.501	0	6
Year is 2009	0.600	0.490	0	1

B. Estimated factor loadings

	All assets		Durable assets		Livestock assets		Productive assets	
	1998	2009	1998	2009	1998	2009	1998	2009
Barrel	0.710	0.721					0.816	0.825
Chain saw	0.382	0.393					0.428	0.443
Corn mill	-0.001	0.034					0.016	0.052
Cutlass	0.932	0.933					0.935	0.935
Gallon container	0.000	0.039					0.006	0.022
Hammer	0.338	0.341					0.379	0.380
Hoe	0.870	0.898					0.922	0.944
Knapsack	0.059	0.091					0.110	0.147
Mattock	0.002	0.048					0.004	0.047
Mist blower	0.914	0.916					0.929	0.930
Pick axe	0.023	0.023					0.033	0.033
Pump	0.085	0.083					0.088	0.089
Rake	0.016	0.030					0.071	0.094
Saw	0.031	0.042					0.077	0.087
Shovel	0.023	0.044					0.060	0.086
Sprayer	-0.049	0.036					-0.050	0.049
Cows (f)	0.885	0.886			0.774	0.774		
Goats, kids (f)	0.298	0.582			0.412	0.674		
Goats, kids (m)	0.211	0.467			0.337	0.578		
Goats, adults (f)	0.210	0.555			0.337	0.640		
Goats, adults (m)	0.133	0.492			0.205	0.560		
Lambs (f)	0.428	0.731			0.536	0.793		
Lambs (m)	0.277	0.612			0.416	0.723		
Sheep (f)	0.222	0.558			0.373	0.678		
Sheep (m)	0.231	0.562			0.361	0.661		
Chickens, broilers (f)	-0.096	0.038			-0.064	0.028		
Chickens, broilers (m)	0.136	0.151			0.198	0.209		
Chickens, layers (f)	-0.100	0.034			-0.059	0.049		
Chickens, layers (m)	-0.114	0.031			-0.070	0.063		
Chickens, local (f)	0.610	0.626			0.700	0.706		
Chickens, local (m)	0.506	0.579			0.590	0.648		
Cows (m)	0.886	0.886			0.774	0.774		
Ducks (f)	0.003	0.031			0.041	0.044		
Ducks (m)	-0.004	0.036			0.035	0.052		
Guinea pigs (f)	0.044	0.049			0.081	0.082		
Guinea pigs (m)	0.041	0.059			0.082	0.093		
Pigs adults (f)	0.013	0.071			0.054	0.141		
Pigs adults (m)	0.046	0.064			0.119	0.142		
Piglets (f)	0.001	0.006			-0.021	-0.019		
Piglets (m)	0.011	0.017			-0.015	-0.012		
Rabbits (f)	0.125	0.170			0.146	0.190		

Rabbits (m)	0.089	0.188			0.109	0.210
Bicycle	0.177	0.180	0.372	0.379		
Car	0.539	0.624	0.545	0.628		
Fan	0.414	0.416	0.770	0.772		
Generator	0.888	0.888	0.470	0.471		
Gun	-0.042	0.011	-0.082	0.035		
Radio	0.433	0.437	0.694	0.699		
Refrigerator	0.487	0.488	0.783	0.785		
Sewing machine	0.052	0.111	0.018	0.095		
Television	0.405	0.416	0.815	0.829		

CHAPTER 4

POVERTY RATES AND THE RETURNS TO FERTILIZER: EMPIRICAL AND SIMULATION EVIDENCE FROM MALAWI¹

1. Introduction

While Asia's Green Revolution resulted in a doubling of average yields for staple crops over the 1960s-70s, Africa's agricultural productivity has lagged behind. Several African governments promoted fertilizer use during the 1970s and early 1980s, e.g., through direct subsidies, input credit programs, centralized fertilizer procurement and distribution sites, etc., with some success (Denning *et al.* 2009). However, there was a general phase out of input subsidy programs in the 1990s, primarily due to fiscal constraints or inefficiency. Following severe weather events and/or the 2007-2008 food price crisis, however, several African countries reintroduced yield-increasing policies in the 2000s (Kelly *et al.* 2011). For example, Malawi suffered a severe drought in 2004-5, resulting in approximately 4.2 million people, or 38% of its population, requiring food aid (Denning *et al.* 2009). As a result, the government reinstated a subsidized fertilizer program. Aggregate maize production doubled in 2006, then tripled in 2007, going from a 43% national deficit in 2005 to a 53% surplus in 2007 (Denning *et al.* 2009). In a nation where in 2005 inhabitants consumed approximately 1,193 kcal worth of maize per day and grew maize on approximately 40% of cultivated land (FAOSTAT 2005), the fertilizer subsidy scheme's apparent success in dramatically improving Malawi's food security attracted widespread attention and helped turn fertilizer subsidies into a high-level political issue, not just in Malawi but throughout Africa.

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Despite the Malawi fertilizer program's seeming success, some have criticized its high cost, starting in 2005-2006 at US\$ 50 million, and growing to US\$265 million during the 2008-2009 growing season, due in part to soaring global fertilizer prices (Chibwana *et al.* 2012, Dorward and Chiwra 2011). Others have criticized it as an unwarranted public subsidy of fundamentally private goods.² Still others express doubts as to how much of Malawi's recent maize yield gains can be attributed to its fertilizer subsidy program, the introduction of which fortuitously coincided with several years' favorable growing conditions (Ricker-Gilbert *et al.* 2009). Furthermore, there is some evidence that while subsidies may have increased crop yields, poverty levels have remained the same, raising questions about the program's efficacy in reducing poverty and food insecurity (Chapoto *et al.* 2011).

In this study, we use econometric and simulation analysis of a large-scale, nationwide panel of plot-level experimental data to disentangle the productivity impacts of Malawi's fertilizer subsidy program from those of favorable weather while accounting for the country's heterogeneous soil conditions and pest pressures. We begin by estimating a maize production function using experimental agronomic trial data merged with detailed soils and weather data. Randomized assignment of fertilizer applications combined with detailed agronomic controls enable us to identify the causal effects of fertilizer application on maize yields. We then use the estimated maize production function and historical climate data to generate spatially explicit estimates of the distribution of the expected marginal profitability of fertilizer use in the face of stochastic

² See, for example, the comments by the World Bank's Chief Economist for the Africa Region, Shanta Devarajan, at <http://blogs.worldbank.org/african/fertilizer-subsidies-in-malawi>, and associated responses.

weather, given prevailing maize and fertilizer prices during the subsidy era. Finally, we correlate those results with spatially disaggregated estimates of headcount poverty rates so as to establish whether yield gains reasonably attributable to fertilizer subsidies accrue primarily in poorer or richer areas of the country.

We find that given 2009-2010 maize and fertilizer prices, the fertilizer bundle recommended under Malawi's Agricultural Input Subsidy Program is almost always and everywhere profitable in expectation. Indeed, fertilizer use would remain profitable in expectation even in the face of significant fertilizer price increases and drought year conditions. While the program does appear to favorably affect maize yields and farm profits, however, the spatial pattern of those gains is largely uncorrelated with headcount poverty rates, calling into question the extent to which Malawi's fertilizer subsidies have been pro-poor.

The remainder of the paper is structured as follows. Section 2 reviews the related literature on fertilizer application rates and reviews Malawi's subsidy program. Section 3 describes our data and provides summary statistics. Section 4 estimates the quadratic production function and Section 5 calculates the expected returns to fertilizer and expected marginal benefit to cost ratios. Section 6 explores the spatial correlation of the expected returns to fertilizer estimates with headcount poverty levels. Finally, Section 7 discusses our results and Section 8 concludes with some policy recommendations.

2. Background

Much of the recent economic literature regarding fertilizer use in African agriculture has tried to understand the relatively low observed fertilizer adoption rates

among smallholder farmers and the variability in fertilizer use over seasons despite high expected payoffs (Duflo *et al.* 2011, Marenya and Barrett 2009a,b, Suri 2009, Duflo *et al.* 2008). This puzzle is partially explained by the observed and unobserved heterogeneity among both farmer attributes (e.g., patience, skill) and soil characteristics that make different levels of fertilizer profitable or not (Foltz *et al.* 2011). For example, Marenya and Barrett (2009a,b) show that fertilizer yield responses vary with soil organic matter content, making fertilizer application less profitable on poorer quality soils, and that farmer fertilizer application behavior responds accordingly. Finally, highly volatile fertilizer and crop prices make the profitability of fertilizer application vary with prices, over space and time and may induce risk-averse farmers to forego fertilizer use (Dercon and Christiaensen 2011, Morris *et al.* 2007).

One way in which policy makers have responded to low adoption levels is by subsidizing farmer's fertilizer purchases. Conventional subsidies stimulate demand by lowering the price faced by private buyers, but the gains often accrue disproportionately to suppliers rather than farmers, given relatively price inelastic supply and price elastic demand. Universal subsidies have been/are implemented in several West African countries, including Burkina Faso, Senegal, Mali, Nigeria and Ghana. Several countries in East and Southern Africa, including Kenya, Malawi, Rwanda, Tanzania and Zambia, have implemented subsidy programs using vouchers distributed to targeted farmers, who redeem them at participating retailers for fertilizer at a subsidized price. The retailers in turn redeem the vouchers from the government for the full commercial price. The success of voucher schemes depends largely on their implementation, with the possibility of fraud, leakage and delay. Furthermore, they can be costly to implement. When optimally

implemented, however, targeted subsidy programs may benefit smallholders (Druihe and Barreiro-Hurle 2012).

Malawi's Agricultural Input Subsidy Program (AISP) has distributed vouchers for fertilizer, hybrid or OPV seeds and/or pesticides at reduced prices since 2005; the program continues today. Recipients receive vouchers for one 50 kg bag of basal fertilizer and one 50 kg bag of urea (to cover approximately 1 hectare of land)³. The subsidy covered between 64 to 91 % of the cost of fertilizer between 2005-2010, changing from year to year. In 2007-2008, for example, recipients paid 6.75 \$ while the government paid 24.50 \$ per 50 kg bag of fertilizer, representing 78.4 % subsidization (Doward and Chirwa 2011). Initially, open pollinated variety (OPV) maize seeds were distributed but were subsequently replaced predominantly by hybrid maize varieties. In 2007-2008, AISP also distributed cotton and legume seeds, and in 2008-2009 it also distributed tea and coffee fertilizers. The 2005-2006 program and subsequent program years distributed vouchers to approximately 50% of the farmers in the country. Doward and Chirwa (2011) and Doward *et al.* (2008) contain more details on Malawi's AISP.

The Ministry of Agriculture of Malawi distributes coupons to districts and traditional authorities that allocate them to villages. Village heads and village development committees identify recipient households targeting vulnerable households (especially children and women headed households) that grow maize and/or tobacco and who otherwise could not afford to purchase fertilizer (Doward *et al.* 2008). Field reports find that in practice, there was significant variation in selection criteria, number of coupon recipients and number of coupons per recipient between villages and over time.

³ The average farm in Malawi is 1.12 ha. Farm sizes tend to be smaller in the south where the population density and poverty levels are higher (Holden and Lunduka 2012).

Unofficial criteria such as social networks, e.g., relationships to village leaders, and the duration of stay of a household in the village were likely to have affected the allocation of vouchers to recipients (Doward and Chirwa 2011, Ricker-Gilbert *et al.* 2011, Holden and Lunduka 2010, Doward *et al.* 2008). Indeed, Ricker-Gilbert *et al.* (2011) find that male-headed households with higher assets and more land received more subsidized fertilizer.

Many farmers in Malawi began to grow hybrid maize using an average of 97 kg DAP and 175 kg urea per hectare in the 1980s (the equivalent of 96 kg N and 40 kg phosphate in nutrients), as recommended by extension agents (Benson 1999b). However, due to the diversity in climate and soils throughout Malawi, the blanket rates were not profitable for all farmers; in particular, adding rates of phosphate greater than 20kg/ha did not raise yields at some sites (Benson 1999b). As a result, the Ministry of Agriculture called for fertilizer verification trials to determine which fertilizer combinations would be best suited to different soil types throughout Malawi. A group called the Maize Productivity Task Force (MPTF) (Snapp *et al.* 2010, Benson 1999a) undertook this task. With technical assistance from the International Food Policy and Research Institute and funding from the Rockefeller Foundation, MPTF collected yield and soil data over two seasons in 1995-1996 and 1997-1998.

Beginning in 1998-1999, the MPTF implemented trials comparing cropping systems including legumes and fertilized maize. Indeed, fertilizer application is but one way of addressing soil deficiencies. Foltz *et al.* (2011) suggests that returns to fertilizer may be greater when combined with complementary practices, such as using improved seeds, irrigating, weeding more frequently, etc. Snapp *et al.* (2010) find that N fertilizer efficiency and stability of maize yield response can be optimized when maize

monoculture is broken down with shrubby crop legume such as the semi-perennial pigeonpea (*Cajanus cajan*) or viney legume mucuna (*Mucuna pruriens*) which have high N-fixing capacity. Even across different soil types, they find that rotating maize with semi-perennials yielded 38-67 kg grain/kg N versus 24-31 kg grain/kg N in monoculture maize. In some cases, improving soil organic matter by adopting conservation farming techniques, e.g., reducing soil disturbance, adding manure, ridging to trap/focus water drainage, intercropping or rotating legumes, may be more cost effective in addressing micronutrient deficiencies than fertilizers altogether.⁴

Chibwana *et al.* (2012) measure the impact of Malawi's AISP on cropland allocation decisions and find a positive correlation between participation in the program and the amount of land planted with maize and tobacco and a negative correlation with land to other crops. The authors conclude that the subsidy program therefore promoted the monoculture of crops, thereby increasing farmer risk (growing maize instead of more drought-resistant crops, e.g., cassava and potato) and decreasing soil fertility, but reducing forest pressure. Holden and Lunduka (2012) assess the impacts of Malawi's AISP on the use of manure. Continuous application of N-fertilizer has been shown to lead to more acidic soils, which can be mitigated by the application of organic manure. They find that a 1 % increase in fertilizer use is associated with a 1.94%-1.96% increase in manure for farmers not receiving fertilizer vouchers and a 0.62%-1.66% increase for fertilizer voucher recipients.

⁴ Some conservation agriculture techniques are more difficult to adopt given the use of herbicides that can have long-term toxic effects on legumes (Snapp *et al.* 2010). A farmer must assess the tradeoff between applying herbicides to kill weeds that compete with maize for N and associated labor costs with weeding.

The stated goal of fertilizer subsidy programs is often to both reduce poverty and increase production (Kelly *et al.* 2011). However, achieving both objectives appears difficult. While targeting better off farmers may result in higher yields due to their superior access to fertile land, seasonal financing to purchase complementary inputs, skill, etc., subsidizing the better off also results in a higher crowding out effect of commercial fertilizer (Ricker-Gilbert and Jayne 2013, Ricker-Gilbert *et al.* 2011). Furthermore, if the gains from subsidies accrue primarily to better-off farmers, or in better-off regions of the country, then one necessarily relies on national, rather than local, food and labor markets to propagate the gains to the poor (Minten and Barrett 2008). So the spatial pattern of yield gains may matter to the poverty reduction effects of fertilizer subsidy schemes.

3. Data and summary statistics

The data used in this study come from multiple sources. We use field trial data from on-farm experiments conducted by the MPTF in 1995-1996 and 1997-1998. Six treatments of different fertilizer bundles were randomly assigned across 1,677 sites nationwide in 1995-1996, while experiments with four of those treatments were repeated on 1,407 sites in 1997-1998, with 1,205 overlapping sites across the two years (Table 3). Farmers selected field sites on which fertilizer had not been applied and that had been fallow for at least two years. The 1997-1998 trials were in the same location as the 1995-1996 trials, but not at the exact same site, so as to ensure that the preceding treatments

did not affect subsequent trial's yields (Figure 1)⁵. The sites were managed and led by local farmers who were trained by regional field assistants (FAs) to manage the experiment sites. The FA hosted two field days with local farmers at each site. The first was planned for when the maize was fully grown, but still green, and the second occurred after harvest when the grain yield had been weighed. The FAs collected several types of data including soil samples, farmer comments, crop growth stage dates, incidence of pest attack, and harvest data (Sauer and Tschale 2009, Benson 1999).

The different treatments were conducted on 4-6 (depending on the year) adjacent trial plots at one site, each plot measuring 6.3 m x 9 m, consisting of seven ridges spaced 90 cm apart. The net harvest plot size was five full ridge lengths, or 1/247 ha (0.00405 ha). The basal application of fertilizer was done before planting using the banding method. Two different maize varieties were used. The shorter duration hybrid, MH18, was planted at about two-thirds of all sites – those in lowland areas and in rain-shadow areas in the uplands. The taller, longer duration hybrid, MH17, was planted at the remaining sites. The maize was planted at a rate of three seeds per station, with planting stations spaced 75 cm along the ridge. The top-dressing application of fertilizer was done by the banding method when the maize had reached 45 cm in height. Plots were weeded at least twice (Sauer and Tschale 2009, Benson 1999).

To control for soil heterogeneity that may affect the marginal physical product of fertilizer on maize, we use soil maps generated by the Land Resources Conservation Board at the Ministry of Agriculture in Malawi in collaboration with FAO and UNDP in

⁵ We use *location* to refer to the same geographic area at which one or more *site* was chosen at which to perform the field experiments. Therefore, up to two different *sites* (one for the 1995-1996 trials and one for the 1997-1998 trials) were chosen at one location.

the 1980s and 1990s (Eschweiler *et al.* 1991). The maps contain soil characteristics, including soil type, slope, cation exchange capacity, soil N, P and K content. Given the proximity in location of the trial plots both seasons, we can reasonably assume that the sites shared similar agro-ecological characteristics, although there is surely still unobserved plot-level variation in soil conditions. Nonetheless, we can estimate the marginal impact of fertilizer on maize yields because application rates were randomized across plots, plot management standardized, and we can control for a host of agronomic conditions that might affect the marginal physical product of fertilizer.

Tables 1-3 contain summary statistics from the 1,891 plot trials and soil map data. As expected, yields increase with the N, phosphate and sulphur (S) contents of a fertilizer application. Interestingly, treatment 5 leads to statistically significantly higher (at the 1% level) mean yields than treatment 6, which has a higher N and phosphate content but no S. Yields in 1995-1996 were statistically significantly higher (at the 1 % level) than yields in 1997-1998 for each treatment.

Table 2 shows the mean striga and termite infestation by year at each site, as reported by farmers overseeing the plots. Farmers were asked to observe whether the site was infested by striga, differentiating between infestation on less than 50 % of planting stations (some infestation) or more than 50% (high striga infestation). Between 21-28% (6-7%) of sites suffered moderate (high) infestation each year. Termites were observed on approximately 40% of sites in both years⁶. We have no reason to believe that pest infestation rates are endogenous to the fertilizer treatments. Finally, table 3 shows the

⁶ Pest infestation is not chronic: the correlation between striga infestation between both years is 0.19; the correlation between high striga infestation is 0.12 between both years; and the correlation between termite infestation is 0.10 between both years.

mean soil characteristics for each site. The terrain is flat (steep) on 48 (3) % of sites. The soil is on average acidic.

We also control for climate variability by using daily rainfall and temperature time series data from 23 weather stations scattered throughout Malawi as collected by the Malawi Meteorological Service (Figure 2). Malawi has a diverse agroecology with 55 natural regions. The precipitation pattern is unimodal with 4-6 months of rain falling approximately between December and April, followed by a long dry season (Holden and Lunduka 2010, Gilbert *et al.* 2002). The first year of available rainfall data differs by district, ranging between 1903-1976, and ending in 2009 for all districts. The temperature data also differ in start year, ranging between 1956 and 1984 and ending between 2002 and 2008. Experimental field sites were linked to weather stations based on the matching district and weather station name (a future iteration will create a weighted average of rainfall and temperature based on a site's proximity to the 2-3 closest weather stations).

Following the methodology used and described in Lobell *et al.*'s (2011) study of how growing conditions affect maize production in sub-Saharan Africa, we build three weather indices to control for temperature and rainfall. First, we calculate the number of growing degree days (GDD) between 8 and 30 degrees Celsius to predict maize development rates. Second, we calculate the number of growing degree days above 30 degrees Celsius to control for high temperatures that might harm maize growth. Finally, we calculate the total precipitation for the 21-day period centered on the silking date, to control for anthesis -- the period when maize flowers and is particularly susceptible to drought. Appendix A includes a more thorough description of the construction of these indices. Figure 3 shows these weather indices from 1972 to 2004. As expected, a high

GDD 30+ index corresponds with past drought years, notably seasons 1982-1983, 1991-1992, and 1994-1995. Figure 3 also includes total maize yields (<http://faostat.fao.org>, 2013). High GDD 30+ index and low precipitation years are, as expected, generally accompanied by low maize yields.

District-level median fertilizer prices were calculated from the agriculture module data in the World Bank's 2010 LSMS third Integrated Household Survey for Malawi⁷. In the surveys, respondents were asked the quantity and value of unsubsidized fertilizer purchased. The following analysis, therefore, examines the market cost of fertilizer, not the subsidized cost to farmers or the cost to the government. District-level median maize prices were calculated using the Ministry of Agriculture's monthly maize prices between December 2009 and March 2010. Median maize and fertilizer prices (MK/kg) are summarized in Table 4. The fertilizer prices for DAP are highest, followed by NPK and urea.

Finally, we use IFPRI's HarvestChoice poverty headcount rate map showing the percent of the population living below \$1.25 per capita/day in purchasing power parity at the 2005 reference year⁸. These maps were prepared using Malawi's nationally representative 2004-2005 Integrated Household Survey⁹. Poverty estimates were rasterized to a 5 arc-minute grid where poverty rates are assumed uniform across grid

⁷ Available at <http://web.worldbank.org/WBSITE/EXTERNAL/EXTDEC/EXTRESEARCH/EXTLSMS/EXTSURAGRI/0,,contentMDK:23156208~pagePK:64168445~piPK:64168309~theSitePK:7420261,00.html>

⁸ Available at <http://harvestchoice.org/maps/poverty-headcount-ratio-below-05-ppp-125day-percent-2005>. For more technical details, see http://harvestchoice.org/labs/readme_poverty.

⁹ Available at <http://www.nsomalawi.mw/index.php/publications/integrated-household-survey.html>

cells. We obtain estimated poverty levels for each trial site by creating a continuous rasterized map based on the 5 arc-minute grid cells using a kriging interpolation method in ArcGIS¹⁰. Poverty headcount ranges between 55 – 93 % for the trial sites. We ultimately estimate the correlation between these spatially explicit estimates of poverty rates and our spatially-explicit estimates of the expected marginal benefit/cost ratio for fertilizer application.

4. Maize production function estimation

We first estimate a production function with the experimental data described above, following methods used in other, recent econometric studies of fertilizer’s site-specific impact on maize yields (Maine *et al.* 2007, Liu *et al.* 2006, Anselin *et al.* 2004, Berck *et al.* 2000, Babcock and Pautsch 1998, Mjelde *et al.* 1991). In particular, we estimate a generalized quadratic production function of the form

$$y_{kit} = \alpha_0 + \sum_w \alpha_w x_{kitw} + \sum_w \sum_v \beta_{wv} x_{kitw} x_{kitv} + \eta_i + \delta_t + \varepsilon_{kit}$$

where y_{kit} represents the yield for treatment k on site i in year t , α_0 , α_w and β_{wv} are the parameters of interest, η_i is a site-level fixed effect, δ_t is a year-specific effect, $x_{kitw,v}$ represents all variables (indexed by v and w) potentially affecting yields – nutrient amounts, soil characteristics, temperature and rainfall – and ε_{kit} represents the iid, mean zero, normally distributed regression error. More specifically, we control for site-specific

¹⁰ Poverty headcount rates are interpolated using an ordinary kriging method that relies on a spherical semivariogram model.

field characteristics, i.e., whether the site was infested by striga or termites, as well as site-level soil quality characteristics extracted from national soil maps, i.e., the slope, soil texture, pH, cation exchange capacity (CEC), and N, P and potassium (K) contents, and climate using the indices described above and in more detail in Appendix A. We control for year/season-specific effects by including a dummy variable for the 1995-1996 observations. Any remaining omitted variables are assumed to be orthogonal to the remaining unobserved error component, $\eta_i + \varepsilon_{kit}$. Standard errors are robust to clustering at the site-level in order to correct for any site-level correlation among observations.

The nutrients applied to the field trial sites are as explained above, N, S and phosphate. In sub-humid environments like Malawi, N is known to be the main driver of cereal yield response in soils with low organic matter. However, applying only N as fertilizer (in the form of urea) can lead to S and P deficiencies in the longer term. K is less deficient in Malawi soils except perhaps when cultivating very high yielding tobacco. Zinc and other micronutrients also contribute to soil fertility, but are rarely deficient except perhaps in small, localized areas of Malawi (Benson 1999a,b). Chilimba and Liwimbi (2008) do conclude, however, that generally basal dressing including zinc and/or K is superior to a basal application without them.

Although both S and phosphate are known to contribute to maize yields, we cannot control for both because there is insufficient variation between treatments. Because S more consistently showed yield responses than P in the field trials, NPK 23:21:0+4S was promoted as the basal dressing in Malawi's AISP. We therefore choose to control for N and S in the production function estimation.

The panel data are unbalanced, but the field trial site selection in 1997-1998 was random and therefore the remaining unobservables should be uncorrelated with the regressors. Because we are interested in the marginal effects of fertilizer, we demean the data to make the interpretation of the coefficients more straightforward. The full regression estimation results are reported in Appendix B. A Hausman test confirms that the random effects model, shown in column I, is consistent and efficient.

As expected, N and S have a statistically significant positive effect on yields that diminishes with the application rate. The interaction of N with S is also statistically significantly positive, indicating that each is limiting, leading to complementarities in combining the two nutrients. The estimated marginal yield effect of N fertilizer also varies statistically significantly with weather, increasing (decreasing) with precipitation (GDD over 30). Likewise, the marginal yield effects of S vary statistically significantly with soil P content and slope. The clear implication is that the marginal returns to fertilizer vary predictably across growing seasons and over space, so that any benefits of Malawi's subsidy program will necessarily be uneven. The key questions are how big are those benefits, how unevenly are they spread, and is that variation progressive (regressive), that is, are the marginal gains to additional fertilizer application positively (negatively) correlated with poverty headcount rates?

The coefficient estimates on the other control variables are as one would expect. Consistent with Table 1 and Figure 3, the regression estimates also indicate that yields in the 1995-1996 season were higher. Independently, the GDD 8-30 index and rainfall both have a positive, albeit statistically insignificant, effect on yields, while GDD 30+ has a negative and significant effect. Yields were higher with the shorter stature MH18 hybrid

variety and in higher pH soils, since most of Malawi's farm land is moderately to mildly acidic. High levels of striga and termite infestation and steeply sloped sandy soils are associated with lower yields. Overall, the regression does a reasonably good job of explaining variation in maize yields.

We ran robustness checks on these estimates using both a Hausman-Taylor estimator (model II in Appendix B), which allows some of the regressors to be correlated with the unobserved individual effect, η_i , and a random effects model estimated only on the balanced panel subset of data observed in both years (model III). The results are generally quite consistent across specifications, especially as regards the central parameters of interest relating to the marginal effects of fertilizer application on maize output. The sign of the effect differs for the second order effects of pH where it is negative (as expected) for model I but positive in models II and III.

5. The estimated returns to fertilizer

Given the estimated maize production function, we can estimate the expected marginal physical returns of fertilizer. The expected marginal physical returns to fertilizer, $E[dy_f]$, equals the sum of the marginal products of each element in the fertilizer, N and S, multiplied by the percent of the nutrients in the specific fertilizer:

$$E[dy_f] = \gamma_n \frac{\partial y}{\partial n} dn + \gamma_s \frac{\partial y}{\partial s} ds \quad (2)$$

For example, NPK (23:21:0+4S) contains 23 % N, 21 % P, 0 % K and 4 % S, so $\gamma_n = 23\%$ and $\gamma_s = 4\%$ while urea contains 46% N so that $\gamma_n = 46\%$ and $\gamma_s = 0\%$. Given the estimation results from equation (1), the expected marginal return to fertilizer f is:

$$E[dy_f] = \gamma_n(\alpha_n + \sum_v \beta_{nv} x_{kitv}) + \gamma_s(\alpha_s + \sum_v \beta_{sv} x_{kitv}) \quad (3)$$

The expected marginal returns are a function of multiple terms, including interactions with a host of variables that vary across space and time.

The second and third columns of Table 4 report the estimated marginal returns of NPK (the fertilizer included in the starter pack) and urea. The mean marginal return is higher for urea. Had we been able to control and estimate the marginal returns from phosphate, however, the marginal returns for NPK might be higher, as we implicitly put zero value on the P since S appears more limiting. Furthermore, as explained above, while the application of urea may increase yields in the short term it would likely lead to the depletion of other nutrients in the longer term. Our results are consistent with the literature. For example, Marenya and Barrett (2009a) find marginal returns of 17.64 kg maize per kg of nitrogen.

Using historic climate data at the district-level along with our regression results, we can estimate the distribution of expected marginal returns of NPK and urea at each site for each available year. We calculate the climate indices GDD 30+, GDD 8-30 and rainfall (mm) for each year for each site by using the relevant dates from the 1995-1996 field trials (e.g., silking date). We use the joint distribution of the observed climate indices to simulate the expected marginal returns for each available year for the trial sites. The availability of data varies by trials site and ranges between a start date of 1903-1976 and an end date of 2008, as explained in Section III. We have to assume that soil characteristics remain constant as we do not have annual soil characteristics. The two last columns of Table 4 show the expected mean marginal return of urea and NPK for the entire set of simulated data and are close to the in-sample means (columns 2 and 3).

Given the distribution of expected marginal products of fertilizer and fertilizer and maize prices, we can estimate the probability that fertilizer is profitable for a given plot. While climatic conditions will affect maize prices and fertilizer prices, to a lesser degree, we cannot control for the variation in prices over time due to data constraints. We therefore use district-level median maize and fertilizer prices from the IHS data from 2009-2010, as described above. The expected marginal profit, $E[\pi]$, from fertilizer application is

$$E[\pi] = E[dy_f \cdot p_m] - p_f, \quad (4)$$

where p_m is the price of maize and p_f is the price of fertilizer, the first of which is unknown when farmers make fertilizer purchase decisions, and hence subject to uncertainty, hence the expectations operator.¹¹ The price of fertilizer, however, is known at the time of purchase. From the standard first order conditions of the risk neutral producer's profit maximizing problem, fertilizer application will be profitable in expectation so long as $E[\pi] > 0$, which constitutes a necessary condition for fertilizer application.¹² Table 5 shows the expected profitability, marginal product and benefit/cost¹³ of adding 1kg of urea or NPK. Adding 1 kg of NPK (urea) is (almost) always profitable in expectation.

Maps of the expected profitability expressed in benefit/cost ratio terms offer strong indications as to where the gains from fertilizer use induced by subsidies are concentrated and their magnitude. The higher expected marginal benefit/cost ratios are

¹¹ Lacking data with which to establish the joint distribution of maize prices and the marginal physical product of fertilizer, we must assume these are statistically independent, thus $E[dy_f \cdot p_m] = E[dy_f] \cdot E[p_m]$.

¹² This is not a sufficient condition because risk aversion, liquidity constraints that force the farmer to borrow funds at a positive interest rate in order to purchase fertilizer, and other factors can still make fertilizer use unattractive even with $E[\pi] > 0$.

¹³ Expressed in expected benefit/cost ratio terms, $E[dy_f \cdot p_m] / p_f$

concentrated in the northern region of Karonga, the western region of Mangochi and the southern regions of Blantyre, Chiradzulu and Thyolo.

Because these results are contingent on 2009-2010 prices, we also examine how the expected probability of profitability and benefit-cost ratios might vary with changing fertilizer prices, which are notoriously volatile.¹⁴ Holding maize prices fixed, we increase the price of the fertilizer for the treatment bundle by 50%, 100%, 200% and 500%. The expected profitability of fertilizer application is robust to increases in fertilizer prices up to 200%. But fertilizer use becomes widely – but not everywhere – unprofitable with fertilizer price increases of 500 % (Table 7).

Similarly, we compare how expected marginal returns and the probability of expected profitability vary with changing climatic conditions. We compare results estimated for a drought year, 1991, and for a year with favorable rainfall and temperatures, 1984. The likelihood of profitability of urea decreases to 94.2% in a drought year, but remains profitable 100% of the time for NPK. The expected profitability of fertilizer irrespective of growing conditions is a striking result. Expected marginal benefit to cost ratios are greater than 4 in all cases (Table 8).

6. Are Fertilizer Subsidies Pro-Poor?

While fertilizer subsidy programs are often motivated by governments' desire to reduce both poverty and food insecurity, this may not be an effective instrument if poorer farmers live in areas where growing conditions are less favorable or cultivate soils that do

¹⁴ For example, international DAP and urea prices increased roughly six-fold from 2004-2008 before retreating sharply by 2009-10 and settling at roughly two to three times the 2004 prices by 2012-13 (<http://www.africafertilizer.org/Data-Centre/Monthly-International-Prices-for-Fertilizers.aspx>).

not respond as well to fertilizers as those of better-off farmers (Kelly *et al.* 2011, Marenya and Barrett 2009a).

Using the poverty headcount rate maps described above, we generate the predicted percent of the population living below US\$1.25 per capita/day at each trial site location. We correlate these poverty rates with the entire set of simulated expected marginal benefit to cost (EMBC) ratios, by district, where the number of sites per district vary between 57 and 5,272.

Table 9 and Figure 5 show the correlation estimates by district and make evident the weak relationship between poverty and the returns of fertilizer. The mean correlation between urea (NPK) EMBC and poverty is 0.006 (0.069) over the entire set of data ($n = 44,501$), statistically significantly different from zero at the one percent level but very small in magnitude. The overall correlation coefficient over the entire data set is 0.011 for urea and 0.001 for NPK. These very slightly positive correlations indicate that regions with higher poverty levels are associated with higher returns, making the benefits of fertilizer subsidies very mildly spatially progressive. Nevertheless, the values are negative for many districts, as high as -0.991 (-0.999) for urea (NPK), indicating that higher (low) poverty levels are associated with low returns (higher returns). The districts of Blantyre, Kasungu and Nkhotakota all display a high positive correlation between poverty rates and expected marginal returns.

7. Discussion

Our results indicate that when optimally applied (i.e., at the right time and in the correct quantity) the fertilizer distributed under the AISP – NPK (23:21:0+4S) – is

profitable in expectation in all regions in Malawi. Even if fertilizer prices were to rise by as much as 200%, the expected marginal benefit to cost ratio would still exceed 1. Furthermore, even in a drought year, the returns to fertilizer remain high. Our results confirm that the fertilizer recommendations from the MPTF do respond to the climate and soil types of Malawi, making the starter pack a good bundle to promote so as to profitably expand maize output.

Our results also indicate, however, that the expected benefits of Malawi's fertilizer subsidies vary significantly across space, and not always in ways that concentrate the gains in the poorest regions. The overall correlation between location-specific estimated poverty headcount rates and expected marginal returns to fertilizer is very mildly positive, leaving it unclear whether fertilizer subsidies really are pro-poor, especially if the benefits are concentrated among wealthier farmers within a given location (Ricker-Gilbert *et al.* 2011). Geographic targeting of poor regions with high expected marginal returns could help the government of Malawi ensure its subsidy program is pro-poor and help increase national production (Lang *et al.* 2012). Targeting the poor in this way could not only concentrate gains in the poorest areas but also prospectively reduce the potential crowding out effect of subsidization. Furthermore, targeting the poor who otherwise might not purchase their own fertilizer would give them the opportunity to learn about the benefits of fertilizer application (e.g., which fertilizer to apply and how/when to apply it), increasing their likelihood of continued use if subsidization were to cease.

8. Conclusions

The fertilizer bundle distributed under Malawi's AISP appears very profitable on average, and across years with strikingly different growing conditions and across sub-regions with markedly different soils and other attributes. Nevertheless, the sustainability of Malawi's subsidy program remains precarious due to its high costs. Targeting regions known to have high quality soils that respond most highly to fertilizer and are populated by the worst off can help increase the efficiency of the program and reduce costs while achieving its goals of poverty reduction and increasing food security.

9. References

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10. Figures

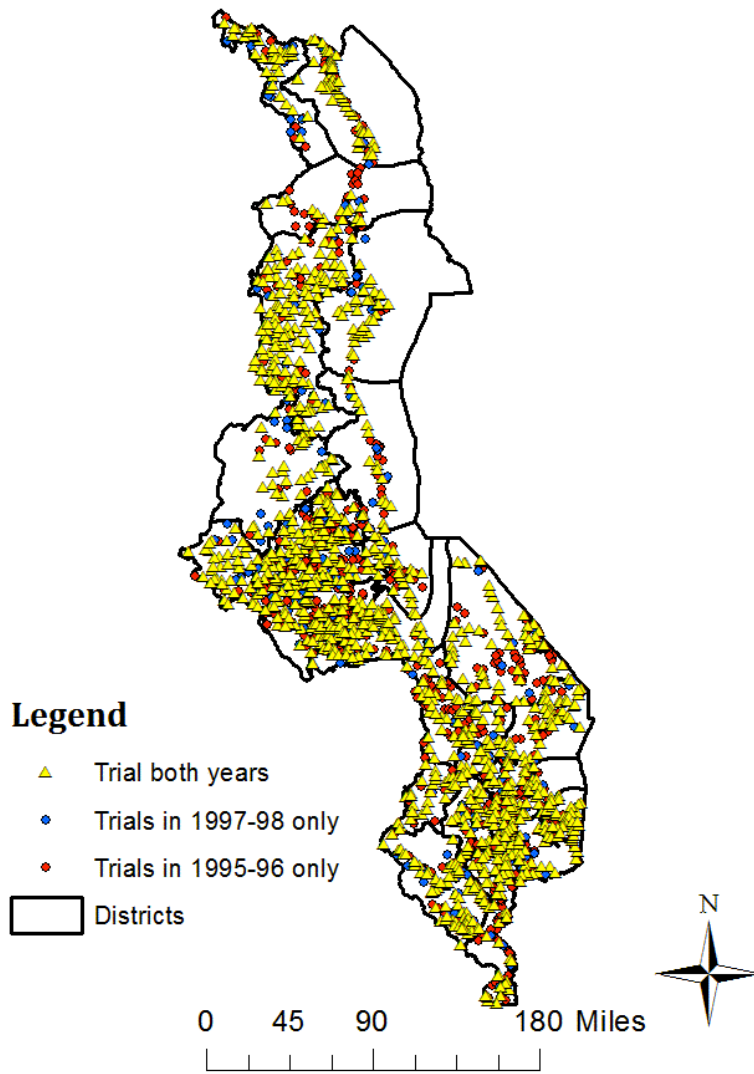


Figure 1. Field trial sites

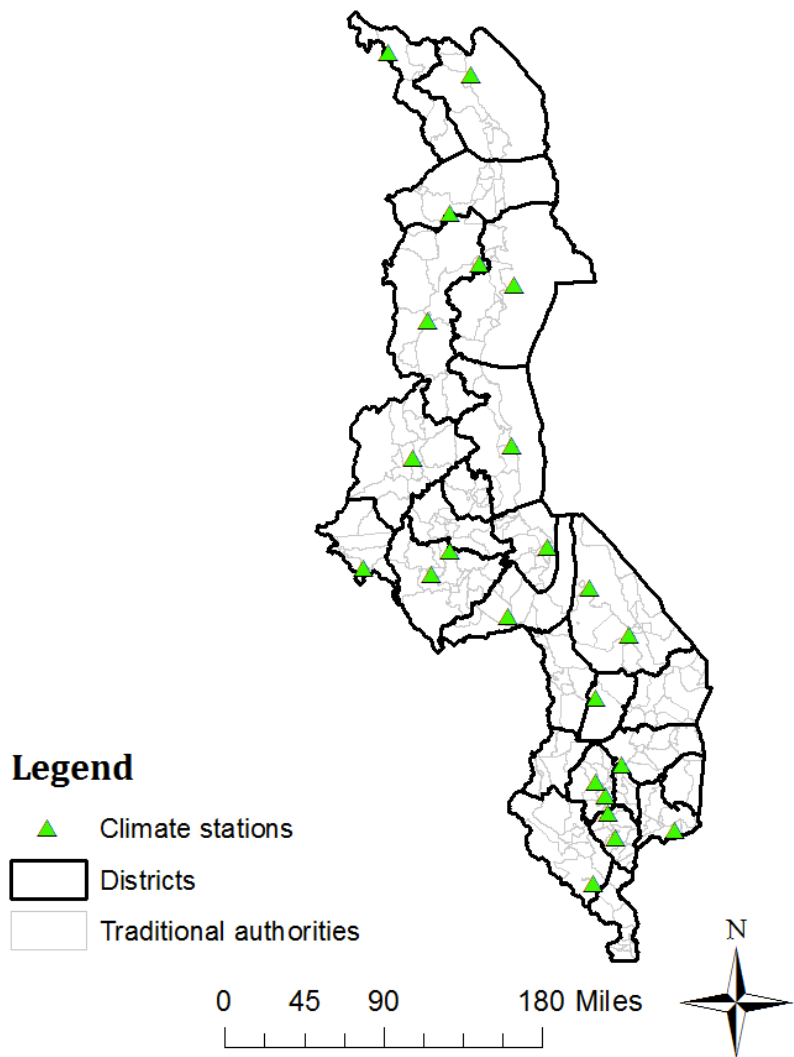


Figure 2. Climate stations

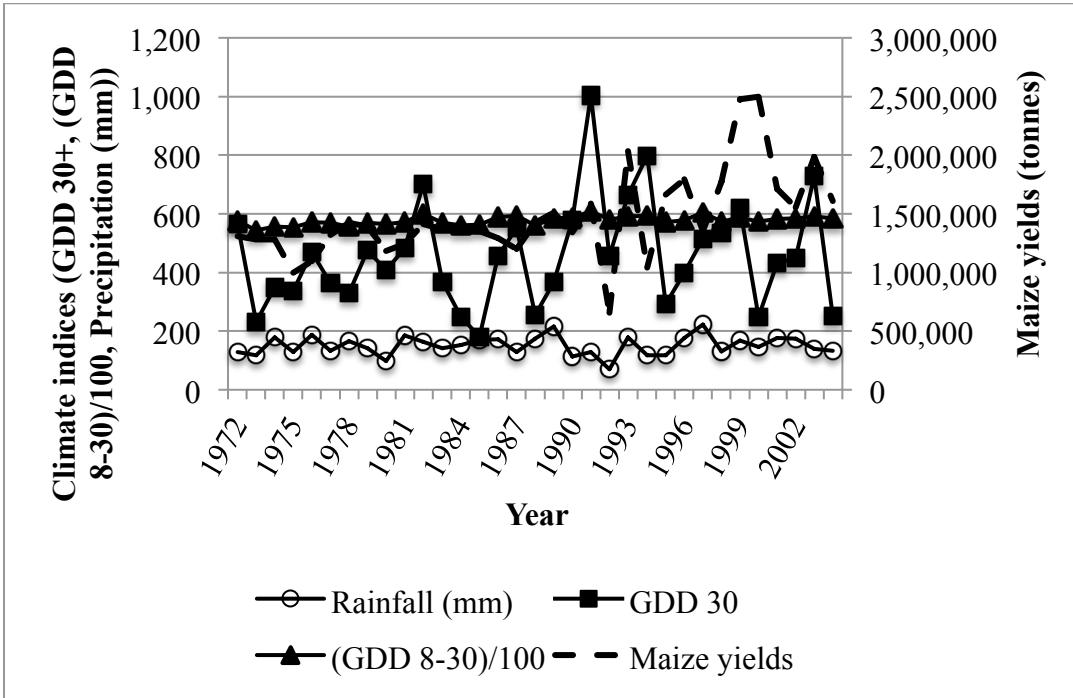


Figure 3. Climate indices and maize yields, 1972-2004

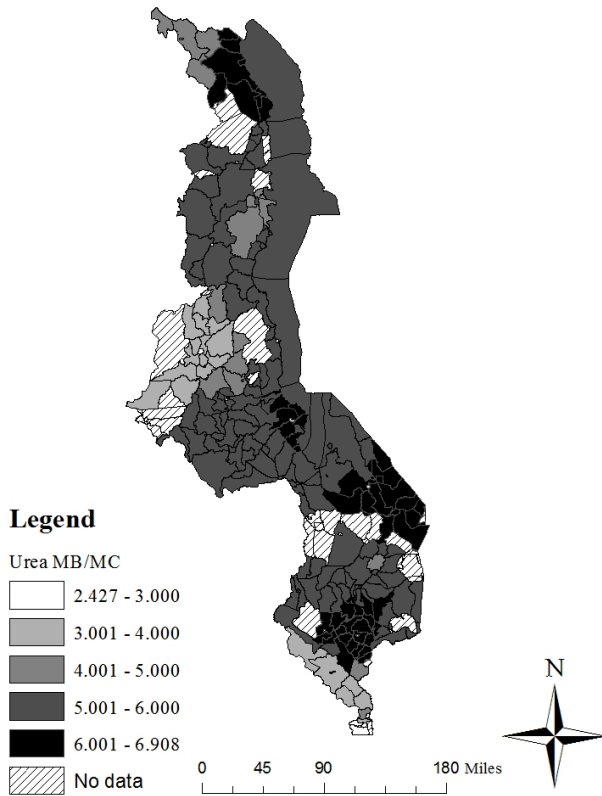
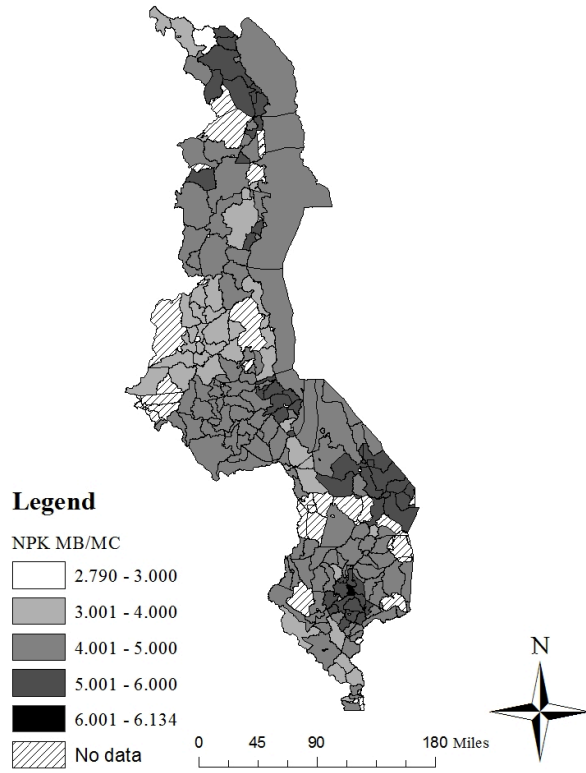


Figure 4. Expected marginal benefit/cost ratio (top: NPK, bottom: urea)

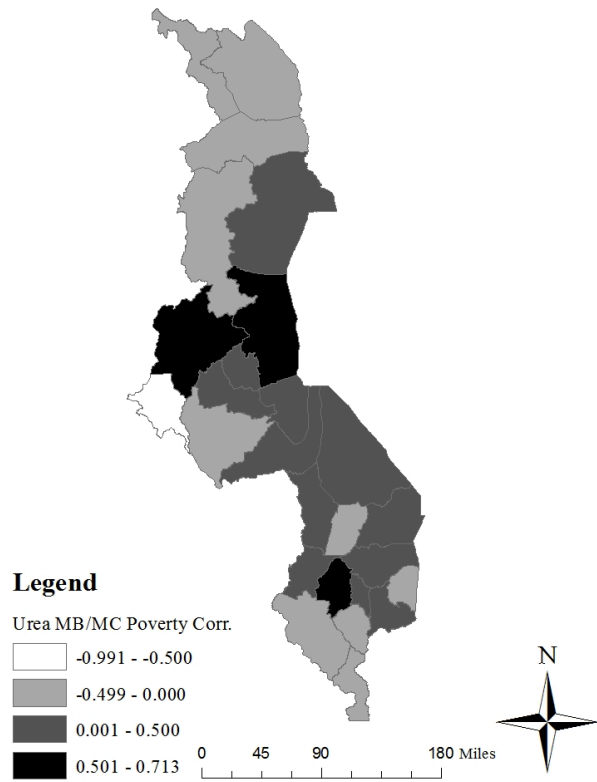
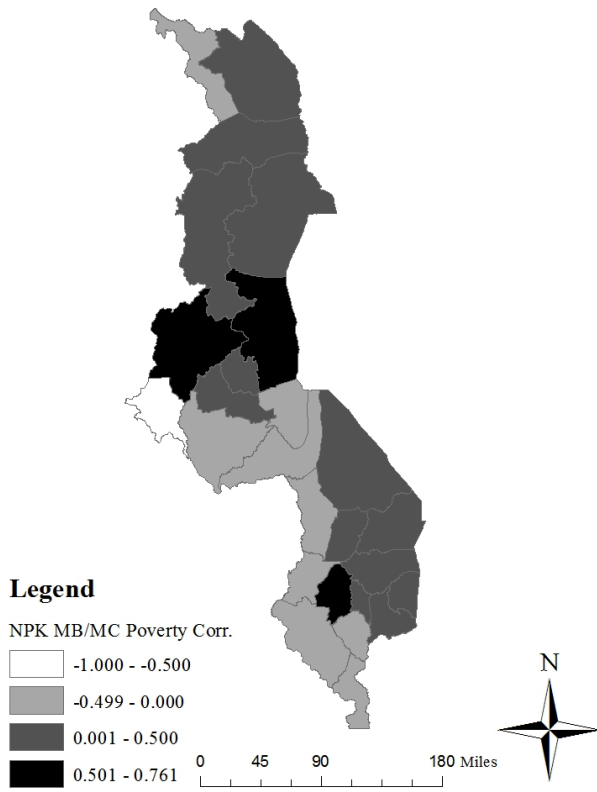


Figure 5. Correlation coefficients between poverty headcount rates & MB/MC

11. Tables

	Nutrients (kg/ha)			Fertilizer		Mean Yields (kg/ha)	
	<i>N</i>	<i>P</i>	<i>S</i>	<i>Basal (50 kg bags/ha)</i>	<i>Top dressing (50 kg bags/ha)</i>	<i>1995-1996 Trial</i>	<i>1997-1998 Trial</i>
1	0	0	0	0	0	1,410***	1,124***
2	35	0	0	0	1.5 Urea	2,183	-
3	35	10	2	1 x 23:21:0+4S	1 Urea	2,358***	1,997***
4	69	21	4	2 x 23:21:0+4S	2 Urea	2,882***	2,523***
5	92	21	4	2 x 23:21:0+4S	3 Urea	3,147***	2,915***
6	96	40	0	1.75 DAP ⁺	3.5 Urea	2,947	-

Table 1. Treatments

⁺ DAP: di-ammonium phosphate

*** Differences in mean yields between years are statistically significant at the 1 % level

	<u>1995-1996</u>	<u>1997-1998</u>
Striga infested	27.8%	21.0%
High striga infestation	6.4%	6.7%
Termite infested	39.8%	38.8%

Table 2. Summary statistics, striga and termite infestation

	<u>Mean</u>	<u>Std. Dev.</u>
Maize variety (D, 1 = MH18)	0.666	0.472
Terrain is flat (D)	0.476	0.500
Terrain is steep (D)	0.026	0.160
Soil is sandy (D)	0.053	0.225
Soil is sandy/clay (D)	0.021	0.144
pH	5.881	0.410
Soil has high cation exchange capacity	0.253	0.435
Soil has high N content	0.021	0.142
Soil has high P content	0.061	0.239
Soil has high K content	0.881	0.324

Table 3. Summary statistics, soil characteristics by trial site (from soil map, n=1,891)

	<u>Mean</u>	<u>Std. Dev</u>	<u>Min</u>	<u>Max</u>
Maize	46.39	6.68	32.67	63.28
DAP	106.19	10.89	90.00	153.00
NPK	102.32	8.45	80.00	120.00
UREA	97.52	5.28	89.47	110.00

Table 4. Summary statistics prices (n = 23 districts)

	In-sample*		Entire joint distribution**	
	<i>Urea</i>	<i>NPK</i>	<i>Urea</i>	<i>NPK</i>
Mean marginal returns	11.54	9.83	11.39	9.81
Std. Dev.	0.98	0.96	1.49	0.97
Median marginal returns	11.80	9.89	11.76	9.88
Min. marginal returns	4.78	6.16	-1.91	5.38
Max. marginal returns	12.85	11.80	13.77	11.86

Table 5. Expected marginal returns of urea and NPK (23:21:0+4S) (kg maize per kg of fertilizer)

* n = 2,860, **n = 44,535

	Urea			NPK		
	<i>Mean</i>	<i>Std. Dev.</i>	<i>Median</i>	<i>Mean</i>	<i>Std. Dev.</i>	<i>Median</i>
Expected Profitability	0.998	0.05	1.00	1.00	0.00	1.00
Expected Marginal Product	11.39	1.49	11.76	9.81	0.97	9.88
Expected B/C	5.39	0.94	5.36	4.43	0.70	4.37

Table 6. Expected probability of profitability, expected marginal product, expected benefit/cost (n = 44,535) (using 2009-2010 prices)

Price increases:		Urea			NPK		
		<i>Mean</i>	<i>Std. Dev.</i>	<i>Median</i>	<i>Mean</i>	<i>Std. Dev.</i>	<i>Median</i>
50%	Profitability	0.996	0.062	1.000	1.000	0.000	1.000
	Expected B/C	3.596	0.626	3.575	2.951	0.466	2.914
100%	Profitability	0.993	0.082	1.000	1.000	0.000	1.000
	Expected B/C	2.697	0.469	2.681	2.213	0.349	2.186
200%	Profitability	0.978	0.147	1.000	0.974	0.159	1.000
	Expected B/C	1.798	0.313	1.787	1.475	0.233	1.457
500%	Profitability	0.243	0.429	0.000	0.011	0.102	0.000
	Expected B/C	0.899	0.156	0.894	0.738	0.116	0.729

Table 7. Expected probability of profitability and expected benefit to cost ratio with 50-500% fertilizer price increases from 2009-2010 prices (n = 44,535)

	1984			1991		
	<i>Mean</i>	<i>Std. Dev.</i>	<i>Median</i>	<i>Mean</i>	<i>Std. Dev.</i>	<i>Median</i>
<u>Urea:</u>						
Profitability	1.000	0.000	1.000	0.942	0.233	1.000
Marginal						
Returns	11.654	0.862	11.827	10.586	2.676	11.479
B/C	5.509	0.815	5.365	4.971	1.367	5.188
<u>NPK:</u>						
Profitability	1.000	0.000	1.000	1.000	0.000	1.000
Marginal						
Returns	9.849	0.955	9.898	9.746	1.031	9.845
B/C	4.419	0.709	4.372	4.373	0.712	4.334
n		1361			1353	

Table 8. Expected probability of profitability, expected marginal returns and expected benefit/cost for a drought year (1991) and a favorable growing year for maize (1985)

	Urea & poverty correlation	NPK & poverty correlation	n
Balaka	-0.001	0.486	68
Blantyre	0.560	0.547	1088
Chikwawa	-0.372	-0.098	3264
Chiradzulu	0.399	0.274	850
Chitipa	-0.280	-0.262	1514
Dedza	0.029	-0.060	2954
Dowa	0.209	0.394	2453
Karonga	-0.108	0.062	2129
Kasungu	0.592	0.500	778
Lilongwe	-0.256	-0.098	5272
Machinga	0.269	0.358	1088
Mangochi	0.174	0.116	2800
Mchinji	-0.991	-1.000	57
Mulanje	0.057	0.156	1020
Mwanza	0.002	-0.362	1190
Mzimba	-0.049	0.029	4765
Nkhata Bay	0.444	0.353	1360
Nkhotakota	0.713	0.761	1360
Nsanje	-0.493	-0.311	1258
Ntcheu	0.163	-0.265	502
Ntchisi	0.268	0.171	1092
Phalombe	-0.359	0.226	1530
Rumphu	-0.108	0.072	805
Salima	0.412	-0.193	1496
Thyolo	-0.299	-0.220	1360
Zomba	0.002	0.241	2482

Table 9. Correlation between poverty headcount rates and the expected benefit/cost of NPK and urea. (The number of sites by district varies (n)).

12. Appendices

A. Construction of the climate indices, following Lobell et al. (2011)

Growing degree days were calculated at each field trial site as:

$$GDD_{base,opt} = \sum_{t=1}^N DD_t \quad DD = \begin{cases} 0 & \text{if } T_t < T_{base} \\ T - T_{base} & \text{if } T_{base} \leq T_t \leq T_{opt} \\ T_{opt} - T_{base} & \text{if } T_t > T_{opt} \end{cases}$$

where t is an hour within the growing season. T_t is the average temperature during the hour and is determined by interpolating a sine curve between the minimum and maximum temperatures in a day. N is the number of hours between planting and harvesting. Therefore, the $GDD_{8,30}$ corresponds to $T_{base} = 8$ degrees Celsius and $T_{opt} = 30$ degrees C and GDD_{30+} corresponds to $T_{base} = 30$ degrees C and $T_{opt} = \text{infinity}$.

Precipitation is controlled for by summing the total precipitation 10 days before and 10 days after silking, controlling for anthesis, the period of time during which a flower is open and functional and most susceptible to drought.

B. Quadratic production function results

Notes: left hand side variable is yields (kg/ha); model I uses a random effects specification, model II uses a Hausman-Taylor specification, model III uses a random effects specification on the subset of sites with data from both seasons; * $p < 0.05$, ** $p < 0.01$

	I. RE	II. H-T	III. RE (balanced panel only)
Year (D, 1 = 95-96)	343.724** (41.664)	365.461** (18.648)	353.374** (44.008)
N (N) Fertilizer	16.926** (0.372)	16.924** (0.497)	16.948** (0.449)
Sulphur (S) Fertilizer	25.886** (6.542)	25.976** (9.343)	29.155** (7.900)
Growing degree days index (8-30C)	0.004 (0.003)	0.010** (0.002)	0.005 (0.004)
Growing degree days index (+30C)	-0.166** (0.047)	-0.179** (0.036)	-0.178** (0.052)
Precipitation Index	0.169 (0.364)	-0.003 (0.161)	0.234 (0.382)
pH	268.060** (61.414)	332.781* (160.150)	285.536** (67.261)
Striga infested (D)	-121.002* (60.516)	-91.155** (32.344)	-116.473 (64.600)

Striga infested (high) (D)	-551.455**	-514.456**	-551.903**
	(94.138)	(52.394)	(101.359)
Termite infested (D)	-255.904**	-307.234**	-277.079**
	(51.216)	(25.199)	(54.566)
Maize variety (D, 1 = MH18)	245.942**	407.212**	233.058**
	(51.448)	(135.526)	(57.706)
Terrain is flat (D)	97.635*	242.324	135.282**
	(43.158)	(305.348)	(48.784)
Terrain is steep (D)	-343.457**	1,095.497	-277.279*
	(113.085)	(752.869)	(137.236)
Soil is sandy	-320.476**	-1,338.079*	-329.528**
	(95.383)	(656.951)	(106.874)
Soil is sandy/clay	-513.868**	-1,939.703	-561.435**
	(155.396)	(1,277.606)	(179.156)
Squared: N fertilizer	-0.101**	-0.101**	-0.094**
	(0.008)	(0.011)	(0.009)
Squared: S fertilizer	-35.752**	-35.773**	-35.725**
	(3.965)	(6.133)	(4.582)
Squared: precipitation index	0.004	0.006**	0.004
	(0.003)	(0.001)	(0.003)
Squared: pH	-8.087	131.080	37.839
	(56.821)	(178.511)	(61.027)
Interaction: GDD 8-30, pH	0.017*	0.018**	0.017*
	(0.008)	(0.004)	(0.008)
Interaction: GDD 30+, pH	-0.025	-0.050	-0.005
	(0.071)	(0.041)	(0.074)
Interaction: Precipitation, S	-0.044	-0.053	-0.011
	(0.076)	(0.067)	(0.099)
Interaction: Precipitation, pH	-0.268	-0.250	-0.174
	(0.824)	(0.356)	(0.860)
Interaction: Precipitation, N	0.008*	0.008*	0.009
	(0.004)	(0.003)	(0.005)
Interaction: N, S Fertilizers	1.226**	1.227**	1.265**
	(0.196)	(0.277)	(0.236)
Interaction: N, pH	0.165	0.119	0.274
	(0.561)	(0.538)	(0.662)
Interaction: pH, S	-2.368	-1.412	-2.113
	(12.157)	(11.500)	(14.678)
Interaction: GDD 30+, S	0.013	0.014	0.014
	(0.010)	(0.010)	(0.013)
Interaction: GDD 30+, N	-0.003**	-0.003**	-0.003**
	(0.000)	(0.000)	(0.001)
Interaction: S, Flat terrain	-21.180*	-20.946**	-30.246**
	(8.564)	(7.615)	(10.469)
Interaction: S, Steep terrain	-52.008**	-53.039*	-67.619**
	(18.596)	(22.103)	(24.576)
Interaction: S, Sandy soil	-30.896	-29.370	-47.791*
	(16.570)	(15.460)	(19.979)
Interaction: S, Sandy/Clay soil	28.022	28.930	13.086
	(23.777)	(24.850)	(30.188)
Interaction: S, High CEC	-13.875	-13.137	-17.260

	(10.255)	(9.284)	(12.849)
Interaction: S, High N	-18.348	-19.364	-9.813
	(22.491)	(23.006)	(28.773)
Interaction: S, High P	-47.209**	-48.736**	-58.807**
	(16.865)	(14.742)	(20.988)
Interaction: S, High K	-1.901	-3.175	-11.477
	(13.385)	(11.859)	(15.831)
Constant	197.997**	162.873**	147.159**
	(31.298)	(50.088)	(35.748)
Within R2	0.52	.	0.49
Between R2	0.10	.	0.12
Overall R2	0.34	.	0.35
<i>N</i>	10,984	10,984	7,996