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Smallholder Cropping and Input Responses to Changes in Expected Prices and Market Access in Central and Northern Mozambique, 2008-2011

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DIRECTORATE OF ECONOMICS

Report Series

The Directorate of Economics of the Mozambican Ministry of Agriculture in collaboration with Michigan State University produces several publication series concerning socio-economics applied research, food security and nutrition. Publications under the Research Summary series (*Flash*) are short (3 - 4 pages), carefully focused reports designated to provide timely research results on issues of great interest. Publications under the Research Report Series and Working Paper Series seek to provide longer, more in depth treatment of agricultural research issues. It is hoped that these reports series and their dissemination will contribute to the design and implementation of programs and policies in Mozambique. Their publication is all seen as an important step in the Directorate's mission to analyze agricultural policies and agricultural research in Mozambique.

Comments and suggestion from interested users on reports under each of these series help to identify additional questions for consideration in later data analyses and report writing, and in the design of further research activities. Users of these reports are encouraged to submit comments and inform us of ongoing information and analysis needs.

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EXECUTIVE SUMMARY

Recent analysis of domestic prices of key staple crops in several major retail markets in Mozambique finds that due to increased demand from both international and domestic sources, since 2008, the country's consumers and producers of staple crops appear to have entered a new higher-price environment for domestic food staples. This situation creates both a challenge and an opportunity for Mozambique, which is commonly referred to as the *food price dilemma*. In short, the dilemma for the Government of Mozambique (GoM) policymakers is that urban consumers (and the majority of rural households who are net buyers of key staple foods like maize) prefer lower food prices (relative to other prices in the economy) as this improves their welfare. On the other hand, the minority of rural smallholder households that are net sellers of key food staples prefer higher prices for their marketed surplus as this improves their welfare.

Higher food staple prices create a serious challenge for Mozambican policy-makers as it reduces the welfare of all urban households and the majority of rural households. That said, higher prices also represent an opportunity in they may help to initiate an increase in smallholder factor demand (i.e., input use in crop production) and output supply (crop production and yields). If an increase in smallholder factor demand is combined with private sector investment in provision of improved crop inputs (such as improved seed varieties, inorganic fertilizer, animal traction rental services, large livestock veterinary services, etc.), this could initiate a virtuous cycle of both farm and private sector investment that could lead to higher smallholder food crop productivity.

Given the serious challenge that Mozambican households face from a higher food price environment, there are three empirical and vital questions related to the extent and nature of smallholder response to this environment for which GoM policymakers require answers.

1) To what extent have the input and cropping decisions of our sample small- and medium-holder households in the center and north responded to increases in domestic food prices between 2007/08 and 2010/11. If so, how they responded – via extensification of crop production (increasing area planted to food crops), intensification (increasing labor and/or other inputs applied per hectare), and/or a combination of both.
2) What role have changes in expected crop prices and market access played in affecting smallholder cropping and input behavior, relative to other household- and village-level factors?
3) Are there conditions or factors that appear to be constraining a more robust smallholder supply response to this higher food price environment, and what implications (if any) there are for public policies that might alleviate those constraints? In this paper, we address each of those three empirical questions using descriptive and econometric analysis of panel rural household data from selected central and northern Mozambique districts, which cover smallholder input and cropping choices and outcomes during the main seasons of 2007/08 and 2010/11.

Our descriptive and econometric analysis of the 2008-11 partial panel household survey data produced ten findings related to the three questions above:

1) *Smallholders are responding to higher food staple prices through a combination of both extensification (planting more area to annual crops) and intensification (applying more inputs per hectare*, be it family labor, hired labor and/or improved

inputs that generate higher yields, such as use of animal traction, inorganic fertilizer, organic fertilizer, and/or improved seed varieties).

a) In addition, it is important to note that total landholding is increasing even faster than area cultivated. Thus, the large increases in area cultivated (on average) do not appear to be coming at the expense of fallows or permanent crops; in fact, the ratio of total area cultivated to annual crops to total landholding remained relatively constant (on average) over the two years of our panel, across all areas of our sample.

2) *In addition to expanding their total area cultivated, households increased the number of crops grown from 6.8 to 8 crops, on average.* However, in Tete we see an exception to the extensification and diversification trend, as we do not find a statistically significant increase in total area cultivated in that province, and the average number of crops actually fell somewhat there in 2010/11. This suggests that farmers in Tete responded to higher prices of food and cash crops by specializing, while farmers elsewhere in the center and north of our sample responded via both extensification of total crop area and diversification of the crops they grew.
3) *There was a large increase from 2008 to 2011 in the percentage of households growing cassava and pigeon pea,* and small but notable increases in the percentages of household growing maize, small/large groundnuts, cowpea and common bean. The percentage of households growing rice and the three main cash crops (sesame, cotton, tobacco) stayed constant over time, while there was a decline in the percentage of households growing sorghum.
4) *Average yields of all crops increased more than the 10% between 2008 and 2011, with the exception of rice and cotton, whose average yields fell by 5% and 25%, respectively*. Given that weather conditions for crop production during the main season were clearly better in 2010/11 relative to 2007/08, we use multivariate regression analysis (econometrics) to differentiate between the roles of different time-constant and time-varying village- and household-level factors – other than improved weather conditions – that may explain variation in yields both across households and over time.
5) Econometric analysis of household crop participation and area planted to each crop show that *the primary drivers of extensification appear to be increases in expected crop prices.* These price effects can be categorized into four groups:
    a) We find four crops for which the *own price* (expected price of the crop) has a positive and significant effect on participation in growing that crop (maize, large groundnut, pigeon pea, and tobacco) and three crops for which own price has a significant and positive effect on area planted (maize, common bean, and sesame).
    b) We find evidence of a negative effect of competing crops in the case of rice (which has a negative effect on maize area), cowpea (small groundnuts), common bean (cowpea), and pigeon pea (small groundnuts, common bean).
    c) There was large increase from 2008 to 2011 in the expected price of the price of the dominant cereal staple crop maize, and this had a significant and positive effect on area planted to (or participation in) cowpea, common bean, and pigeon pea. The reason for this is that maize is grown by most rural Mozambican smallholders, and is most often grown in an intercrop with legumes.
    d) There was a dramatic increase in cassava production from 2008 to 2011 via both extensification and intensification. This was not driven by the changes in the price of cassava, but rather by rising maize and rice prices, which both had strong positive effects on cassava area planted.

6) Econometric analysis also finds *significant effects of better market access (such as proximity to a formal market, to a buying depot for that crop) on crop participation and area planted.* For example, the presence of a maize mill in the village has a positive effect on maize area.
    a) In addition, there is a positive effect of household receipt of agricultural market price information via radio on area planted to sesame and small groundnut participation, perhaps because cooking oil and small groundnuts are among the food commodity prices reportedly weekly by SIMA via radio.
7) *Expected crop prices also help to explain the average increases in yield of most of these crops between 2008 and 2011*, controlling for changes in weather conditions over time.
    a) For example, we see positive own-price effects on yield in the case of maize, pigeon pea, sesame, and tobacco; intercropping price effects in the case of pigeon pea (i.e., an increase in the maize price increased pigeon pea yields); and competing price effects (negative effects on yield) in the case of large groundnut (prices of pigeon pea and sesame), pigeon pea (prices of rice and small groundnuts), and sesame (price of common bean).

Unfortunately, we were unable to assess the true effect of most of our market access variables given that they did not vary over time. That said, while these price and market access effects tell us that smallholders are intensifying the production of specific crops – which implies that they are increasing the levels of one or more inputs per hectare applied to that crop – the partial effects of price and market access on crop yield does not tell us how smallholders are intensifying their production. To try to address that question, we looked at a combination of descriptive analysis of household input use and econometric analysis of the determinants of smallholder crop yields (especially agroecological factors and/or factors of production), as noted in the next three findings.

8) There was a dramatic increase in the percentage of households hiring temporary labor across all provinces, with a sample average increase from 21.5% of households in 2008 to 31% in 2011). *There was also a significant increase in the percentage of households using animal traction (in central provinces only), from 25.9% in 2008 to 43.1% to 2011 in Tete, and from 9.8 to 14.4% in Manica/Sofala combined.*
    a) We find that animal traction use increases yields of cassava by 270%, of common bean by 179%, and of tobacco by 186%.[1]
9) *The percentage of households applying manure to any crop (within the central provinces) increased from 4.6% in 2008 to 13.1% in 2011*, and this percentage increased for every crop with the exception of rice and sorghum.
    a) Application of manure to a specific crop had large positive and significant effects in several cases – increasing yields of maize by 44%, of cassava by 179%, and of large groundnut by 192%. Use of inorganic fertilizer did not change over time, very few smallholders acquire it, and most of it continues to be used on tobacco or sugarcane.
10) The percentage of households using purchased improved food crop seed varieties increased from 11.9% in 2008 to 20.3% in 2011, with percentage increases for each food crop except sorghum (nor for pigeon pea and cassava, for which information on seed type was not observed).

[1] As that variable is not observed at the crop-level, we cannot conclude for certain that significant effects of, say, animal traction on a given crop are causal given that it is possible that the farmer did not prepare all his/her fields using animal traction.

a) Use of purchased improved seed increased yields of small groundnut by 66%. The combination of manure applied to cowpea and purchase of an improved cowpea variety increased cowpea yield by 207%.

In summary, we find that while there has been a robust smallholder response to higher food prices, by both extensification and intensification of crop production, there remain serious constraints to sustained and even larger supply response that will be required if the GoM is to help smallholder farmers, private sector input and output market actors, and the Central Statiscal Office (CSO) to collectively solve the *food price dilemma* – that is, to maintain favorable prices for farmers while reducing retail food prices for both urban consumers and rural net buyers. Solving this dilemma will require achieving a number of goals simultaneously:

1) Maintain favorable output to input price ratios for farmers, which will require both:
    a. A reduction in transportation costs (for both inputs and crop outputs), and
    b. A mix of public and private investments and an policy enabling environment that will help improve smallholder access to improved inputs such as seeds of improved varieties, large livestock, animal traction rental services, inorganic fertilizer, and quality extension services);
2) Reduce retail food prices for both urban consumers and the majority of rural households who are net buyers of staples such as maize, which will require:
    a. Increased smallholder food production and volumes of marketed surplus and
    b. Lower transportation costs

Achieving those two goals will require significant GoM investment and policy attention on several key constraints that are listed below. These policy prescriptions come from a combination of the empirical findings noted above, lessons learned from several long-term studies of success stories from Asia in widespread poverty reduction and improvements in smallholder food staple productivity (EIU 2008; Fan, Gulati, and Thorat 2008), a recent study that simulated the effect of public agricultural expenditure (by type of expenditure) on Mozambique's agricultural growth rate (Mogues, Benin, and Woldeyohanne 2012), and others studies as noted directly below.

a) Increase investment in secondary and tertiary rural roads so as to reduce transportation costs that raise prices for consumers and lower the crop output/input price ratios facing smallholders;
b) Implement research needed to assess the exact nature and extent of the constraints to large livestock keeping in northern provinces, which is preventing small- and medium-holders north of the Zambezi river from accessing not only the income, asset growth, and resilience opportunities that come from raising large livestock, but also improving their crop productivity via animal traction and manure application;
c) Provide the public goods required to alleviate the constraints to large livestock holding that are found in northern provinces (tsetse eradication efforts vaccination campaigns, large livestock extension promotion, etc.);
d) Increase the proportion of agricultural R&D within total ag sector spending (Mogues, Benin, and Woldeyohanne 2012), and focus an increasing share of that budget on crops with the greatest potential for poverty reduction, namely maize and cassava (Walker et al. 2006);
e) Carefully engage in efforts to facilitate dissemination of improved seed varieties in a way that helps to facilitate private sector investment in developing seed supply chains and improve relationships between private sector retailers, village community leaders, and government and/or NGO extension efforts; these efforts must be spatially

coordinated with the key crop production constraints faced by farmers in targeted communities as well as with investments in secondary and tertiary rural road investments.

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We also thank the 1,150 smallholder farm households and community leaders that participated in not just TIA08 household and village surveys but also agreed to be re-interviewed in late 2011 (to respond to questions regarding the 2010/11 agricultural year). Without the time and care which they took in participating in this survey, the analysis in this and several other papers would not have been possible.

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ACRONYMS

AE	adult equivalents
APE	Average Partial Effect
CAADP	Comprehensive Africa Agriculture Development Programme
CAP	*Censo Agro-Pecuaria* (National Agricultural and Livestock Census)
CPI	consumer price index
Cragg DH	Cragg Double Hurdle model
CRE	Correlated Random Effects
CSO	Central Statistical Office
CV	coefficient of variation
DAP	Departamento de Análises de Políticas
DE	Directorate of Economics
EIU	Economist Intelligence Unit
GDP	Gross Domestic Product
GoM	Government of Mozambique
HH	Household.
IAI	*Inquérito Agrícola Integrado* (National Integrated Agricultural Household Survey)
ICRISAT	International Crops Research Institute for the Semi-arid Tropics
IFPRI	Institute for Food Policy Research Institute
IIAM	*Instituto de Investigacao Agraria de Mocambique* (National Agricultural Research Institute)
INE	*Instituto Nacional Estatistica* (National Statistics Institute)
IOF	*Inquérito aos Orçamentos Familiares* (National Household Budget Survey)
kg/ha	kilograms per hectare
km	kilometer
LGP	length of growing period
LR	likelihood ratio
MINAG	Ministry of Agriculture
MSU	Michigan State University
MTN	*Meticais da Nova* (Mozambique currency as of 2006)
NGOs	Non-governmental Organizations
OLS-FE	Ordinary Least Squares, with household fixed effects
PAE	Public Agricultural Expenditure
PAPA	Action Plan for Food Production
PNISA	National Agriculture Investment Plan 2014–2018 (CAADP)
PP11	Partial Panel Survey 2008/2011
R&D	Research and Development
SIMA	*Sistema de Informacao de Precoas Agricolas* (Agricultural Market Price Information System)
TIA	*Trabalho de Inquérito Agrícola* (National Agricultural Household Survey)
TLU	tropical livestock units
USAID	United States Agency for International Development

1. INTRODUCTION

Much of the empirical literature following the 2007-2008 food price crisis has focused on adverse effects of higher prices during that period on consumers in developing countries (Heady and Fan 2008; Ivanic, Martin, and Zaman 2012). By contrast, little attention has been given to empirical assessment of how smallholder farmers are responding to increases in domestic prices of food staples. While there is a large empirical literature on supply response in developing countries, much of this literature has focused on aggregated national-level supply response of growers of specific crops to price changes over time. Given data limitations, the literature that investigates supply response of smallholder farmers in Sub-Saharan Africa using large-sample household survey data is considerably smaller, and to our knowledge there is no such empirical study that has investigated the supply response of smallholder Mozambican farmers.

The extent to which prices have risen in a given country is an important empirical question, given that price transmission from international to domestic markets is not always strong, especially in the context of a country like Mozambique with relatively high transport costs from the coast inland and from the north to the south of the country. However, evidence from the Agricultural Markets Information System) price data in Mozambique shows that, with some variation by crop and market, food staple prices in Mozambique also rose sharply in 2008 and in some cases have remained well above previous levels through 2011 (Cunguara et al. 2012; Mather et al. 2013).

The rise in international staple food prices observed in 2007-2008 was driven by a range of factors, several of which one would expect to continue for the foreseeable future. This includes increased demand for maize as biofuel, and increased demand for soybeans and cereals in general as inputs for meat/dairy production to satisfy growing incomes in Brazil, Russia, India, China, South Africa and other developing countries. There has also been a recent increase in domestic demand for various food crops from recent investments in agro-processing in Mozambique. For example, demand for maize and soybean has increased considerably over the past decade due to from private investment in poultry-feeding operations in the center and north. This has notably spurred rapid growth in soybean production, as data from the national agricultural and rural household income survey, the *Trabalho do Inquérito Agricola* (TIA 2008), show that total production of soybeans (which is used for poultry feeding) increased from 705 tons in 2002 to 5,023 tons by 2012.[2]

Likewise, the opening of a brewery in Nampula that uses primarily cassava flour has increased demand for cassava, while export demand from Asia for pigeon pea has led to rapid increases in smallholder production of this crop in recent years. In addition to the increased demand for food crops for poultry production and agro-industry, rapid growth in urban populations and per capita incomes is likewise increasing domestic demand for staple cereals, legumes and root crops. For example, as a result of post-war recovery and pro-growth development policies, Mozambique has experienced rapid economic growth over the last two decades, with an average annual Gross Domestic Product (GDP) growth rate of 8.3% between 1994 and 2008. There has been relatively fast urbanization, with United Nations

[2] We note that the TIA sampling design was focused on minimizing standard errors for estimates of rural household production of widely grown food staples such as maize and cassava, not emerging crops. Thus, estimates of participation/production of crops not widely grown (such as soybeans) need to be taken with caution as their Standard Errors are clearly higher than those for widely grown crops.

estimates of the percent of urban population tripling from 13% in 1980 to 38% in 2010 (United Nations 2010).

The combination of: a) growing domestic demand for cereals and grain-legumes from agro-processing industries and foreign consumers; b), continued growth in average per capita household urban and rural incomes; and c) rapid urbanization imply that there is now an urgent need for Mozambican smallholders to improve both their aggregate food staple production as well as their productivity (MPD/DNEAP 2010). This presents Mozambique with a serious challenge given that agricultural productivity in general has remained stagnant since 2002 or so, as recent increases in total agricultural production have been met primarily through area expansion (Mather, Cunguara, and Boughton 2008; World Bank 2008; Mogues, Benin, and Woldeyohanne 2012). To add to the urgency of this challenge, increases in food staple production and productivity are required not only to meet growing domestic demand for food staples, but to also make progress in reducing rural poverty rates. For example, although Mozambique has enjoyed robust growth in GDP per capita since 1996 or so, this growth was only broad-based from 1996 to 2002/03, as poverty rates fell between those years yet did not fall (on average) between 2002/03 and 2008/09 (MPD/DEAP 2010).

Thus, there are both opportunities and great challenges inherent in achieving increased smallholder food crop productivity in Mozambique. For example, there is untapped potential and opportunity for broad-based, agricultural-sector-led economic growth in Mozambique given that the country does have areas of medium to high agroecological potential in which population density is very low, and given that most food crop production currently does not include use of improved technologies such as inorganic or organic manure or improved seed varieties. Secondly, TIA rural household survey data show that the average yield for the most important staple crop, maize, is about 800 kg/ha (kilograms per hectare) (Walker et al. 2006), which is only 12-16% of the potential yield of 5-6.5 tons/ha (Howard et al. 2003). Yields of other staple crops are equally low, even by Sub-Saharan African standards. Thus, from a technical perspective, given that modern input use is so low and that Mozambique does have areas of medium to high agroecological potential in which population density is currently very low, there would appear to be a significant opportunity for increasing average smallholder food crop yields – at least in the medium/high potential areas – if their access to improved inputs could be increased.

On the other hand, rural smallholders in Mozambique also face several serious challenges that help to explain why we observe such low yields and input use in rural Mozambique in the first place, including agro-ecological conditions, poor access to input, output and credit markets, and limited access to information regarding improved crop production technologies (inputs and/or management practices) and market conditions/prices/etc. Firstly, essentially all cash and food crop production in rural Mozambique is under rainfed conditions. Second, low household incomes, limited to no access to affordable credit for agricultural inputs, and limited investment in agro-dealer distribution networks mean that households face serious constraints to obtaining improved inputs both due to lack of access to credit and physical distance to input retailers. Third, limited household access in agro-dealers is likely linked to very low rural road densities in the center and north, which also results in poor access to output markets. Fourth, the majority of rural households in the center and north do not receive extension advice (from government or non-governmental organizations (NGOs)) on improved crop production technologies nor do many live in villages where they can learn from their neighbors' experience with such improved technologies. Fifth, there is virtually no large livestock north of the Zambezi river, which contains much of Mozambique's most fertile and cultivable areas in northern provinces such as Niassa, Cabo Delgado, and Nampula. The absence of large livestock in these areas means that smallholders there have both minimal access to animal manure for use as fertilizer and no access to animal traction, which has been found in both Mozambique (Mather 2009) and neighboring countries to have positive effects on crop income, via both extensification and intensification of crop production.

Given that higher domestic food staple prices reduce the welfare of urban consumers as well as the majority of rural households (who are net buyers of key staples like maize – meaning they buy more maize during the year than they produce themselves, net of any sales they may make)[3], the extent to which smallholder farmers in rural Mozambique are able to respond to the general increase in the domestic price of various food staples is an important empirical question for the Government of Mozambique (GoM). That is, given that Mozambique appears to now be in a higher domestic price environment for a few key staple crops, the GoM needs to know the extent to which the smallholder sector (the dominant source of crop production in Mozambique) will be able to respond through increased marketed food staple crop production. For example, smallholders relying entirely on rainfed production and with limited access to animal traction (in the north) and other improved inputs such as inorganic fertilizer and improved varieties tend to be less responsive to increases in food staple prices (Sadoulet and de Janvry 1995). GoM therefore needs to know how smallholder farmers are responding to higher food staple prices in Mozambique (via intensification, extensification, or both) and whether or not farmers face constraints to increasing their production that could be alleviated through public policies and/or investments.

In this paper, we use descriptive and econometric analysis of panel household data from selected districts of central and northern Mozambique to measure if and how smallholders in these areas have responded to the general rise of domestic staple food prices in Mozambique since 2007/08, and how they have responded – whether through intensification, extensification or a combination of both. The survey data consist of responses from 1,186 smallholder farmers who were interviewed with respect to the agricultural seasons of both 2007/08 and 2010/11.

The remainder of the paper is structured as follows. In Section 2, we describe the data sources for our analysis, while we present our conceptual framework in Section 3. This is followed by discussion of empirical models that we present in Section 4, and a discussion of estimation issues in Section 5. We then discuss descriptive results in Section 6, econometric analysis of input demand in Section 7, and econometric analysis of crop area, yield and production in Section 8. We conclude in Section 9 with key findings and policy recommendations.

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[3] As per computations by the authors using weighted TIA08 survey data, among TI08 households, 18% (12%, 4%) of those in the north (center, south) were net sellers of maize in 2007/08, 50% (71%, 78%) were net buyers of maize, and 32% (17%, 18%) did not participate in maize markets as buyers or sellers that year (i.e., autarkic households). While TIA does not record the quantity of maize purchased by the household, we computed the net maize production per AE of each household (production – sales) and categorized households as a net buyer if they noted that they bought maize that year and that their net production per AE was less than that of the average household consumption per AE at the poverty line level of consumption, as per the *Inquérito aos Orçamentos Familiares* (IOF) defined poverty level consumption basket for that IOF consumption zone (MPD/DEAP 2010).

2. DATA SOURCES

2.1. Household Survey Data

In 2008, the Mozambican Ministry of Agriculture (MINAG) in collaboration with the National Institute of Statistics (INE) conducted a national agricultural and rural household income survey (TIA 08). The sampling frame was derived from the National Population Census of 2007, using a stratified, clustered sample design that is representative of small- and medium-scale farm households[4] at the provincial and national levels. The sample was stratified by province (10 provinces, Maputo city excluded) and agro-ecological zones, and included 138 districts. A total of n=5,968 rural households were interviewed in 687 communities (clusters), with recall questions covering the household's demographics, farm and non-farm activities, crop and livestock production, farm equipment owned/used and household assets (including livestock holdings and landholding and land tenure status), access to and use of agricultural inputs (among others) during the 2007/08 agricultural year. In 2011, Michigan State University (MSU) with MINAG revisited TIA08 households in selected districts of the center and north of the country from five provinces: Nampula, Zambézia, Tete, Manica, and Sofala. These districts were largely of medium to higher agro-ecological potential and were selected on the basis of their production of maize, sesame, soya, and sunflower. About 18% of smallholder farmers that were interviewed in 2008 in the selected districts were not re-interviewed in 2011, mainly due to household migration or dissolution. The resulting sample includes n=1,186 households and creates a *partial panel* with 2007/08 TIA households from these select districts.

2.2. Community-level Survey Data

TIA08 and the Partial Panel 2011 (PP11) survey both included a community questionnaire, in addition to the TIA household survey instrument. From these community questionnaires, we use information related to community-level access to input and output markets, agro-processing infrastructure, the month of the main season planting in a given year for maize and for rice[5], and the average village wage paid for different types of crop-related activities.

2.3. Data on Market Prices, Agro-ecological Potential, and Market Access

In addition to data from the TIA partial panel household survey data, we also use monthly retail price data of most of the key food crops in rural Mozambique, collected from urban and rural markets across Mozambique by SIMA (Agricultural Markets Information System). In addition to SIMA price data, we use the TIA07 and CAP10 (*Censo Agro-Pecuaria* or Agricultural Census of 2010) household surveys as a source for district-level farmgate sales prices (of various crops) from the 2006/07 and 2009/10 agricultural main seasons, respectively.

To inflate the monthly SIMA prices used in this paper to real 2010/11 levels, we use the monthly regional consumer price index (CPI) from the center and north as produced by INE.[6]

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[4] Please see Appendix B-1 for details on how MINAG defines small- and medium-scale households.

[5] We use the village-specific month of main season planting of maize (which may vary by year) to create seasonal rainfall variables for maize and all other crops but rice, for which we generate a separate seasonal rainfall variable based on the village-specific month of main season rice planting.

[6] The regional monthly CPI generated by INE is based on expenditure data from the cities of Maputo (south), Beira (center) and Nampula (north) and on-going price monitoring by INE of the food and non-food items within the CPI consumption basket.

To inflate 2007/08 values (and 2006/07 district-median farmgate post-harvest period price) to 2010/11 (2009/10) levels, we use the difference between the annual average regional CPI (from INE) for the 12 month period covered by the 2007/08 TIA survey and the same 12 months in 2010/11 (2006/07 and 2010/11).

Data on agro-ecological zones (10) comes from INIA (2002). We also incorporate information from several geospatial datasets that were matched to TIA08 village spatial coordinates (collected in the TIA08 community survey). For example, we use locally interpolated time-series data on rainfall from the University of East Anglia's CRU-TS 3.1 Climate Database (CRU 2011; Mitchell and Jones 2005). Information on the length of growing period – one of several indicators of agro-ecological potential – comes from the GAEZ 3.0 database (Fischer, van Velthuizen. and Nachtergaele 2000), which is measured in terms of the number of days experiencing temperatures above 5°C when moisture conditions are adequate for plant growth.[7] Elevation data were obtained from NASA's SRTM data (Rodriguez et al. 2005), which is also used to generate an estimate of slope. Chamberlin (2013) used various data sources within his own *travel time* model to estimate travel time to the nearest town of 30,000 residents or more, as described in Chamberlin (2013). However, we note that Chamberlin constructed this travel time variable using a road map from Mozamique that is dated to be approximately from 2002.

[7] LGP is often measured in terms of the number of days experiencing temperatures > 5°C when moisture conditions are adequate for plant growth. Under rain-fed conditions, the start of the growing period is defined by the start of the rainy season. The growing period for most crops continues beyond the rainy season and, to a greater or lesser extent, crops mature on moisture stored in the soil profile (notes from J.Chamberlain).

3. CONCEPTUAL FRAMEWORK

In this section, we outline the conceptual framework from which we derive estimable models by which we measure the effect of changes in output prices and market access on smallholder factor demand (i.e., input use) and output supply (i.e., total and crop-specific area planted and crop production). We begin by using the agricultural household model approach of Singh, Squire, and Strauss (1986) and assume that a representative farm household in rural Mozambique maximizes utility within an environment characterized by imperfect markets for outputs (primarily food staples), inputs (fertilizer) and credit.[8] We assume that because of these market imperfections, household consumption decisions are not separable from decisions concerning household production (i.e., household input use and expected crop output levels). Under these assumptions, the representative farm household maximizes expected utility by allocating its resource endowment (land, labor, capital) across farm and non-farm activities as a function of input and output prices, conditioned by household and village-level factors. The solution to this optimization problem yields a set of output supply and factor demand equations, each of which are a function of expected output prices, variable input prices, and quasi-fixed factors (household-, community-, and district-level characteristics).

One implication of our assumption of non-separability is that these output supply and input demand functions also depend upon characteristics of household consumption decisions, such as household wealth/income or demographic characteristics (de Janvry and Sadoulet 2006). Another implication of the non-separability assumption is that unlike in a standard (separable) producer model of crop output supply, the prices of *all other goods* in the economy are relevant (because the farm household's consumption decisions affect its production decisions), thus the prices we include in an output supply or factor demand model (under the assumption of non-separability) are not simply the nominal prices of crop outputs and inputs. We address this by using a regional CPI to inflate prices (values) from the year 2006/07 (2007/08) to 2009/10 (2010/11) levels.

Given these assumptions, our output supply and factor demand models as derived from the constrained utility maximization model can be expressed as follows, as described by Sadoulet and de Janvry (1995):

$$(1) \qquad Q = f(P_0, P_w, T, C, A, Z^p, Z^c)$$

where Q represents either an output or input level, P_0 is a vector of expected prices of crops (outputs), P_w is a vector of input prices, T represents the fixed transaction costs of accessing an output or input market, such as travel time to the nearest town or distance to the nearest fertilizer retailer, and C is a measure of credit access. A represents household fixed productive assets such as total landholding, and Z^prepresents other household characteristics related to production, while Z^crepresents household socio-demographic characteristics related to consumption decisions.

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[8] We use the term *imperfect market* although we note that in practice, this term is often synonymous with *market failure*. Market failure does not necessarily mean the non-existence of a market, rather this event is simply an extreme case of market failure. More commonly, an imperfect or failed market refers to a situation where a market may exist for some households (who participate as buyers or sellers of an input or output), while other households do not participate, as their gains from participation are less than the costs, once transaction costs are included. Therefore, in this context, market failure is household-specific instead of commodity- or input-specific.

4. EMPIRICAL MODELS

4.1. Estimable Model

From the conceptual model above, we estimate the effect of output prices and market access on output supply and input demand as follows:

$$(2) \qquad Q_{it} = \beta X_{it} + \varepsilon_{it}$$
$$(3) \qquad \varepsilon_{it} = c_i + \mu_{it}$$

Q_{it} refers to the dependent variable of interest for output supply or input demand for household *i* (n=1 of 1,186) in year *t* (the 2007/08 and 2010/11 agricultural years). X_{it} is a vector of controls that are typically included in a model of household output supply or input demand function, such as agro-ecological potential and seasonal rainfall, output and input prices, measures of the fixed costs of access to input and output markets, household productive and financial assets, and household consumption characteristics.

As noted in the introduction, apart from simply investigating whether farmers have responded or not to increases in expected crop prices, we are interested in *how* they have responded – via extensification, intensification, or a combination of both. Extensification refers to an increase in area planted to all crops or to a given crops. We measure *extensification* simply by whether smallholders increase total area cultivated and/or area cultivated to a specific crop, on average. However, in this paper, we not only are interested to know whether or not extensification occurred over time, but if so, to what extent was it driven by changes in expected crop prices (on average), thus we estimate double-hurdle regression models that investigate the effect of expected prices on both the probability of growing a crop (participation) and the area planted to that crop (the extent of participation). This multi-variate approach enables us to measure the effect of expected crop prices on household decisions regarding which crop they cultivate and how much area is planted to each, while controlling for other factors that also influence household area planted (to all crops or to a given crop).

Intensification refers to an increase in input use per hectare, which may take various forms:

- Increased labor per hectare (in fertilizer application, weeding, or harvesting)
- Increased seeding rates (quantity of seed planted per hectare)
- Increased in the percentage of households using improved seed varieties, which implies a technological shift from a lower to a higher yielding variety, or one with higher resistance to biotic/abiotic stress)
- Increase in the percentage of households using inorganic or organic fertilizer in annual crop production, and/or an increase in the quantity of inorganic or organic fertilizer used per hectare
- Use of animal traction (which likely increases the land preparation cost per hectare and implies a technological shift from manual to animal traction land preparation)
- Use of manual or fixed irrigation equipment

Thus, for the intensification indicators above that are observed by the TIA survey instrument, we first assess the extent to which it appears that households have increased their use of such inputs in general and/or their quantity of inputs applied per hectare. However, our key interest in this paper is to assess the extent to which intensification of smallholder crop production is driven by changes in expected crop prices. We formally test this relationship in two ways. First, we estimate ordinary least square-fixed effects (OLS-FE) regressions of the log of yield of each crop in order to measure the effect of expected prices on the yield of a given crop, while controlling for other factors that also influence household crop yield. Second, we also estimate probit or double-hurdle models of input use on annual crops (or input use per hectare) to assess the determinants of their use. This multi-variate approach enables us to measure the partial effects of expected crop prices on the probability of smallholder use of a given input (or the extent of use, in the case of hired labor), while controlling for other factors which also affect household input use.

We note that for regressions of area planted to a given crop and (output supply) and for fertilizer use on food crops (input demand), we use *expected* rainfall given that actual seasonal rainfall is not known when farmers make their cropping and input decisions. By contrast, we use actual seasonal rainfall for regressions of household crop production (output supply). Because the post-harvest prices for food and cash crops paid by private traders to smallholders in Mozambique are not known to farmers at the time that they make their cropping, input and output supply decisions, farmers must make these decisions based on the crop output prices that they *expect* to receive at harvest. Thus, for all models, we use *expected* post-harvest output prices.

The error term ε_{it} in (3) is a function of two components. The first component c_i represents unobserved time-constant household-level factors such as soil quality, farm management skill, and/or risk preferences that may be correlated with observable household-level determinants of household commercial fertilizer demand. The second component μ_{it} represents unobserved time-varying shocks that may affect output supply or input demand, such as adverse climatic, pest or crop disease events, household-specific health shocks, among others.

4.2. Measures of Time-constant Agro-ecological Potential and Time-varying Season-specific Agro-ecological Conditions

To control for spatial variation in agro-ecological potential (on average), we include binary indicators for each of five different agro-ecological zones (for four of the five zones from the 10-zone classification system of INIA (2002) in which the partial panel villages are located[9]). Given that nearly all crop production in Mozambique is rainfed, we include a village-level measure of expected seasonal rainfall[10] during the main growing season (for maize). We also compute the coefficient of variation of expected seasonal rainfall as a measure of rainfall variability (risk).[11] We also include village-level information on elevation (meters above sea level), average slope (degrees), and the length of growing period (days). Finally, we include a binary indicator for the year represented by the second survey wave (2010/11).

[9] The partial panel villages are found in zones 4 through 10; we use zones 4 and 6 as the base category, combine 9 and 10 into one binary indicator (given small sample size of each), and thus we use four binary indicators that represent five agro-ecological zones found in the central and northern districts covered by the partial panel sample.
[10] We measure main season rainfall as the planting month and the three months following that month, as based on the community-level survey indication of when that maize (rice) was planted this year in that village. We then compute expected main season rainfall as a ten-year moving-average of that village-specific main season rainfall from the ten main seasons preceding that year.
[11] This rainfall variables are derived from rainfall estimates based on data from satellites (such as on cloud cover and cloud top temperatures) and rain stations, which are combined to interpolate estimates of decadal (10-day period) rainfall, which can be matched to sample households/villages using global positioning system (GPS) coordinates. Rainfall estimates were matched to 1360 sample households using GPS coordinates, and to the village for the remaining households.

To control for spatial variation in season-specific and time-varying agro-ecological conditions in our yield and production regressions, we include measures such as actual seasonal rainfall (based upon the planting month for maize that year as indicated by a village leader), the coefficient of variation in expected seasonal rainfall (a measure of weather risk), and village-respondent indicators of adverse shocks in a given year such as drought, flooding, or crop disease (and the approximate percentage of households affected). That said, these time-varying measures of agroecological conditions in 2007/08 and 2010/11 main seasons are not ideal for several reasons. First, while village-level seasonal cumulative rainfall is clearly an important factor in crop production for a given season, the distribution of that cumulative rainfall *during* the season is also quite important, as it is possible to receive an average level of cumulative rainfall yet have suffered several periods of drought during the season. Thus, ideally it would be better to also include a measure such as days of drought during the main growing season.

Rainfall can also come to quickly at once, causing flooding. That said, the TIA08 and PP11 community surveys asked the village leader whether the village had suffered from a specific kind of production-related shock that main season (drought, flood, cyclone, or crop disease) and if yes, to indicate the proportion of growers affected (options included less than half, half, more than half, most households). While these variables are better than no village-level shock information, they inherently are susceptible to two forms of bias. First, what is considered a *drought* in a given year by one village leader may not be a drought from the perspective of the leader of a different village, thus this is a somewhat subjective measure of an adverse shock. Second, even though the village leader gives an estimate of how many villagers were affected by the given shock, we have no measure of the extent of the damage – that is, many areas of Mozambique (even in medium to high potential zones) may receive some type of drought in a given season, but for the purposes of measuring the effect of this event on yields, we ideally need a measure of the extent of the drought (i.e., days of drought), not simply whether what a village leader defines as drought occurred or not that year. By contrast, our measures of expected rainfall, actual seasonal rainfall, and the expected CV of expected seasonal rainfall are consistent measures of moisture-related production potential and risk.

4.3. Crop Output Prices

4.3.1. Output Price Expectations

We assume that a farmer's expected crop price is based on information available to the farmer at or before planting, such as prices observed by the farmer in previous years. However, because our two waves of panel survey data are three years apart, farm-gate post-harvest crop price data for the partial panel villages in the years preceding each survey wave are not available. Fortunately, there are two sources of available market price data appropriate for our purposes; the first is monthly retail price data from a number of urban and rural markets across the central and northern provinces, while the second are observations of crop prices in the TIA08 partial panel districts from the year prior to each of the partial panel survey years of 2007/08 and 2010/11. The second source of price data we can use is farmgate sale prices observed in household surveys that cover the agricultural years of 2006/07 (TIA07) and 2009/10 (CAP10). Like TIA08, CAP10 covered all districts in the country. TIA07 had roughly the same sample size as TIA08 while CAP10 was considerably larger, covering about 40,000 farm households.

While SIMA collects weekly price data for most of the main food crops, it does not collect data on the cash crops of interest to us nor does it provide sufficient spatial variation of cassava flour prices. Thus, for crops not covered by SIMA, we only have one year of data prior to our partial panel agricultural years of 2007/08 and 2009/10 with which to derive a price expectation. Therefore, for consistency (and simplicity) we assume that farmers' price expectations are naïve in that their estimate of this year's post-harvest price is the price they observed during the same time period last year.

4.3.2. Food Crop Prices

SIMA collects weekly prices of many of the food crops of interest to us from a number of urban and rural retail markets in the center and north of the country, including prices for: maize (grain), rice (grain), small groundnuts, large groundnuts, common beans, cowpea, and cassava flour. For each of these crops (except cassava), and for each TIA08 district, we use SIMA weekly retail price data to compute an average retail price for the planting period of the 2007/08 main season (i.e., October to December) and the three quarters prior to that. The SIMA market(s) used as the reference price for a given TIA08 district is preferably a SIMA market(s) within that district; otherwise, the one to two SIMA markets closest to that district, keeping in mind typical trade flows from production zones to demand centers within and outside of Mozambique. For more details on how we decided which SIMA markets to assign to a given district (by crops), and how we computed average quarterly prices, please see Appendix B-2. Because SIMA prices of cassava flour are only consistently observed in two markets (Quelimane and Nampula) during the time periods we need, thus we instead use district-median farmgate sale prices from TIA07 and CAP10 to estimate the expected price in 2007/08 and 2010/11 for each partial panel district.

Although we could use provincial or district-median post-harvest prices from TIA07 or CAP10 for each food crop as the expected price of those food crops for the 2007/08 and 2010/11 main seasons, respectively, there is a distinct theoretical advantage for using quarterly SIMA prices instead. For example, from TIA07 and CAP10, we observe farmgate sales prices, which for cereals are likely within three months of harvest, while those of beans are made primarily 3-4 months from harvest.[12] In the case of TIA07, we also observe from a community survey the average village prices received by farmers for sales made in the primary sales months, which we know to be soon after the main season harvest for the vast majority of rural Mozambican smallholders. By contrast, SIMA weekly price data enables us to generate expected prices from the four quarters leading up to the planting period for a given main season.

If we use the TIA07/CAP10 post-harvest prices as the expected prices by which smallholders make their input and cropping decisions for a given main season, we are assuming that these farmers use the price of these crops during the immediate post-harvest period as their decision price (i.e., in economic terms, the opportunity cost of each crop they produce). By contrast, SIMA price data enables us to estimate farmer price responsiveness to prices observed in periods of the year *other* than simply the market prices observed during the period of the year when most sales of grains and beans are sold – the months following the main season post-harvest period (April-June or so). This is potentially a very important

[12] This assumption is based on the only representative household-level data we have on the month of sale of grain crops, information which was collected by TIA05, and which showed that a large percentage of maize sales in Mozambique occur during the second quarter (April-June), while those for beans are in the second and third quarter (July-Sept). Therefore, to the best of our knowledge, cereal crop sales are made soon after the main season harvest (April-June). By contrast, TIA data shows us that cassava is not usually harvested until Aug-Sept-Oct, thus while TIA does not collect information on the month of cassava sale, it clearly would have to occur after the harvest months.

distinction given that even for maize, the main staple crop in many parts of the central and northern Mozambique included in the partial panel sample, over 50% of households are net buyers of maize. Thus, such households most likely consume their own maize production from the post-harvest month until sometime during the lean season when their stored maize is used up, at which point they will have to purchase grain from the market – precisely at the time of year when maize prices are highest (the lean season). Thus, for the majority of rural smallholders in these areas, who are net buyers of maize, the most appropriate price to use as their *decision price*—which best approximates the opportunity cost of a household's own production of maize—is not the price during the post-harvest period, but rather the price of maize during the lean season. The reason for this is because the more maize the household produces (based on the market price of maize they expect during the lean season), the less maize they will have to buy during the lean season when maize prices are at their highest.

This is not to say that prices in other quarters of the year are irrelevant, because for households that are surplus maize producers, the price in the post-harvest period may be the price on which they base their input and cropping decisions. However, because the number of large and even small net sellers of maize in rural Mozambique (even in the center and north) are so much smaller than those of net buyers (Mather, Boughton, and Jayne 2011), the most appropriate price to use as the decision price for smallholder maize production – on average – is likely to be the price in a quarter other than the immediate post-harvest quarter (April-June), thus perhaps quarter 3 (July-September), quarter four (October-December), or perhaps even quarter one (January-March) when cereal prices are at their highest in Mozambique. That said, there are disadvantages as well to our use of SIMA quarterly prices instead of those from TIA07 and CAP10; a discussion of these disadvantages is found in Appendix B-3.

4.3.3. Cash Crop Prices

Because SIMA does not track prices of the cash crops of interest to us due to either their continue or growing importance in the partial panel districts (pigeon pea, tobacco, cotton, sesame), we use the district-median post-harvest farm-gate prices observed by TIA07 and CAP10 as the naïve price expectation for pigeon pea, tobacco and cotton prices in the partial panel years. The case of cotton is somewhat different, as cotton growers are given an indicative or potential cotton price in October (just prior to planting), though the actual price they will receive is only announced during the marketing period. However, the only prices we observe are the actual post-harvest sale prices from last year and this year. We assume that the actual cotton price paid in 2008 and 2011 is closer to the indicative price (on which growers make their production and input decisions) as opposed to last year's actual price paid, thus we use the actual village price of cotton that year (in 2007/08 and 2010/11) as an estimate of the farmer's expected price of cotton that season.

For districts that did not grow non-food cash crops such as tobacco or cotton, we assume a price of 1 for that crop in that district, thus the log of that expected price is 0. We believe that this assumption is reasonable as non-food crops such as cotton or tobacco have little to no value if grown in a district outside of concession areas, as the grower would essentially not be able to sell it.[13]

[13] This assumption is also necessary, as seen from the case of a farmer's decision regarding his/her area planted to maize. Because maize is grown in every district and village in the partial panel sample, it would not make sense to leave the expected price of an important cash crop such as tobacco out of the model, as the price of tobacco may well have an effect on maize area planted in a province such as Tete (where tobacco is a key cash crop). That is, if the expected tobacco price were missing in areas where farmers do not grow tobacco, then we

4.4. Village-level Measures of Market Access

The PP11 community level survey obtained measures of community access to various types of input sellers and output buyers. For example, distance from the village to the nearest formal market (kilometer (km)), distance to nearest fertilizer retailer (km) and distance to nearest seed retailer (km). Unfortunately, these measures are only observed in 2012, thus we either have to proceed without such measures or assume that these measures are largely unchanged since 2008. We assume the later in part because there does not appear to have been a significant increase between 2008 and 2012 in fertilizer and improved seed use in the center and north as observed in TIA08 and the *Inquérito Agrícola Integrado* (IAI) IAI2012, and in part because TIA does not collect information on prices of fertilizer or improved seeds, which leaves us with at best a proxy for input price (distance to the nearest input retailer).

The PP11 community level survey also asked if a crop output buying depot was located in the village (or in a nearby village), which commodities were purchased there, and when was the first year that it appeared (back to 2008). This question was specifically added to the PP11 community survey given rapid appraisal interviews by MSU in central and northern Mozambique in 2011, which indicated that a number of large agro-processing companies had recently made investments in these regions and were beginning to set up buying depots for a range of food crops (in addition to depots for cash crops such as tobacco and cotton that have been in these regions for years). Because the survey asks for recall information on buying depots for earlier seasons, we are able to construct a variable (for example) that equals one for villages that had a maize buying depot in or near their village that season and the season before.[14] That said, there is not much variation over time in these depots (most that we observed in 2011 appear to have started in 2008), thus the retrospective information does not enable us to use a time-average of this variable (as explained below in Section 5.3.).

Because the work of Chamberlin and Jayne (2013) demonstrates that the optimal measure of market access may vary by region and by crop, we also include an alternative measure of market access, which is the travel time (hours) from the village to the nearest town of 30,000 residents or more. This variable was computed using a travel time model developed by Chamberlin (2013), using the following spatial data from Mozambique: the spatial coordinates of each partial panel village, a spatial map from 2002 of all roads (of any type), towns/cities as well as spatial topographical information on the land terrain between the village and the nearest road.

4.5. Household Production, Marketing, and Financial Assets

To control for inter-household variation in assets related to crop production, we include various measures of household ownership (or control) of production assets. For example, we include the household's total landholding[15] as a measure of land access. We include a

would either have to drop farmers from those areas from the maize area regression (if we wanted to include the tobacco price as an explanatory variable) or else drop the tobacco price variable from the regression of household maize area cultivated.

[14] Because the recall information only goes back to 2008, our binary indicator for a buying depot for a given crop equals one in 2007/08 if a depot was in or near the village in 2008, and equals one in 2010/11 if a depot was in or near the village in both 2010 and 2011.

[15] Household total landholding is defined as land for which the household has title or use-rights in that agricultural year; this excludes land which is rented or borrowed in. Thus, total landholding is the sum of household land area that is cultivated to annual or perennial crops (excluding land rented in), in fallow, and gardens.

measure of the household's tropical livestock units[16] (TLU) as a measure of wealth, which also serves as a proxy for either credit access or the ability to self-finance inputs that require cash (such as inorganic fertilizer, improved seeds, hired labor, etc.). Because we do not have reliable village-level data on agricultural wages, and because the majority of labor used in smallholder crop production is family labor, we use the number of prime-age adults (ages 15 to 64) who claim agriculture as a primary or secondary occupation as a proxy for availability of family labor (along with its square). We include squared terms of both total landholding and family adults working in agriculture as we typically expect to see declining marginal returns to both land and labor in crop production.

We include a binary variable which equals one if the household used tractor or animal traction (a suitable animal and equipment) – and zero, otherwise – as use of animal traction may increase area cultivated by reducing labor constraints during land preparation, may increase crop production by increasing cultivated area, and may increase crop productivity (yields) due to more timely planting and improved soil aeration and weed control. Household choices regarding input use are typically considered to be endogenous due to either omitted variable bias or the simultaneity of input decisions and realized outputs. However, we decided to use household use of animal traction instead of the seemingly-more exogenous household ownership of animal traction as the econometric options available to us mean that ironically, use of former variable enables us to more likely control for potential omitted variable bias.[17]

In our models of crop yield, we include three additional binary indicators of household input use on that crop, in the event that the variable was observed for the crop and that there were at least n=25 households which applied the input to that crop. These inputs include: application of inorganic fertilizer on the crop (that =1 if the household did so and zero, otherwise); application of organic fertilizer (manure) on the crop; and household use of improved seed of that crop (this is only available for a few food crops) that was purchased that year. Like use of animal traction, including these inputs into our yield models could introduce endogeneity bias. However, use of OLS-FE controls for any time-constant household and/or plot-related factors related to use of these inputs – such as plot quality, soil quality, farmer management skill, etc. While there is also the potential for endogeneity due to time-varying unobserved factors and/or simultaneity bias, we argue that these sources of bias are likely to be of concern given that our models control for time-varying agronomic factors such as actual rainfall and expected coefficient of variation (CV) of rainfall and because the most likely source of bias for the partial effects of input use is from time-constant factors (such as soil quality and farm management skill) that we are already effectively controlling for via the addition of household fixed effects to our OLS regressions.

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[16] TLU = cattle + 0.6*donkeys + 0.4*pigs + 0.2*(goats + sheep) + 0.02*chickens + 0.06*ducks/geese/turkeys + 0.04*rabbits (FAO 2007).

[17] For example, there is almost no variation over time in household ownership of animal traction, while if we use household use of animal traction, this enables to help control for the potential and likely correlation between omitted (unobserved) factors like farm management ability or soil quality and animal traction use via inclusion of the time-average of household use of animal traction as a regressor, via the Correlated Random Effects method described below in Section 5.3. Thus, within the context of the large number of non-linear models we are estimating for area planted to a crop, crop production, etc, OLS with fixed effects is not an option, thus ironically the best way to control for the possible correlation between animal traction ownership (or use) and unobserved factors like farmer management skill or soil quality is to use the CRE approach, which requires a time-average term as well as a time-varying term that exhibits a reasonable amount of variation from one year to the next (which the household use of animal traction does while household ownership does not).

We include head's years of education as a measure of human capital, while head's age and age squared is included as a proxy for lifecycle wealth effects, though it may also measure human capital in terms of years of farming and marketing experience. In the interest of testing for gender disparities in smallholder output supply and input demand behaviour, we include a binary variable which equals one if the household is headed by a single female (and zero, otherwise).

Household receipt of market price information via radio should theoretically serve to dramatically reduce the costs of acquiring market price information for rural households. Because receipt of this information could enable households to better anticipate when prices for a given crop are heading upward (downward) in a given year, and may therefore, have an effect on that household's output supply or input demand. To reduce the potential for endogeneity issues with this explanatory variable (due to either simultaneity bias or reverse causation), we only define household receipt of market information to =1 in cases where the household also owns a radio (roughly 75% of all households which report receipt of market price information also own a radio, and market price information is broadcast via radio to many rural areas of Mozambique).

4.6. Household Consumption Characteristics

Because of our assumption that household production and consumption decisions are not made separately in rural Mozambique (Section 3), we include three variables that serve as a measure of the consumption needs of different kinds of household members that are assumed to be dependents: children age 0-4, children age 5-14, and adults 65 or older.

5. ESTIMATION ISSUES

5.1. Modeling a Corner Solution Dependent Variable

An econometric concern for modeling a variable such as area grown to a crop such as cowpeas is the fact that not all farm households grow cowpeas, thus the area planted to cowpeas of non-growers is zero. If the distribution of such a dependent variable exhibits a reasonably large number of cases lumped at zero (as in the case of cowpeas and every crop other than perhaps maize), this can create problems for standard OLS regression. We approach the statistical challenge posed by observations of zero area planted to a crop like cowpeas not as a missing data problem (which is typically modeled using a variant of the Heckman two-step approach, as in Goetz (1992)), but rather as a corner solution. The rationale for a corner solution model in this case is that observing that a farmer plants zero area to cowpeas represents a valid economic choice to be explained, not a reflection of missing data.

The standard approach to modeling a corner solution dependent variable is to use either a Tobit or a double-hurdle (DH) model. When the household's decision to plant a crop (or not) and the decision regarding how much area of the crop to plant (hectares) are made simultaneously, the Tobit model (Tobin 1958) is appropriate for analyzing the factors affecting the joint decision. The DH model proposed by Cragg (1971) is a more flexible version of the Tobit in that it allows the household decision regarding whether to plant a crop and how much area of it to plant to be determined by different processes. The Cragg version of the DH model consists of two stages or hurdles: the first hurdle uses a probit estimator to model the household's decision to plant the crop or not. The second hurdle uses a truncated normal estimator to model the household's decision regarding the area planted to the crop. By contrast, the log-normal DH model uses a probit as the first stage but a log-normal as the second stage.[18] We first use a likelihood ratio (LR) test to determine whether our data is better fit by a Tobit or by a Cragg DH. Assuming that a Cragg model fits the data better than a Tobit, we then use a Vuong test (Vuong 1989) to determine whether a truncated normal or a log-normal second stage model better fits the regression for the dependent variable in question.

Estimating either form of the DH requires the additional assumption that there is no correlation between the error terms for each of the two hurdles, conditional on the explanatory variables. Ricker-Gilbert, Jayne, and Chirwa (2011) note studies that have relaxed this assumption in the DH model, and which have found that their results are similar whether this assumption is relaxed or maintained (Jones 1992; Garcia and Labeaga 1996). We proceed by maintaining this assumption as well.

5.2. Obtaining Verage Partial Effects

Because the partial effect of an explanatory variable in a nonlinear equation is specific to each observation (because it depends on the level of all explanatory variables, not just its own coefficient), one typically computes the partial effects for a given explanatory variable at the mean of all the explanatory variables. However, Wooldridge (2002) notes that because the

[18] The log-normal second stage is only run using cases where the area planted to the crop > 0, though the three partial effects that can be computed from either type of DH model are the same, though the formulas used to compute the conditional and unconditional quantity partial effects related to the extent of participation (such as the quantity of area planted) differ between the Cragg and log-normal DH models, due to the difference in their second stage estimator.

partial effect computed at the means of the explanatory variables may not in fact be representative of the actual household population, he recommends computing the average partial effect (APE) instead. To facilitate interpretation of the results from the non-linear models such as Tobit and the DH, we compute APE for each explanatory variable.

5.3. Controlling for Unobserved Time-constant Heterogeneity c_i

If unobservable time-constant characteristics such as soil quality, farm management ability, or risk preferences are correlated with observable determinants of a household's decision regarding area planted to a given crop, input use on that crop, or the quantity of the crop to produce (such as total land area owned, household wealth level, head's education level, etc.), this can lead to biased coefficient estimates (i.e., termed omitted variable bias by Wooldridge (2002)). The household data set used in this paper is longitudinal, which offers the analytical advantage of enabling us to control for time-constant unobservable household characteristics (c_i). The fixed effect (FE) estimator is usually the most practical way to control for these unobserved time-constant household characteristics, since using FE requires no assumption regarding the correlation between observable determinants (vector X_{it}) and unobservable heterogeneity (c_i). However, the FE estimator is problematic for this application as the FE Tobit and Probit estimators have been shown to be inconsistent (Wooldridge 2002), while the FE truncated normal estimator has been shown to be biased when T<5 (Greene 2004).

We estimate each of the probit and DH models in this paper with Correlated Random Effects (CRE) (Mundlak 1978; Chamberlain 1984), which explicitly accounts for unobserved heterogeneity and its correlation with observables, while yielding a fixed-effects-like interpretation. In contrast to traditional random effects, the CRE estimator allows for correlation between unobserved heterogeneity (c_i) and the vector of explanatory variables across all time periods (X_{it}) by assuming that the correlation takes the form of: $c_i = \tau + \alpha\overline{X_i} + a_i$ where $\overline{X_i}$ is the time-average of X_{it}, with t = 1, . . . , T; τ is a constant, and a_i is the error term with a normal distribution, $a_i|X_i \sim Normal(0, \sigma^2 a)$. We estimate a reduced form of the model in which τ is absorbed into the intercept term and $\overline{X_i}$ are added to the set of explanatory variables.

The validity of the assumption that a household's time-constant unobservables are in fact correlated with the time-average of each time-varying household and community-level explanatory factor in the model rests on what those observable, time-varying factors are, as well as the dependent variable and the explanatory factors of most interest. We have confidence that our time-average terms meet this assumption for several reasons. First, household total landholding has been shown to be highly correlated with household wealth and income in southern and eastern Africa (Jayne et al. 2003), and household wealth tends to be correlated with factors such as household-level farmer management skills, soil quality, social capital, etc. Thus, if the time-average of total landholding is positively correlated with these kinds of unobserved time-constant household-level factors, this means that this time-average term is at least partially modeling the unobserved time-constant factors that, otherwise, would be in the error term (and may be correlated with a household's price responsiveness). Likewise, the time-average of household tropical livestock units is a secondary measure of household-level wealth, while the time-average of household use of animal traction is likely correlated with farmer management skill and soil quality.

Another important time-average term is that of the expected output price itself – that is, our main focus in this study is on the responsiveness of household area planted to a crop, production of that crop or input use given a change in the expected output price. Yet some districts may have higher or lower prices on average due to agro-ecological or infrastructure factors that are unobserved. But because we include the time-average of each expected crop output price in our models of output supply and input demand, this means that we are controlling for spatial differences in average price levels over time (which might be correlated with time-constant unobservable factors that could be correlated with the district-level price in any given year). In turn, this means that the APE that we estimate on the time-varying output price variable is actually the household's output supply response to variations in the district's average price level, and that the time-average term helps control for potential correlation between the price observed in any given district in a given year and unobserved time-constant agro-ecological factors, infrastructure levels, etc.

We note that we do not compute time-average terms for any of the market access variables, either because they do not vary over time (some are only observed in 2011) or because their actual variability between 2008 to 2011 is so small that the time variation is not sufficient with which to include both a time-average and time-varying term for such a variable. We therefore must assume that these variables are at least partially uncorrelated with any unobservable household heterogeneity, conditional on the other variables in the model (Wooldridge 2002). For example, although one might expect the distance to fertilizer retailer to be correlated with factors such as agro-ecological potential and market infrastructure, we note that we already have multiple community-level controls for these variables (i.e., expected rainfall, elevation, length of growing period, travel time to nearest town). Therefore, many aspects of agro-ecological potential are already included in our regression and thus would not be unobserved, thereby creating a problem of omitted variable bias due to correlation between these factors and the measure of distance to fertilizer retailer. That said, our model could be improved with the addition of spatial soil information, as unobserved soil quality might be correlated with a variable such as distance to fertilizer retailer (though if soil quality is correlated with the time-average of cash crop prices, such correlation would ease our concern).

5.4. Controlling for Unobserved Shocks μ_{it}

While the CRE approach outlined above controls for time-constant unobserved household heterogeneity (c_i), our estimate of the APE of the expected price of a given crop on the area planted to that crop may still be subject to another source of endogeneity bias. This could occur if unobserved time-varying shocks μ_{it} are correlated with explanatory variables X_{it} of interest in (2). Such unobserved time-varying shocks could include adverse climatic, pest or crop disease events, household-specific health shocks, etc.

However, we do have some observed factors that may help to control for such unobserved time-varying shocks. For example, we include in each model a year dummy that =1 for the second year of the panel wave, and this will pick up the average effect of all unobserved factors (across the whole sample). In each model, we also include binary indicators of the agro-ecological zone in which that village resides, which incorporates various characteristics such as elevation, rainfall, soil type, and also rainfall variability. More importantly, our production and yield models already include both the actual seasonal rainfall plus a community-level measure of the coefficient of variation of expected seasonal rainfall, a measure of expected seasonal rainfall variability. That said, this is not necessarily the same as the probability of a drought shock, which would be preferable (a measure that could possibly be generated if the CRU rainfall data is available in 10-day increments (or less), though such data was not available for this study. That said, we would expect that the CV of expected seasonal rainfall is positively correlated with the probability of drought shock. In addition, while the TIA community surveys collect data on the incidence of adverse shocks like crop disease, pests, and droughts or flooding, these data unfortunately are not retrospective, thus we cannot use it to generate an expectation of the risk of adverse shocks of this nature – which is what the farmer observes/understands at the time that he/she makes cropping and input decisions which we model in this paper. In addition, there are two potential biases or weaknesses in these measures, as noted in Section 4.2. above. That said, we incorporate these variables in our yield regressions when they are significant and/or not unreasonably far from it.

In summary, we have only minimal observable controls that can guard against potential bias of model coefficients due to correlation with unobserved time-varying shocks at the household- or village-level. However, because our primary interest is in household price responsiveness (i.e., the APE on output price variables), we do not feel that this is a major cause for concern, for two reasons. First, because most of our price variables are measured at the district-level, they are less likely to be susceptible to community-level and household-level adverse shocks. Second, the primary concern in estimating a household's price responsiveness is likely to be correlation between the price variable and household time-constant unobservables such as farmer management skill (including marketing experience and knowledge), soil quality etc., – that influence how that specific household responds to a given expected crop output price, because households with a lower levels of management skill or soil quality may well be less responsive to the same expected crop output price as farmers with higher levels of those unobserved time-constant factors. Yet, as we note in Section 5.3., we are confident that our household and community-level time-average variables effectively control for these unobserved time-constant factors.

5.5. Panel Attrition

For our econometric work, we only use TIA08 households (from specific districts in the north and center) that were interviewed in 2008 and re-interviewed 2011. Panel household surveys typically have to contend with at least some sample attrition over time, given that some households move away from a village over time and others dissolve as part of a typical household life-cycle. If households that are not re-interviewed are a non-random sub-sample of the population, then using the re-interviewed households to estimate the means or partial effects of variables during one of the later panel time periods may result in biased estimates.

To test for attrition bias, we follow the regression-based approach described in Wooldridge (2002) and define an attrition indicator variable that is equal to one if the household dropped out of the sample in the next wave of the panel survey, and equal to zero, otherwise. This binary variable is then included as an additional explanatory variable in each regression model for each crop, which is run using all household observations from 2007/08 (in panel villages only). If the coefficient on this binary variable is statistically different from zero, this indicates the presence of attrition bias with respect to that model.

We applied this regression-based attrition test to each output supply and input demand model to explicitly test for evidence of attrition bias and report the findings in Appendix Tables A-1 and A-2. In the case of models where we find evidence of attrition bias, we use the Inverse Probability Weighting method (Wooldridge 2002) to generate sampling weights that are adjusted for panel attrition bias. We then apply these attrition-adjustment weights to each model noted in Appendix Tables A-1 and A-2 in which we found evidence of attrition bias.

5.6. Additional Estimation Issues

For those food crops with sufficient quarterly data from SIMA, we have to decide which quarter to use in a given model, due to the high collinearity of the prices for a given crop across quarters in the same year. To arrive at the *optimal* quarterly price to use in the set of models for each food crop (e.g., area planted to maize, maize production and maize yield), we began with the post-harvest quarter (April-June) yet tried the quarters for July-Sept and the planting period itself (Oct-Dec). As we explain in Appendix A-2, the reason for this is because most households are net buyers of food staple crops, their decision price may well not be that during the period of most household sales (April-June) but rather the period during which they will have to purchase the commodity from a local market, which often is during the lean season (Oct-Dec and Jan-Mar), when prices are considerably higher. We therefore ran models using the price from each of those three quarters (keeping the quarter consistent across all crop prices in a given model) and chose the one that was both consistent with theory (i.e., positive) and made sense from the Mozambican context.

6. DESCRIPTIVE ANALYSIS

6.1. Expected Prices and Access to Output and Input Markets

While we noted above that the average real prices of various commodities from SIMA markets across the country showed rather large increases between 2008 and 2011, before proceeding to assess smallholder input and output behavior over time, we first investigate the real expected prices that the smallholder households in our partial panel 2008-11 sample faced when making crop input and output decisions preceding the 2007/08 and 2010/11 main growing seasons. Although these real prices are adjusted for inflation, we nevertheless see very large increases in the expected prices of several key food staple crops such as maize, rice, and pigeon pea, ranging between 21 and 73%, depending on the crop and the quarter of the year (Table 1). While the expected price of cassava actually fell by 22%, this large decline in price should be taken within the context that although this is a key staple crop in many regions of our sample – and equal with maize in importance in Nampula and Zambezia – very few cassava growers in Mozambique actually sell cassava. That is, as we will see in the large increase in cassava participation, area planted, production and yields below – and in our econometric analysis of these variables in Section 8 – smallholders in our sample appear to base their cassava input and output decisions on the prices of other key staples, such as maize, rice, and some legumes.

Of the key legume crops, the expected price of both small and large groundnut increased between 11 to 22% from 2008 to 2011, depending on the crop and quarter, while that of cowpea (third quarter) increased 14%. The one exception we see is that the expected price of common bean did not increase (at least in the 3rd quarter). The prices of cash crops such as cotton, tobacco and sesame increased dramatically from 2008 to 2010, and the average village farm wage increased by 12.5%.

As we noted in the introduction, there has also been a recent increase in domestic demand for various food crops in the center and north of the country due to three main factors: recent investments in agro-processing in those regions, increased export demand for crops such as pigeon pea, and increasing demand from both rural and urban net buyers of staple grains, legumes and root crops due to both increases in international prices and increasing average household incomes per capita (at least among the upper deciles of the rural and urban household income distribution). The increase in demand for staple grains, legumes, root crops, and oilseeds is seen in the villages within our partial panel sample in the form of an increased percentage of villages that have a maize mill in their village, and an oilseed or cassava plant in or near their village (Table 2).

Table 1. Average Expected Real Prices of Food and Cash Crops and Observed Wages Faced by Sample Smallholders for the Main Cropping Seasons of 2007/08 and 2010/11

Real price (2010/11 MTN/kg)[1] or wage	2007/08	2010/11	% change
Real exp. price of maize, Q2 (Apr-Jun)	4.8	7.3	51.5%
Real exp. price of maize, Q3 (Jul-Sep)	5.9	8.2	40.2%
Real exp. price of maize, Q4 (Oct-Dec)	7.9	9.6	21.3%
Real exp. price of maize, Q1 (Jan-Mar)	5.7	10.0	73.2%
Real exp. price of rice, Q2 (Apr-Jun)	22.4	26.6	18.7%
Real exp. price of rice, Q3 (Jul-Sep)	22.9	28.9	26.0%
Real exp. price of rice, Q4 (Oct-Dec)	23.5	32.0	36.3%
Real exp. price of rice, Q1 (Jan-Mar)	21.3	29.9	40.6%
Real exp. price of L.groundnut, Q3 (Jul-Sep)	30.9	37.7	22.2%
Real exp. price of L.groundnut, Q4 (Oct-Dec)	34.9	38.9	11.6%
Real exp. price of S.groundnut, Q3 (Jul-Sep)	34.2	38.3	12.1%
Real exp. price of S.groundnut, Q4 (Oct-Dec)	39.8	44.7	12.3%
Real exp. price of common bean, Q3 (Jul-Sep)	38.6	38.5	-0.3%
Real exp. price of cowpea, Q3 (Jul-Sep)	18.8	21.4	14.2%
Real exp. price of cassava	10.7	8.4	-21.6%
Real exp. price of pigeon pea	5.6	8.1	43.5%
Real exp. price of cotton	4.7	6.6	40.2%
Real exp. price of tobacco	8.6	18.1	110.4%
Real exp. price of sesame	15.6	26.9	72.7%
Real average village farm wage (MTN/day)	124.0	139.6	12.5%

Table 2. Smallholder Access to Agro-Processing Plants and Buying Depots in or Near Village, 2008 – 2011

Province	Maize mill in village		Maize mill near village		Rice Mill in/near village		Oilseed plant in/near village		Cassava plant in/near village	
	2008	2011	2008	2011	2008	2011	2008	2011	2008	2011
Nampula	60.5	69.8	25.9	16.8	2.8	1.8	8.8	7.7	0.0	3.9
Zambezia	51.7	74.5	34.5	19.3	0.0	2.6	3.5	2.6	6.5	5.4
Tete	73.0	78.3	19.8	21.7	0.0	0.0	0.0	0.0	0.0	0.0
Manica	76.6	95.9	17.6	4.1	0.0	0.0	1.2	6.7	0.0	0.0
Sofala	79.0	92.4	16.2	7.6	13.1	9.1	0.0	0.0	0.0	0.0
Total	65.4	80.5	24.7	15.1	2.8	2.7	2.9	3.2	2.1	2.4

Province	Buying depot (for crop below) in/near village in year noted and in year prior[1]									
	Maize		Rice		Tobacco		Sesame		Soybean	
	2008	2011	2008	2011	2008	2011	2008	2011	2008	2011
Nampula	9.7	9.7	0.0	0.0	3.8	3.8	6.0	6.0	0.0	0.0
Zambezia	6.2	6.2	4.6	4.6	9.7	9.7	2.7	2.7	0.0	0.0
Tete	11.0	14.6	8.8	8.8	7.8	7.8	0.0	3.7	0.0	3.7
Manica	64.8	69.3	27.5	27.5	0.0	0.0	40.4	42.3	24.8	24.8
Sofala	6.2	12.8	6.0	6.0	0.0	0.0	8.5	15.1	0.0	0.0
Total	16.3	18.7	8.1	8.1	5.2	5.2	9.4	11.4	3.6	4.3

Notes: 1) See footnote 20 below.

Another market access indicator that was observed in the 2011 village survey was the presence of a buying depot in or near the village, which crops were purchased, and in which years the depot was present. We then computed the percentage of our sample households that lived in a village in which there was a buying depot for a given crop the year before 2007/08 (and 2010/11) as well as that year.[19] We do not find much of an increase in the presence of crop-specific buying depots in or near the village between 2008 and 2011 when we look at the sample averages of the presence of these depots, yet we do see increases in depot prevalence for some crops in some provinces. For example, we see an increase in maize buying depots in or near the village from 6% in 2008 to 12% in 2011 for Sofala; an increase in depots purchasing sesame in Sofala from 8.5 to 15%, and an increase in depots purchasing soybean from 0 to 3.7% in Tete.

Unfortunately, our measure of distance to specific types of input or output markets was observed in 2010/11, so in our regression analysis below, we have to assume that this reported distance is the same for 2007/08. While there is certainly variation within the sample villages in a given province in our sample, it is clear that the average distance to these output and input markets varies considerably across provinces (Table 3). Another point to note is that while the average distance to a formal market is 16 km (for our sample), the average distance to the nearest seed retailer is 30 km (ranging from 15 to 52 km, depending on the province) while the average distance to the nearest fertilizer retailer is 52 km. This in itself helps to explain why use of improved maize, rice, and legume varieties is considerably lower in rural Mozambique than in neighboring Zambia and Tanzania.

6.2. Agroecological Potential and Conditions over Time

In order to put our results regarding input use, area planted, and output and yield achieved by year and province into context, we also need to consider how agro-ecological potential varies by province, as well as actual weather conditions in the two main seasons we observe in our TIA-PP household data (that cover the main seasons of 2007/08 and 2010/11). We note that main season cumulative rainfall was considerably higher on average in all our sample areas except in Nampula (where it remained constant) (Table 4). That said, the percentage of households living in villages where their village leader noted that 50% or more village farmers had suffered from drought conditions only fell in Nampula and Zambezia.

Table 3. Smallholder Average Distance to Output and Input Markets, 2010/11

	Travel time to town of 30k+	--------- Distance (km) to nearest: -----------					% villages that received:	
			Motorable road					
Province		Formal market	Dry season	Wet season	Fertilizer retailer	Seed retailer	Fertilizer fair	Seed fair
Nampula	14.9	4.9	3.1	0.8	45.8	26.0	12.6	47.4
Zambezia	8.2	26.5	3.3	16.5	55.8	27.1	7.3	47.0
Tete	10.6	19.1	5.3	5.0	55.3	52.6	8.0	22.6
Manica	4.3	0.2	4.9	3.5	64.4	34.3	7.0	57.9
Sofala	5.6	20.7	21.9	14.9	35.1	15.3	11.1	50.9
Total	8.8	16.3	7.0	9.4	51.6	30.4	9.0	45.0

[19] The TIAPP Community survey asked for recall data on the presence of buying depots in or near the village from 2007 to 2012, thus technically we may not have information on presence of a buying depot in both the 2007/08 and 2006/07 main seasons.

Table 4. Constant and Time-Varying Agro-Ecological Conditions Facing Sample Smallholders in 2008 and 2011

	% of sample HHs by agro-ecological zone[1]				Eleva-	LGP[2]
Province	Low	Low-Med	Medium	High	tion (m)	(days)
Nampula	0.0	38.5	41.8	19.7	387	175.0
Zambezia	0.0	0.0	53.9	46.1	503	236.8
Tete	0.0	0.0	11.0	89.0	1,197	165.0
Manica	9.7	0.0	90.3	0.0	559	191.0
Sofala	31.3	49.5	19.2	0.0	129	206.0
Total	6.8	15.6	43.5	34.1	549	200.7

	Cumulative main season rainfall		Expected cumu. main season rainfall		CV of exp. cumul. m.season rainfall	
Province	2008	2011	2008	2011	2008	2011
Nampula	387	389	467	413	6.7	6.7
Zambezia	249	384	396	396	3.4	34.7
Tete	183	294	375	364	3.2	7.0
Manica	202	286	349	326	2.9	5.4
Sofala	183	240	324	323	2.6	4.8
Total	248	330	388	371	3.8	15.2

	% villages in which 50% or more village HHs affected by:					
	Drought[4]		Floods[4]		Crop disease[4]	
Province	2008	2011	2008	2011	2008	2011
Nampula	49.0	27.0	4.6	0.0	52.9	39.5
Zambezia	55.6	46.3	27.8	13.5	68.6	51.8
Tete	24.4	27.6	25.9	8.5	24.6	24.6
Manica	64.8	65.4	33.8	7.4	60.2	9.9
Sofala	80.7	84.6	58.1	28.2	74.3	68.2
Total	55.2	48.8	29.1	11.8	58.7	41.4

Notes: Notes: 1) 4-zone categorization of agro-ecological potential based on the INIA 10-zone agrocological zone classification, aggregated into 4 groups based on potential for maize production; 2) LGP = length of growing period (see Section 2); 4) Based on the opinion of the village leaders who responded to the TIA08 and PP2011 community survey (Section 4.2.).

This suggests that our cumulative rainfall variable may not be capturing drought periods during the season and/or that responses to the community questionnaire regarding the occurrence and extent of adverse village shocks in a given season may be overly subjective. That said, the occurrence of reported problems from flooding was considerably less in all areas, and reported problems from crop diseases fell considerably in three of the five provinces. These combined results regarding rainfall and crop disease suggest that our sample farmers enjoyed better growing conditions in 2010/11 relative to 2007/08.

6.3. Household Demographics

The data show an average increase in household size (number of members) of our sample households from 5.4 members in 2007/08 to 6.5 in 2010/11, an increase of 20% (Table 5). However, when we look at household size adjusted for adult equivalents (AE), we find that average household size in AEs increases from 4.5 to 4.9, an increase of 8.8% (Table 5). This latter result suggests that the increase of 1.1 members on average is likely due to the birth or arrival of a child to the household[20]. Indeed, about 52% of new members were born after the first panel wave, and marriage was the second reason for the increase in household size, accounting for about 12% of new household members. The implication of these demographic changes for our purposes is that while some households gained an additional adult (i.e., potential laborer in farm activities), on average, most households did not gain an additional adult but rather a young child. Nevertheless, an increase of 8.8% in household AE implies that these sample households have at least an 8.8% increase in consumption requirements, on average.

Table 5. Household Demographics by Location and Year

Province/ Demographics	Nampula			Zambezia			Tete		
	2008	2011	Pvalue	2008	2011	Pvalue	2008	2011	Pvalue
Mean head's age (years)	40.9	43.6	0.059	39.0	41.1	0.064	40.8	43.6	0.020
Mean head's education (years)	3.1	2.5	0.137	2.8	3.1	0.089	2.5	2.3	0.768
1=HH head is female (%)	17.3	21.7	0.450	12.5	17.9	0.214	21.5	22.8	0.725
1=HH head is single female (%)	7.7	12.5	0.439	8.6	13.5	0.213	16.6	15.4	0.895
1=HH head is married female (%)	9.6	9.2	0.852	3.8	4.3	0.806	4.9	7.3	0.384
Mean HH size (# of members)	4.7	5.8	0.000	5.2	6.3	0.000	5.1	5.6	0.008
Mean HH size (adult equivalents)	4.0	4.3	0.120	4.4	4.7	0.009	4.3	4.5	0.455
Mean # of HH members age 0-4	0.8	0.9	0.815	1.0	0.9	0.465	0.9	0.6	0.000
Mean # of HH members age 5-14	1.6	1.7	0.420	1.7	2.0	0.009	1.8	2.0	0.183
Mean # of members age 15-64	2.3	2.4	0.223	2.5	2.7	0.024	2.4	2.5	0.172
Mean # of HH members age 65+	0.1	0.1	0.318	0.1	0.1	0.881	0.1	0.2	0.190
Province/ Demographics	Manica			Sofala			Total		
	2008	2011	Pvalue	2008	2011	Pvalue	2008	2011	Pvalue
Mean head's age (years)	40.6	43.4	0.048	44.5	46.7	0.058	40.8	43.3	0.000
Mean head's education (years)	4.1	4.4	0.370	3.1	3.0	0.879	3.0	3.0	0.681
1=HH head is female (%)	20.0	18.1	0.630	19.0	20.2	0.642	17.2	19.9	0.552
1=HH head is single female (%)	18.4	13.8	0.433	15.0	16.1	0.896	12.4	14.2	0.714
1=HH head is married female (%)	1.6	4.4	0.611	4.1	4.1	0.505	4.8	5.7	0.621
Mean HH size (# of members)	5.9	7.8	0.000	6.2	7.3	0.000	5.4	6.5	0.000
Mean HH size (adult equivalents)	4.9	6.2	0.000	5.2	5.4	0.081	4.5	4.9	0.000
Mean # of HH members age 0-4	1.2	1.3	0.561	1.1	0.8	0.010	1.0	0.9	0.004
Mean # of HH members age 5-14	2.1	2.5	0.011	2.1	2.2	0.226	1.8	2.0	0.000
Mean # of members age 15-64	2.6	2.4	0.000	2.9	3.2	0.007	2.5	2.8	0.000
Mean # of HH members age 65+	0.1	0.1	0.159	0.1	0.2	0.251	0.1	0.1	0.021

Notes: H_a: The difference between the two years is not zero. Single female headed households include those female heads who self-identified as single, separated, divorced or widowed. Married female-headed households are those who self-identified as married, in marital union, or polygamous. HH= Household.

[20] Adult equivalents is a measure that adjusts the size of a household to reflect its caloric consumption needs based on the age and gender or each individual in the household (WHO 1985). In this scale, a male adult age 18 to 49 represents 1.0. Thus, in the case of our sample, while the number of household members increased by 1.1 on average, household AE only increased by 0.4 on average because most of these new members are young children, whose AE measure is less than 1.0.

Head's education remains low, with no significant change other than in Zambezia Province. Low levels of education make it difficult for smallholders to engage in profitable or high return non-farm income generating activities (Walker et al. 2004), and increase household reliance upon subsistence farming.

6.4. Household Cropping Decisions

6.4.1. Total Landholding, Area Cultivated, Number of Crops Grown

Between 2007/08 and 2010/11, smallholders[21] in the areas of our sample in the central and northern provinces increased their mean total landholding from 2.41 to 3.01 ha (Table 6), an increase of 25%.[22] However, there was considerable variation across provinces in this change in mean total landholding, ranging from an increase of only 4% in Nampula to a high of 56% in Manica, smallholders in our sample also increased total area cultivated (to annual crops) from 2.0 to 2.37 ha across those two years, an increase of 18.6%. There are two key implications of these observed increases in average total landholding and total area cultivated to annual crops. First, when observing semi-subsistence farm households in Mozambique over time (as in the TIA02-05 panel household survey), it is common to find that they increase their total landholding and total area cultivated to annual and permanent crops, given that their consumption requirements increase as new members are added to the household (such as a new spouse, or the birth of a child or the return of a child who was previously living with another relative), on average. However, we noted above that household AE (which is a measure of household caloric consumption needs) increased by 8.8% on average, thus the increase in cultivated area of 18.6% is clearly far beyond what one would expect if these households were simply expanding their total landholding and area cultivated in response to their increased household consumption needs. Second, the fact that total landholding is increasing even faster than area cultivated means that the large increases (on average) in area cultivated do not appear to be coming at the expense of fallows or permanent crops; in fact, the ratio of total area cultivated to annual crops to total landholding remained relatively constant (on average) over the two years of our panel, across all areas of our sample.

Table 6. Smallholder Land Access and Use by Location and Year

Province	Mean total landholding (ha)			Mean total cultivated area (ha)			Mean total cultivated area per AE (ha/AE)			Mean number of fields cultivated			Mean number of crops grown		
	2008	2011	Pvalue	2008	2011	Pvalue	2008	2011	Pvalue	2008	2011	Pvalue	2008	2011	Pvalue
Nampula	2.80	2.92	0.09	2.15	2.15	0.38	0.598	0.586	0.18	2.69	2.51	0.46	5.4	6.2	0.00
Zambezia	2.24	2.88	0.00	1.77	2.18	0.00	0.495	0.562	0.92	2.71	2.70	0.79	7.0	8.3	0.00
Tete	2.77	3.15	0.27	2.54	2.95	0.26	0.634	0.686	0.60	2.03	1.67	0.00	7.3	6.4	1.00
Manica	1.88	2.94	0.00	1.50	2.04	0.00	0.407	0.418	0.13	1.70	2.01	0.00	7.5	8.1	0.02
Sofala	2.37	3.28	0.00	2.14	2.63	0.16	0.461	0.561	0.67	2.12	2.77	0.00	5.1	11.0	0.00
Total	2.41	3.01	0.00	2.00	2.37	0.01	0.520	0.567	0.17	2.34	2.39	0.02	6.8	8.0	0.00

H_a: The difference between the two years is not zero

[21] From this point on, we use the term smallholders to refer to both small- and medium-holders, as the weighted number of medium-holders in the overall TIA sample (and this limited partial panel sample is quite small).
[22] Total landholding includes area cultivated to annual crops, permanent crops, and fallow. Cultivated area refers to annual crops only.

Increases in total area cultivated are usually met through cultivation of additional (new) fields. The average number of fields (*machambas*) cultivated increased significantly in Manica and Sofala, and decreased significantly in Tete (Table 6). This suggests that while in Manica and Sofala smallholder farmers responded to increase in food prices by opening additional fields, in Tete they responded by consolidating smaller plots of land into larger fields.

In addition, we also find that our sample smallholders not only increased their total area cultivated on average (Table 6), they also increased their number of crops grown from 6.8 in 2007/08 to 8.1 in 2010/11. This increase in the number of crops grown on average is significant in all but Tete, which is also the only province in which we find no significant increase in total landholding or total area cultivated (though a positive increase in the means of both of those variables). Thus, farmers are increasing area cultivated not only among crops they grew previously (in 2007/08) but also by planting crops that they were not planning in 2007/08.

6.4.2. Participation in Maize, Cassava, Sorghum, and Rice Production

Before discussing where we see increases in crop participation and for which crops, we first note that to speak usefully of cropping systems in rural Mozambique, one must look at the regional and/or provincial level because there is significant variation in cropping systems (and crop choice) across different agro-ecological zones within the country. Second, we also wish to highlight (again) that the partial panel sample is a sub-sample of the TIA08 survey districts from the central and northern regions, and was intentionally selected to include as many medium and high-potential districts as possible. For that reason, results in the following tables should not be taken to be fully representative of provinces such as Nampula or Zambezia, as our partial panel sample did not include many of the TIA08 sample districts from those provinces.

With that in mind, we note that, just as in the full TIA08 sample, maize is clearly the dominant staple crop in our sample districts from the central provinces, with the lowest participation rate in maize production being the 92% of growers in Sofala in 2008 and 2011 (Table 7).

Table 7. Smallholder Farmers Growing Selected Crops (%)

Province	Maize		Rice		Sorghum		Cassava		L.Groundnuts		S.Groundnuts	
	2008	2011	2008	2011	2008	2011	2008	2011	2008	2011	2008	2011
Nampula	73.9	80.7	7.9	11.1	35.1	41.2	80.4	86.2	13.0	18.9	31.7	36.1
Zambezia	89.2	96.3	26.7	27.7	37.5	38.5	71.3	82.6	12.0	14.0	15.0	13.2
Tete	99.1	100.0	0.1	0.0	2.8	2.5	10.4	13.0	34.0	36.4	25.8	35.4
Manica	99.6	99.4	2.1	0.5	54.6	34.8	28.5	53.8	4.0	4.1	12.9	17.6
Sofala	93.7	91.5	34.9	29.6	62.7	48.4	26.8	64.9	7.8	13.7	15.3	23.1
Total	90.4	93.7	16.7	16.4	37.8	33.8	48.2	63.7	14.2	17.4	19.7	23.7

Province	Cowpeas		Comm. beans		Pigeonpeas		Sesame		Cotton		Tobacco	
	2008	2011	2008	2011	2008	2011	2008	2011	2008	2011	2008	2011
Nampula	41.8	58.0	1.3	0.8	12.1	20.4	22.4	12.8	9.2	13.7	0.8	0.0
Zambezia	29.6	29.5	11.6	11.7	70.0	89.2	3.5	5.5	5.5	1.9	3.6	4.8
Tete	41.6	32.4	66.5	67.5	0.9	4.2	1.5	0.0	2.7	2.7	18.0	21.5
Manica	32.2	29.2	8.0	19.9	3.7	16.3	15.7	12.7	1.0	0.7	0.8	0.7
Sofala	35.3	57.0	5.6	8.8	7.2	46.3	35.4	43.3	5.0	7.1	0.3	1.3
Total	35.3	39.9	16.6	18.9	26.4	43.5	13.9	13.4	4.9	4.9	4.3	5.2

While maize is also a very important staple crop in Nampula and Zambezia (with 73.9% and 89.2% of our sample growing maize in 2007/08, respectively), cassava is as important (if not more so) in many areas of these two regions, as 80.4% and 71.3% of smallholders in those regions grew cassava in 2007/08, respectively.

Returning to the findings noted above of an average increase in both total household area cultivated and number of crops grown, we, therefore, note that part of the increase in both is explained by an increase in the percentage of maize growers in Nampula (from 73.9% in 2007/08 to 80.7% in 2010/11) and also in Zambezia (from 89.2% to 96.3%). Maize participation in the central zones remained steady over time, though we see an increase in the average area planted to maize (among growers) from 0.90 ha in 2007/08 to 1.03 ha in 2010/11 (Table 8), and average increases in area planted in all provinces but Nampula.

Table 8. Mean Smallholder Area Cultivated by Crop (ha), 2007/08 and 2010/11

------- includes all households (growers and non-growers of each crop ----------

Province	Maize		Rice		Sorghum		Cassava		L.Groundnut		S.Groundnut	
	2008	2011	2008	2011	2008	2011	2008	2011	2008	2011	2008	2011
Nampula	0.58	0.47	0.04	0.12	0.13	0.17	0.58	0.49	0.04	0.05	0.16	0.14
Zambezia	0.69	0.76	0.10	0.15	0.13	0.13	0.32	0.36	0.03	0.03	0.03	0.03
Tete	1.19	1.61	0.00	0.00	0.01	0.01	0.02	0.02	0.16	0.28	0.06	0.13
Manica	0.98	1.19	0.00	0.01	0.19	0.13	0.03	0.10	0.01	0.01	0.02	0.04
Sofala	0.93	0.96	0.19	0.24	0.33	0.25	0.06	0.16	0.01	0.03	0.04	0.07
Total	0.83	0.93	0.07	0.11	0.15	0.14	0.23	0.25	0.05	0.07	0.06	0.07

Province	Cowpea		Comm. bean		Pigeon pea		Sesame		Cotton		Tobacco	
	2008	2011	2008	2011	2008	2011	2008	2011	2008	2011	2008	2011
Nampula	0.14	0.16	0.01	0.00	0.04	0.09	0.13	0.09	0.10	0.13	0.00	0.00
Zambezia	0.06	0.05	0.03	0.04	0.24	0.38	0.01	0.01	0.03	0.02	0.02	0.03
Tete	0.15	0.10	0.25	0.24	0.00	0.01	0.00	0.00	0.02	0.03	0.16	0.16
Manica	0.05	0.08	0.02	0.05	0.01	0.06	0.04	0.07	0.00	0.00	0.00	0.01
Sofala	0.08	0.11	0.02	0.01	0.01	0.09	0.20	0.17	0.05	0.06	0.00	0.00
Total	0.09	0.09	0.06	0.07	0.09	0.16	0.07	0.06	0.04	0.04	0.03	0.04

---------------- includes only growers of each crop each year --------------

Province	Maize		Rice		Sorghum		Cassava		L.Groundnut		S.Groundnut	
	2008	2011	2008	2011	2008	2011	2008	2011	2008	2011	2008	2011
Nampula	0.73	0.63	0.54	0.93	0.14	0.20	0.69	0.57	0.35	0.26	0.46	0.39
Zambezia	0.75	0.81	0.35	0.51	0.12	0.13	0.47	0.46	0.25	0.20	0.24	0.23
Tete	1.23	1.55	0.34	.	0.01	0.01	0.21	0.13	0.46	0.71	0.25	0.37
Manica	0.97	1.22	0.26	0.26	0.19	0.13	0.14	0.21	0.20	0.25	0.18	0.25
Sofala	0.98	1.07	0.53	0.83	0.32	0.26	0.21	0.27	0.18	0.21	0.26	0.29
Total	0.90	1.03	0.43	0.65	0.15	0.14	0.49	0.42	0.33	0.40	0.31	0.33

Province	Cowpea		Comm.bean		Pigeon pea		Sesame		Cotton		Tobacco	
	2008	2011	2008	2011	2008	2011	2008	2011	2008	2011	2008	2011
Nampula	0.32	0.28	0.32	0.21	0.30	0.38	0.63	0.68	0.89	0.91	0.24	.
Zambezia	0.21	0.18	0.41	0.32	0.35	0.44	0.47	0.24	0.73	1.06	0.58	0.71
Tete	0.35	0.31	0.38	0.36	0.30	0.22	0.20	.	0.70	1.20	0.89	0.80
Manica	0.17	0.26	0.20	0.32	0.16	0.41	0.32	0.54	0.25	0.50	0.48	0.73
Sofala	0.21	0.19	0.24	0.16	0.13	0.21	0.56	0.42	1.08	0.89	0.23	0.08
Total	0.25	0.24	0.36	0.33	0.34	0.39	0.55	0.46	0.86	0.94	0.77	0.74

We see much larger increases in participation for cassava, the second-most grown staple crop in these provinces. While the largest increases in participation occurred in Manica and Sofala (where the percentage of smallholders growing cassava doubled), there were even noticeable increases in cassava participation in Nampula and Zambezia (Table 7). It appears that much of the gains in cassava participation in Manica and Sofala came at the expense of sorghum production, which previously was the second-most grown crop in those zones (second only to maize) (Table 7). While there were increases in sorghum in Nampula and Zambezia, they were offset in aggregate by declining participation in Manica and Sofala. Thus, in aggregate, sorghum participation stayed about the same over time, as did average area planted to sorghum (Table 8). While rice is a major staple in the diets of rural households from Sofala and Zambezia, it was only grown by 28% of smallholders (in our sample) in Zambezia in 2010/11 and by 30% of smallholders in Sofala (Table 7), and by even fewer households in Nampula (11%). However, while rice participation did not change much (apart from a slight decline in Sofala) across our two panel years, the average area planted to rice among growers increased by about 30% from 0.43 ha in 2007/08 to 0.65 ha in 2010/11 (Table 8).

6.4.3. Participation in Bean and Groundnut Production

Common beans and groundnuts not only provide rural Mozambican households with a valuable source of vegetable protein, but they also serve as an important source of cash for many smallholders, who are more likely to sell those crops (20 to 40% of growers, depending on the province, crop and year) relative to staples such as maize, rice or cassava. In addition, cultivating these crops helps to fix nitrogen in farmer's fields, thus helping to maintain soil fertility over time, in the near absence of inorganic fertilizer use and minimal use of manure on food crops.

In contrast with the other provinces of the central and north regions, very few Tete farmers produce either cassava or sorghum – they grow maize as their main source of starch, and then grow a number of other crops – as 68% grew common beans in 2010/11, 35% grew large or small groundnuts, and 33% cowpea (Table 7). While the percentage of smallholders growing common beans increased quite a bit in Manica and Sofala over our two panel years, it stayed constant in Tete and the northern provinces. Participation in large groundnut production stayed relatively constant over time except for a doubling in Sofala from 7.8% to 13.7% of smallholders. By contrast, participation in small groundnut production rose considerably in both Sofala, Manica and Tete.

6.4.4. Participation in Emerging Food and Cash Crops: Pigeon Pea and Sesame

Apart from the large increase in cassava participation, the largest increase in participation in our sample areas is seen in pigeon pea, which was grown by 26.4% of our smallholders in 2008 and by 43.8% in 2011. In fact, smallholder area planted to pigeon pea has also increased in all provinces, except in Tete (Table 8) where only 4% of households grew this crop in 2011 (Table 7). The increase in pigeon pea participation seen between 2008 and 2011 has its roots in promotion efforts that began in the mid-2000's, when World Vision in collaboration with the International Crops Research Institute for the Semi-arid Tropics (ICRISAT) promoted the cultivation of pigeon peas in Gurue and its surrounding districts in Zambezia Province to feed the Tur Dahl processing plant located in Gurue. Although the factory was built in 2002, it faced various problems such as the inability to use sun-drying due to rains, unexperienced staff, and delay in processing the raw material. These problems combined to result in low quality dahl. Thus, at present, most pigeon pea production is exported without processing. Most of the seed is likely to come from Malawi, initially through ICRISAT. The combination of the Tur processing plant and proximity to Malawi has made Zambezia Province the top producer of pigeon pea in the country.

With respect to sesame, while 35% (16%) of smallholders in Sofala (Manica grew sesame in 2008, participation increased to 43% in Sofala in 2011 yet fell to 12.7% in Manica that year. using all households)

6.4.5. Participation in Non-Traditional Export Crops: Tobacco and Cotton

While both tobacco and cotton offer quite high returns per hectare for smallholders (relative to food crops), participation in both crops is constrained to areas where tobacco and cotton companies decide to contract growers. Nearly all the tobacco production in our partial panel sample comes from Tete, where 18% of smallholders grew the crop in 2008 and 22% in 2011. While there are some cotton producers in every province covered by our partial panel sample, there are quite few within our sample (probably because cotton is not generally grown in zones with high potential for crops like maize or tobacco), with the highest number found in Nampula, where there was a slight increase in participation from 9.2% in 2008 to 13.7% in 2010.

6.5. Smallholder Input Use

6.5.1. Animal Traction

While use of animal traction can certainly imply extensification (in the event that it enables a household to cultivate more area than if they relied only on manual labor for land preparation), it also has potential intensification aspects as it is known to provide for more timely land preparation and thus planting, for better soil aeration, and for improved weed management. There was a large increase in animal traction use across our panel years, especially in Tete, where 26% of smallholder farmers used animal traction in 2008 while 43% did in 2011 (Table 9). Manica was ranked second in animal traction use in both years, with about 13% in 2008 and 18% in 2011, but the increase was not statistically significant.

While animal traction use increased considerably in Tete and Manica, ownership of a plough or of a complete animal traction package (plough and draught animal) did not increase much over time (Table 9). This is perhaps not too surprising given that the gap between our panel waves is only three years, and the purchase of a plough and/or draught animal is a major expense for rural Mozambican households (and prohibitive for many). We also note that the percentage of sample households that live in a village where animal traction is available (defined as such if any sample household in that village either owned or used animal traction that year) increased in Tete from 85% in 2008 to 98% in 2011, and from 22% to 26% in Sofala. However, this variable also shows that while 97% of households in Tete lived in a village in 2011 where there is potential access to traction rental, only about 43% actually used animal traction.

We see the same pattern in Manica and Sofala, where although 52% and 26% of households in our sample in those provinces lived in a village in which animal traction was potentially available for rent, the percentage of households actually using animal traction is about half (or less) of those percentages. Further research is warranted to assess why more households in these villages who do not own animal traction are not renting it from a neighbor, as the constraints could be due to lack of cash on hand (i.e., credit constraints), lack of knowledge of the potential productivity benefits from animal traction (i.e., insufficient farmer knowledge

Table 9. Smallholder Ownership, Use of, and Access to Animal Traction and Use of Hired Temporary or Permanent Labor, 2007/08 and 2010/11

	HH owns plough (%)		HH owns plough & bovine/burro (%)		HH used animal traction (%)		% HHs in village with animal traction (%)[1]	
Province	2008	2011	2008	2011	2008	2011	2008	2011
Nampula	0.0	0.4	0.0	0.0	0.0	0.4	0.0	2.7
Zambezia	0.6	0.4	0.0	0.4	0.5	0.3	3.3	1.7
Tete	18.2	12.6	13.5	11.3	25.9	43.1	84.8	97.6
Manica	11.9	13.7	11.3	11.6	12.7	17.5	54.0	51.6
Sofala	8.8	10.8	5.2	9.1	6.7	10.5	22.2	26.0
Total	6.3	6.1	4.7	5.2	7.8	12.2	26.0	28.5

	----------- HH hired temporary farm labor for crop production (%) ---							
	For land preparation (A)		For planting or transplanting		For weeding (C)		For harvest (D)	
Province	2008	2011	2008	2011	2008	2011	2008	2011
Nampula	5.8	14.1	4.0	10.8	8.4	7.4	4.9	8.4
Zambezia	17.8	23.5	2.8	5.2	8.8	16.0	3.9	6.7
Tete	9.0	20.7	3.1	7.4	16.2	17.2	5.0	14.3
Manica	18.7	28.7	6.1	16.2	23.8	31.9	4.8	14.3
Sofala	18.2	28.1	8.0	10.0	10.2	30.8	8.7	12.5
Total	14.1	22.6	4.5	9.1	12.2	19.3	5.3	10.3

	----------- HH hired temporary farm labor for crop production (%) ---							
	Extensification: (A or B)		Intensification: (C or D)		For extensification & intensification		For any task	
Province	2008	2011	2008	2011	2008	2011	2008	2011
Nampula	7.0	16.4	9.6	12.4	4.6	10.6	12.0	18.2
Zambezia	19.0	24.6	9.7	18.1	8.3	14.1	20.4	28.7
Tete	9.7	20.8	17.5	21.7	5.4	18.0	21.8	24.5
Manica	19.3	29.0	24.5	32.0	10.8	23.4	33.0	38.1
Sofala	19.3	31.1	14.4	34.4	11.4	19.9	22.3	45.6
Total	15.1	24.1	13.8	22.4	8.0	16.3	20.9	30.2

Notes: 1) This is defined as =1 if a sample household in that village owns or used animal traction; H_a: The difference between the two years is not zero.

that could be addressed by effective extension efforts), and/or poor performance of the local traction rental market (such as limited numbers of animals and plows available for rental relative to demand for hiring this service).

6.5.2. Hiring of Temporary Labor

We next consider household use of hired temporary labor in crop-related activities.[23] From 2008 to 2010, the percentage of households hiring temporary labor increased significantly for

[23] We do not consider permanent labor in this paper as the use of permanent hired labor for crop production was very low in both years (between 0 to 2%, depending on the province), and did not change significantly over time.

each of the main tasks of annual crop production – land preparation (14.1 to 22.6%), planting or transplanting (4.5 to 9.1%), weeding (12.2 to 19.2%) and for harvesting (5.3 to 10.3%) (Table 9). If we look simply at whether a household hired any temporary labor (for any of those four crop-related tasks), this percentage also increased considerably, from 21% in 2008 to 30% in 2011 across the full sample, with increases in each province.

We next break these tasks into those that are more likely associated with extensification (land preparation and planting) and those with intensification (weeding and harvest). The percentage of households that hired temporary labor for extensification-related tasks rose from 14.1% in 2008 to 22.6% in 2011 across the full sample, though we see sizeable increases in this percentage in every province. The percentage of households that hired temporary labor for intensification-related tasks rose from 13.8% in 2008 to 22.4% in 2011, again with increases in every province. The largest increases in hiring temporary labor for both extensification and intensification were found in Zambezia and Sofala, where the percentage of households hiring for extensification doubled (Zambezia) or tripled (Sofala), while that for intensification doubled (in both Zambezia and Sofala). Approximately half the households who hire temporary labor are hiring some for both extensification and intensification tasks (Table 9).

While it is clear that the percentage of households hiring temporary labor for extensification, intensification, or any crop-related task is increasing in all provinces, this does not tell us whether the number of labor hours hired is increasing. TIA does not record hourly data for family or hired labor, as this would only be appropriate if enumerators visited households multiple times during the cropping season. However, TIA does ask households to report the expenditure they made for hiring temporary labor for each of the four tasks. We aggregate these costs and then divide by the household's area planted to both annual and permanent crops (since the hired labor cost data is not crop-specific). We find that the average of the costs of temporary hired labor per hectare (computed among all households) for tasks related to extensification rose by 46% across our full sample, and rose in each province except in Sofala (Table 10). Because we noted above that the average real village wage (*Meticais da Nova*/day (MTN)) rose about 12.5% (over the full sample) from 2008 to 2011, this implies that the increase in average cost per hectare of hired labor for extensification tasks suggests that more labor-days per hectare have been hired in 2011 than in 2008. Similarly, we find that the average cost per hectare of hired temporary labor for intensification tasks increased by 52% across our full sample, and increased in each province except for one – Nampula. Finally, we find that the cost per hectare of hired temporary labor for any task rose by 52% overall, and in each province.

We next investigated to see if specific crops were associated with hired temporary labor. For example, transplanting of rice is highly labor-intensive, as is tobacco production in general. However, we found (unexpectedly) that there were no rice or tobacco producers hiring temporary labor (at least in our sample). We then looked at households that use animal traction, given that these households might be expected to cultivate more area and thus need additional labor at peak labor demand times during the season. Yet, we found that no households that used animal traction hired temporary labor. This suggests two things: first, that hiring temporary labor for land preparation is a substitute to using animal traction for land preparation (which is to be expected), and second that households that use animal traction have sufficient family labor with which to do weeding and harvesting tasks.

Table 10. Average Smallholder Cost of Hired Temporary Labor Per Hectare, by Type of Labor Task and Overall, 2007/08 and 2010/11

	Mean HH cost of temporary hired labor for crop production per hectare (real MTN/ha), computed among all households[1]								
	For land prep or planting (extens.)			For weeding/harvest (intensification)			For any task		
Province	2008	2011	% ch	2008	2011	% ch	2008	2011	% ch
Nampula	49	85	73%	63	40	-36%	112	130	16%
Zambezia	145	188	29%	66	98	48%	212	288	36%
Tete	68	161	137%	113	192	70%	181	354	96%
Manica	246	494	100%	241	489	103%	443	965	118%
Sofala	220	190	-13%	171	220	28%	392	413	5%
Total	140	204	46%	116	177	52%	250	381	52%

Notes: 1) cost per hectare capped at 15,000 MTN/ha; denominator includes area planted to both annual and permanent crops.

6.5.3. Application of Manure on Annual Crops

Although Zambezia and Nampula have medium and small livestock, there is virtually no application of animal manure on crops in those zones in either year (Table 11). There are likely two reasons for this. First, there is virtually no large livestock in those provinces (as tsetse fly is known to be prevalent north of the Zambezi river, thus infecting large livestock there with trypanosomosis), their average TLU[24] were less than half those in Tete, Manica and Sofala), and smaller livestock obviously produce less manure than larger livestock. Second, the livestock in Zambezia and Nampula are primarily goats and chickens, the latter of which is not usually penned at night,[25] as cattle are in the central provinces (for fear of being stolen). The reason that having cattle penned results in more manure application on fields is because these pens are often quite close to the owners' house (for security), which means that the cattle manure is very close to their house. Thus, anecdotal evidence suggests that these households routinely shovel the manure out of the pens and apply it to their fields both because they know the manure will improve crop yields and because they need to move the manure away from their house anyway.

Although the average TLU in Zambezia increased by 43% from 2007/08 to 2010/11, Tete, Manica and Sofala all had increases of 40% or more and by 2010/11 have more than three times the TLU relative to households in the northern provinces (Table 11). Thus, it is not surprising that manure application is much higher in the central provinces. For example, our sample smallholders from Tete, which have the highest TLU levels in the country (and in this sample), had the highest percentage of growers applying manure to any crop – and this percentage doubled from 11% in 2007/08 to 22% in 2010/11. Although manure application was almost non-existent in Manica and Sofala in 2007/08, levels there increased in 2010/11 to 12.7% and 6% of households, respectively.

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[24] TLU is defined in Section 4.5.

[25] The reason for this may be that the median number of chickens owned is seven, which may be too small a number for which a pen would be justified in terms of economic returns relative to the cost of the materials needed. Second, even if seven chickens were penned, they would not produce much manure relative to, say, one cow.

Another very interesting development is that while a number of Tete growers applied manure to a various food crops in 2007/08, hardly any manure was applied to crops in Sofala that year, and in Manica, manure was only applied that year to common beans (5% of those

Table 11. Average Household Tropical Livestock Units and Percentage of Smallholders Applying Manure to Any Crop, and among Those Growing Specific Crops, 2007/08 and 2010/11

	Tropical Livestock Units (mean)		----- % HHs that apply manure to[1] ------					
			Any crop		Maize		Cassava	
Province	2008	2011	2008	2011	2008	2011	2008	2011
Nampula	0.74	0.80	0.8	0.0	0.0	0.0	0.0	0.0
Zambezia	0.66	0.94	0.0	0.6	0.0	0.3	0.0	0.1
Tete	2.41	3.50	11.2	22.8	7.9	18.0	0.9	19.1
Manica	2.00	2.94	2.4	12.7	1.6	12.6	1.2	6.7
Sofala	2.14	2.91	0.9	6.2	0.0	4.9	0.0	2.3
Total (Central)[2]	2.17	3.10	4.6	13.1	3.1	11.3	0.6	5.3
	----------- % HHs that apply manure to[1] ------------							
	Large gr.nut		S. groundnut		Cowpea		Common bean	
Province	2008	2011	2008	2011	2008	2011	2008	2011
Nampula	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Zambezia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tete	2.2	7.0	15.4	17.6	5.6	13.2	7.0	16.4
Manica	0.0	15.9	0.0	13.9	3.1	18.1	5.8	10.3
Sofala	0.0	1.2	0.1	4.0	0.0	6.7	0.0	6.7
Total (Central)[2]	1.5	5.6	7.1	11.7	6.3	14.0	2.8	10.5
	Pigeon pea		Cotton		Tobacco		Sesame	
Province	2008	2011	2008	2011	2008	2011	2008	2011
Nampula	0.0	0.0	0.0	0.0	na	na	0.0	0.0
Zambezia	0.0	0.3	0.0	0.0	0.0	6.3	0.0	0.0
Tete	0.0	13.8	0.0	12.0	2.4	8.5	1.8	0.0
Manica	0.0	6.8	0.0	2.9	0.0	0.0	0.0	10.8
Sofala	0.0	3.2	0.0	2.4	0.0	0.0	0.0	6.2
Total (Central)[2]	0.0	4.5	0.0	5.2	2.3	7.5	0.1	6.7

Notes: 1) computed only among households that grew the crop; 2) computed only among sample households from Tete, Manica, and Sofala; No sample households used manure on rice in either year.

growers), Cassava (3%), and almost none on maize or cassava (1-2%). However, in 2010/11, manure application increased dramatically on many food crops in Manica, several food crops in Sofala, and on sesame in both Manica/Sofala.

6.5.4. Application of Inorganic Fertilizer on Annual Crops

Inorganic fertilizer in Mozambique is almost exclusively tied to tobacco production, which notably is confined primarily to Tete and Manica (Table 12). Second, with the exception of common bean, only in Tete is inorganic fertilizer applied to other food crops such as maize, groundnuts and cowpeas.

Table 12. Percentage of Smallholders Using Inorganic Fertilizer on Any Crop, and among Those Growing Specific Crops, 2007/08 and 2010/11

	-------- % of smallholders applying inorganic fertilizer to: ---------									
	Any crop		Maize		Cassava		L. Groundnut		S. Groundnut	
Province	2008	2011	2008	2011	2008	2011	2008	2011	2008	2011
Nampula	8.9	4.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Zambezia	1.2	2.4	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tete	32.2	33.5	18.2	23.5	8.3	7.3	9.1	0.0	11.8	8.4
Manica	5.6	5.1	0.1	3.0	0.0	0.0	0.0	0.0	0.0	0.0
Sofala	1.0	0.3	0.7	0.3	2.5	0.0	0.0	0.0	0.0	0.9
Total	8.7	8.2	3.9	5.0	0.6	0.3	3.8	0.0	2.7	2.4

	Cowpea		Common bean		Pigeon pea		Cotton		Tobacco	
Province	2008	2011	2008	2011	2008	2011	2008	2011	2008	2011
Nampula	0.0	0.0	39.5	0.0	0.0	0.0	0.0	0.0	na	na
Zambezia	0.0	0.0	0.0	0.0	0.0	0.0	14.6	17.6	0.0	35.6
Tete	15.1	9.2	11.6	10.5	47.5	0.0	0.0	0.0	87.3	83.9
Manica	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	73.5	21.3
Sofala	0.0	0.0	11.1	0.0	0.0	0.4	0.0	2.9	0.0	0.0
Total	3.2	1.3	8.8	6.2	0.3	0.1	5.2	2.9	62.2	66.3

Notes: Percentages of households that apply manure to a specific crop above are computed using only growers of that crop in each year.

6.5.5. Use of Improved Food Crop Seed Varieties that Were Purchased That Year

Along with the substantial increase in manure application on food crops, we also find an increase from 2007/08 to 2010/11 in use of improved seed variety (of a food crop) that was purchased that year, from 11.9 to 20% (Table 13). These large increases occurred in every province except for Nampula, and cover a range of food crops. For example, the percentage of smallholders using purchased improved maize seed doubled in Tete, Manica and Sofala (to 19, 35 and 19%, respectively). We also see particularly positive changes in Tete, where the percentage of growers using purchase improved seed increased for every food crop over time, though some of the largest increases are seen in Manica, where the percentage using improved/purchase seed for small groundnut (common bean, cowpea) increased from 16.7% (4.4, 3.1%) in 2007/08 to 31% (40, 19%) in 2010/11, respectively (Table 13).

Table 13. Percentage of Smallholders Using Purchased Improved Seed Variety on Any Food Crop, and among Those Growing Specific Crops, 2007/08 and 2010/11

	All HHs		Maize		Rice		Sorghum	
Province	2008	2011	2008	2011	2008	2011	2008	2011
Nampula	3.0	6.7	3.8	4.1	0.0	6.3	0.0	0.0
Zambezia	10.7	18.8	11.3	18.5	0.1	4.3	1.4	2.4
Tete	14.4	21.9	9.9	19.4	0.0	0.0	0.0	1.0
Manica	21.2	40.2	18.2	35.0	0.0	0.0	6.4	0.8
Sofala	13.1	19.3	10.5	18.5	1.7	3.4	4.2	6.4
Total	11.9	20.3	10.9	18.9	0.7	4.3	3.0	2.6
	Large gr.nut		Small gr.nut		Common bean		Cowpea	
Province	2008	2011	2008	2011	2008	2011	2008	2011
Nampula	0.0	0.0	0.0	1.4	0.0	0.0	0.7	1.4
Zambezia	0.0	4.1	6.0	0.3	4.5	12.6	0.0	8.4
Tete	3.7	11.2	4.6	9.2	5.4	10.2	2.7	4.3
Manica	0.0	3.6	16.7	31.0	4.4	39.9	3.1	19.3
Sofala	1.9	3.6	9.0	8.5	14.3	7.5	6.3	6.4
Total	1.7	5.8	5.3	7.7	5.5	14.6	2.2	6.6

Notes: Percentages of households that purchased improved seed of a specific crop are computed using only growers of that crop in each year.

6.5.6. Access to Agricultural Services

Access to agricultural services by smallholder farmers can create the favourable environment for agricultural extensification and/or intensification to occur, depending on the service. We look at changes in the access to extension and price information, and participation into farmers' association. The results show an increase in the proportion of household that received extension visits. The coverage of extension services is lower in the northern provinces of Nampula and Zambezia (Table 14), and higher in Tete and Manica Provinces. The proportion of farmers that received extension services was actually three times greater in Manica in 2011 than in 2008. Participation in farmers' associations increased significantly in Tete and Sofala, although other provinces also experienced an increase.

Table 14. Smallholder Access to Agricultural Services by Location and Year (%)

	Received extension services (%)			Belongs to a farmers' association (%)			Received price information (%)		
Province	2008	2011	Pvalue	2008	2011	Pvalue	2008	2011	Pvalue
Nampula	6.3	12.6	0.129	5.9	4.5	0.521	50.2	49.2	0.272
Zambezia	8.6	10.3	0.461	7.5	10.5	0.881	21.7	58.1	0.000
Tete	18.4	24.9	0.023	6.1	9.6	0.021	39.3	46.2	0.183
Manica	8.2	25.2	0.000	9.0	12.6	0.507	51.9	60.5	0.008
Sofala	9.4	19.9	0.000	5.5	11.0	0.017	31.3	69.3	0.000
Total	10.0	17.2	0.000	6.8	9.6	0.020	36.1	56.6	0.000

H_a: The difference between the two years is not zero.

6.6. Smallholder Crop Production and Yields

To conclude our descriptive analysis of smallholder response to a higher food price environment, we present several tables that show the outcome of smallholder input use and cropping decisions (noted above), on average for the sample as a whole. For example, we show average household crop production by province and year (and for the whole partial panel sample), computed first among all households, and then among only growers in each year (Table 15). We then show average household crop yields by province and year, computed only for growers in each year (Table 16). Finally, we summarize smallholder sample average participation and area planted decisions, and then how sample average production and yield changed over time (Table 16b).

As we noted above, there was a significant increase in total landholding, total area cultivated, and number of crops grown, on average. Some of this increase is to be expected, as the average household size (in adult equivalents) increased by 8.8% from 2008 to 2011, thus the average sample household had 8.8% higher food consumption requirements in 2011 relative to 2008. Given that fact, we have also computed average household production of each crop, computed using all households (Appendix Table 1), as this will help us discern whether percentage increases found in average household production from 2008 to 2011 have exceeded household growth in consumption needs over that same time period.

We also noted above that there was a large increase in the percentage of households growing cassava and pigeon pea, and small but notable increases in the percentages of household growing maize, small/large groundnuts, cowpea and common bean. The percentage of households growing rice and the three main cash crops (sesame, cotton, and tobacco) stayed constant over time, while there was a decline in the percentage of households growing sorghum. However, participation by itself does not tell us whether households pursued extensification of a given crop on average, but this information can be inferred by the household average area planted to each crop, computed using all households. Our sample smallholders pursued extensification of all crops – as measured by an increase in average area planted beyond the 8.8% average increase in household consumption needs – except in the cases of sorghum, cowpea, and sesame (Table 16b).

We next compare the change in average area planted with that of household production per AE (both computed using all households), we see that in the case of crops such as maize, cassava, small and large groundnuts, common bean and pigeon pea, households have pursued extensification (higher average area planted to the crop) and achieved higher yields and production per AE, yet growth in yield and production per AE is larger than the growth in average area planted to those crops (Table 16b). In the case of rice, households have pursued extensification and also achieved higher yields and production per AE, yet the percentage increase in area planted is double that of the yield and production gain (Table 16b). For sorghum and cowpea, we see no evidence of extensification but growth in yields and production per AE.

Given that we noted above that weather conditions for crop production during the main season were clearly better in 2010/11 relative to 2007/08, we cannot make any claims based on the average increase in crop yields alone as to the determinants of each increase in average crop yield. That is, while we can conclude that average yield growth greater than 8.8% exceeded household consumption demand growth over the same time period, without multivariate regression analysis, we cannot determine the extent to which this yield growth was due to better weather conditions, an increase in household crop inputs per hectare (i.e., intensification of crop production – perhaps by higher expected crop prices), and/or a combination of the two. However, the evidence above on input use over time suggests that at least some households did intensify production of some crops, given that we see average increases in use of hired temporary labor and the cost of temporary labor per hectare. In addition, in some provinces, we see significant increases in the average use of improved inputs such as animal traction, manure application on crops, and use of purchased improved seed varieties.

Table 15. Mean Quantity Produced Per Household by Crop, Year, and Province (kg)

------- includes all households (growers and non-growers of each crop ----------

Province	Maize		Rice		Sorghum		Cassava		L.groundnut		S.groundnuts	
	2008	2011	2008	2011	2008	2011	2008	2011	2008	2011	2008	2011
Nampula	275	486	5	19	33	63	1,054	1,702	7	11	20	27
Zambezia	488	668	24	31	44	75	2,048	2,064	6	18	4	7
Tete	856	1,160	0	0	3	2	120	417	32	33	19	22
Manica	809	1,827	1	2	79	88	697	962	1	2	5	19
Sofala	449	791	72	124	130	134	392	1,265	6	6	10	15
Total	539	890	21	35	56	73	1,041	1,407	10	15	11	17

Province	Cowpea		Comm. bean		Pigeon pea		Sesame		Cotton		Tobacco	
	2008	2011	2008	2011	2008	2011	2008	2011	2008	2011	2008	2011
Nampula	29	44	1	0	5	44	47	14	24	65	0	0
Zambezia	13	18	12	20	81	193	3	3	36	6	15	27
Tete	24	34	84	80	4	8	10	0	25	14	140	2,311
Manica	7	9	9	18	1	39	23	32	6	4	2	11
Sofala	7	19	1	2	2	37	66	72	32	29	0	20
Total	16	25	21	24	28	83	26	21	27	22	27	382

---------------- includes only growers of each crop each year ---------------

Province	Maize		Rice		Sorghum		Cassava		L.groundnut		S.groundnuts	
	2008	2011	2008	2011	2008	2011	2008	2011	2008	2011	2008	2011
Nampula	353	673	76	149	102	169	1,311	1,976	56	53	62	75
Zambezia	538	743	87	115	118	193	2,873	2,498	62	128	33	59
Tete	900	1,156	121	.	117	79	1,149	3,205	93	92	73	65
Manica	860	1,917	99	250	145	253	2,448	1,788	31	50	42	105
Sofala	574	1,002	291	452	209	287	1,464	1,950	91	46	60	65
Total	623	1,037	151	222	148	219	2,157	2,209	74	86	54	71

Province	Cowpea		Comm. bean		Pigeon pea		Sesame		Cotton		Tobacco	
	2008	2011	2008	2011	2008	2011	2008	2011	2008	2011	2008	2011
Nampula	61	79	140	161	40	192	202	112	247	484	51	.
Zambezia	50	65	137	170	144	246	103	62	644	304	431	559
Tete	60	117	134	123	415	216	706	.	845	531	781	11,119
Manica	36	36	155	112	40	253	148	255	636	607	257	1,516
Sofala	24	40	52	32	31	94	213	179	634	468	28	1,502
Total	49	67	132	123	131	213	200	162	508	464	634	7,724

Notes: Household mean production by crop computed only among growers of that crop each year; the top 1% of the distribution of each variable are dropped for the computation of the means in this table.

Table 16. Mean Smallholder Yields Per Crop, Year, and Province (kg/ha)

Province	Maize		Rice		Sorghum		Cassava		L.Groundnut		S.Groundnut	
	2008	2011	2008	2011	2008	2011	2008	2011	2008	2011	2008	2011
Nampula	726	1,138	180	220	412	677	2,857	6,433	215	290	225	336
Zambezia	850	1,189	461	489	481	1,066	8,557	9,407	305	554	229	445
Tete	1,105	1,214	358	.	458	976	6,543	18,982	336	440	443	344
Manica	946	1,709	182	619	539	1,065	7,952	8,956	202	235	311	547
Sofala	797	1,131	682	576	693	939	9,757	10,194	556	365	361	407
Total	879	1,258	498	472	544	942	6,694	9,046	319	421	293	387

Province	Cowpea		Common		Pigeon pea		Sesame		Cotton		Tobacco	
	2008	2011	2008	2011	2008	2011	2008	2011	2008	2011	2008	2011
Nampula	300	281	489	307	357	392	265	607	421	537	103	.
Zambezia	398	574	439	729	372	293	474	718	1,119	358	868	1,359
Tete	229	455	506	561	2,601	.	1,647	1,036	2,014	538	1,111	4,301
Manica	245	247	735	459	473	712	266	662	.	1,574	633	2,864
Sofala	302	322	262	279	630	738	370	608	851	1,001	121	5,245
Total	313	379	493	556	531	611	456	689	862	643	995	3,619

Notes: Household mean crop yields computed only among growers of that crop each year; we capped observed yields at realistic maximum values for each crop for the computations in this table.

Table 16b. Summary of Average Changes in Crop Participation, Area Planted, Yield, Production, and Production Per Adult Equivalents, 2008 and 2011

Crop	% of HHs that grew crop 2008	% of HHs that grew crop 2011	% change in HH mean from 2007/08 to 2010/11, computed using: All HHs — HH area planted	Growers only — HH yield	All HHs — HH quantity produced	All HHs — HH qty produced per AE	Growers only — HH area planted	Growers only — HH quantity produced
Maize	90.4	93.7	12.1	43.1	65.0	46.2	14.6	66.5
Rice	16.7	16.4	54.2	(5.2)	64.0	24.8	49.5	46.7
Sorghum	37.8	33.8	(10.0)	73.3	31.8	17.4	(6.3)	47.9
Cassava	48.2	63.7	10.4	35.1	35.2	31.2	(14.6)	2.4
L. groundnuts	14.2	17.4	54.2	32.0	51.6	107.4	21.0	14.6
S. Groundnuts	19.7	23.7	18.5	32.3	51.9	27.6	4.0	35.6
Cowpea	35.3	39.9	(0.9)	21.3	53.6	46.4	(4.9)	61.8
Common bean	16.6	18.9	6.1	12.7	14.7	21.9	(8.5)	(7.0)
Pigeon pea	26.4	43.5	87.6	15.1	197.3	148.9	14.8	17.0
Sesame	13.9	13.4	(14.8)	51.0	(21.0)	(27.0)	(14.9)	1118.6
Cotton	4.9	4.9	11.7	(25.4)	(18.3)		9.9	(19.1)
Tobacco	4.3	5.2	11.6	263.7	1296.9		(4.1)	(8.6)

Notes: Household mean crop yields computed only among growers of that crop each year; we capped observed yields at realistic maximum values for each crop for the computations in this table.

6.7. Smallholder Total Household Income, Tropical Livestock Units, and Crop Income

Given that crop income in rural Mozambique typically accounts for an average of 60 to 90% of total household income per AE (depending on the income quintile), we would expect that changes in mean and median total net household income per AE would likely be associated with changes in household crop income per AE. Subsequently, because we find that average household area cultivated per AE increased considerably between our panel years (2007/08 and 2010/11), while average household crop production per AE and yields of nearly all crops also increased dramatically between those years, we would expect that the combination of higher production levels per AE plus higher prices (even after controlling for inflation) would result in higher average and median household income and crop income. Contrary to this expectation, the results from our panel household survey data find that the mean of total household net crop income per AE only increased by 1.7%, while the median actually *fell* by 0.8%. We also find that mean and median total net crop income *per hectare* fell by 6% and 11% respectively.

When we look at total net household income per AE over the two panel, we find the household average increased in some areas, decreased in others, and overall only increased 4.1% from 2008 to 2011 (Table 16c). We also find that median household total net income per AE actually fell 5.9%. While that minimal change in average total household income per AE (and a fall in medium income per AE) suggests that household welfare did not appear to improve even considering the large increases in mean and median crop income per AE (and yields), it is important to recognize that household income is only one indicator of total household welfare. For example, we find that that mean (median) household TLU per AE increased 32% (21%) from 2008 to 2011, which clearly suggests increased household welfare over that time period, and that increases in yields and crop income per AE have been at least partially used by households to invest in assets (in the form of livestock).

Table 16c. Mean and Median Total Household Net Income Per AE, Tropical Livestock Units Per AE, Household Net Crop Income Per AE, Household Net Crop Income Per Hectare, 2008 and 2011

	Total net household income per AE						Household Tropical Livestock Units per AE					
Province	HH mean		% change	HH median		% change	HH mean		% change	HH median		% change
	2008	2011		2008	2011		2008	2011		2008	2011	
Nampula	3,335	4,268	28.0%	1,946	1,782	-8.5%	0.195	0.213	9.5%	0.065	0.080	21.9%
Zambezia	4,762	3,989	-16.2%	3,144	2,621	-16.7%	0.169	0.221	30.3%	0.076	0.078	2.8%
Tete	5,299	5,636	6.4%	2,820	2,613	-7.3%	0.525	0.720	37.2%	0.147	0.175	19.4%
Manica	5,811	6,253	7.6%	3,403	3,686	8.3%	0.440	0.572	30.1%	0.122	0.137	11.9%
Sofala	6,726	7,674	14.1%	4,131	5,867	42.0%	0.443	0.615	38.8%	0.155	0.202	30.5%
Total	5,079	5,286	4.1%	3,069	2,888	-5.9%	0.323	0.425	31.8%	0.095	0.115	21.1%

	Total household net crop income per AE						Total household net crop income per hectare					
Province	HH mean		% change	HH median		% change	HH mean		% change	HH median		% change
	2008	2011		2008	2011		2008	2011		2008	2011	
Nampula	2,297	2,600	13.2%	1,287	1,277	-0.7%	4,560	4,358	-4.4%	3,108	2,779	-10.6%
Zambezia	3,735	2,710	-27.5%	2,282	1,794	-21.4%	8,545	5,630	-34.1%	5,544	3,955	-28.7%
Tete	3,730	3,572	-4.2%	2,132	1,835	-13.9%	7,156	7,621	6.5%	4,637	3,830	-17.4%
Manica	3,166	3,404	7.5%	1,754	2,134	21.7%	9,387	9,273	-1.2%	6,297	6,647	5.6%
Sofala	2,530	4,428	75.0%	1,379	2,917	111.6%	6,631	9,393	41.7%	4,045	6,289	55.5%
Total	3,180	3,235	1.7%	1,874	1,859	-0.8%	7,355	6,908	-6.1%	4,702	4,187	-11.0%

Notes: All income values above are in real MTN 2010/11.

There is at least one likely explanation for the apparent contradiction between the large average and median increase in TLU per AE yet an increase (decrease) in mean (median) total household income per AE, along with a small increase (decrease) in mean (median) total crop income per AE. This is simply that the standard procedure used by MSU/DAP

(DAP-*Departamento de Análises de Políticas)* to value household production of food crops tends to under-value the true opportunity cost (value) of retained food crops. For example, as noted by Mather, Cunguara, and Boughton (2008), the standard MSU/DAP method of using the district median farmgate sales price observed that year in the TIA data to value retained food crops assumes that the price used to value, say, the maize that a household harvests yet retains for home consumption is the farmgate sales price observed in the survey data. However, this price represents the value of maize at the farmgate in the 3 months following the harvest month – when most maize sales are made[26] – which is when farmgate maize prices are typically the lowest during the year. Yet, given that only 20 to 30% of households even sell maize, and that a majority are net buyers of maize (i.e., most of their maize production is retained for household consumption throughout the year), this does not seem to be appropriate, as the true opportunity cost of a typical household's maize retained food crop production is not the value for which they could sell it in right after harvest (when prices are at their lowest), but rather the average annual rural retail price at which the household would have to purchase whatever volume of that food commodity the household requires for home consumption between harvests. We suspect that if we were to apply the procedure described by Mather, Cunguara, and Boughton (2008) (which values retained food crop production at the average annual retail price in that district, the volume of food crops sold at their actual sale price) that this would dramatically increase crop income per AE for households in this sample – considering that average annual rural retail prices of food crops in our sample areas increased considerably between 2008 and 2011.

[26] Among the 20 to 30% of households that sell maize in a given year, the vast majority these sales are made within 1-3 months of harvest, according to TIA05, the only TIA for which the month of sale is recorded.

7. ECONOMETRIC ANALYSIS OF SMALLHOLDER INPUT DEMAND

7.1. Introduction

In this chapter, we use multivariate regression (econometric) analysis of smallholder factor demand (i.e., input use) to measure the extent to which the increases in total area cultivated and other factors of demand can be attributed to increases in expected real prices of the main food and cash crops in these provinces, while controlling for other factors that theory suggests would affect smallholder demand for these factors.

7.2. Total Area Cultivated

Our econometric analysis of total area cultivated (to annual crops) shows that a large number of factors appear to have played a role in the 18.5% increase in total area cultivated (Table 6) between our two panel years. First, given that there is little to no land rental in these areas of Mozambique, it is not surprising to find that households with larger total landholding have higher levels of total area cultivated. For example, a 1 ha increase in total landholding results in a 0.82 ha increase in total area cultivated to annual crops (Table 17). As noted above, between 2007/08 and 2010/11, smallholders in the areas of our sample in the central and northern provinces increased their mean total area cultivated (ha) by 18.5% while they increased their mean total landholding by 25%. Thus, these increases in area cultivated are not coming at the expense of fallows or permanent crops, as the ratio of total area cultivated to annual crops to total landholding remains relatively constant (on average) across all areas of our sample.

That said, the regression of total area cultivated should tell us some of the factors behind the expansion in both total landholding and total area cultivated. First, we note that smallholders in villages whose community leader indicated in the community survey that land is available for cultivation in that village (that year) have 4% higher area cultivated, on average (Table 17). Second, we find several positive and significant effects of expected food crop prices on total area cultivated, depending on the price quarter we use. For example, if we use the expected post-harvest season price of maize from April-June, we find that a 10% increase in the expected price of maize in this quarter leads to a 3.9% increase in total area cultivated (Table 17, first two columns). We also find that a 10% increase in the expected cowpea price in the third quarter (July-Sept) has a nearly significant effect (p=0.18) that increases total area cultivated by 3.4%. If we instead use the price quarters preferred in the regressions below, we find that the expected price of maize in Oct-Dec does not have a significant effect on area cultivated, by that a 1% increase in the expected price of small groundnuts leads to a 0.1% increase in area cultivated. The effect of cowpea prices is positive though not significant (p=0.18).

Third, we find a significant positive effect of some measures of market access on total area cultivated, as the presence of a maize mill in the village increases it by 14% and a maize mill in a nearby village increases it by 8%. However, we also find that a 10% increase in the distance to the nearest formal market *increases* total land area cultivated by 0.2%. Because households closer to a formal market would likely receive higher prices for their crops than more remote households, we might have expected the effect of distance to market on total landholding to be negative.

On the other hand, if more remote households face lower output prices (and higher input prices and/or virtually no access to improved inputs such as inorganic fertilizer, manure or improved seed), this may suggest that such households respond to higher relative output prices via extensification (increasing their area cultivated) rather than via intensification.

Table 17. OLS Regression of Total Household Area Cultivated, 2007/08-10/11

	OLS			
	Dept var = ln(Total HH area cultivated (ha))			
Explanatory variables	PE	p-value	PE	p-value
Year dummy (1=2011)	-0.193	0.045	-0.115	0.095
ln(real exp price of maize (Apr-Jun)) (Mt/Kg)	0.390	0.086		
ln(real exp price of maize (Oct-Dec)) (Mt/Kg)			0.027	0.838
ln(real exp price of rice (Jul-Sep)) (Mt/Kg)	-0.276	0.384		
ln(real exp price of rice (Jan-Mar)) (Mt/Kg)			0.144	0.308
ln(real exp price of small g.nuts (Jul-Sep)) (Mt/Kg)	0.102	0.416		
ln(real exp price, common beans (Jul-Sep)) (Mt/Kg)	-0.479	0.022	-0.303	0.233
ln(real exp price of cowpea (Jul-Sep)) (Mt/Kg)	0.340	0.175	0.242	0.346
ln(real exp price of cassava) (Mt/kg)	0.018	0.459	-0.012	0.727
ln(real exp price of pigeon pea) (Mt/kg)	0.038	0.604	-0.011	0.880
ln(real exp price of cotton) (Mt/kg)	0.015	0.549	0.011	0.678
ln(real exp price of tobacco) (Mt/kg)	0.019	0.261	0.022	0.187
ln(real exp price of sesame) (Mt/kg)	-0.032	0.550	-0.036	0.504
ln(distance to nearest fertilizer retailer, km)	-0.000	0.988	0.005	0.611
ln(willage ag wage, MTN/day)	0.026	0.214	0.028	0.194
% village households using animal traction	-0.142	0.130	-0.125	0.179
1=village has land available for cultivation	0.040	0.164	0.042	0.138
ln(Travel time to nearest town of 30k+ people (hours))	0.005	0.806	0.000	0.983
ln(Distance to nearest formal market, km)	0.021	0.032	0.015	0.127
1=Village/nearby vil. had maize depot this/last yr	-0.000	0.996	0.018	0.620
1=Village/nearby vil. had rice depot this/last yr	-0.011	0.730	-0.003	0.936
1=Village/nearby vil. had tobaco depot this/last yr	-0.024	0.646	-0.045	0.396
1=Village/nearby vil. had sesame depot this/last yr	-0.003	0.955	0.003	0.939
1=Village has maize mill	0.139	0.008	0.146	0.005
1=Nearby village has maize mill	0.080	0.091	0.094	0.045
1=Village/nearby vil. has other agro-processing equip	-0.074	0.103	-0.080	0.076
ln(Total landholding (Ha))	0.820	0.000	0.820	0.000
# of HH members age 15-64	-0.007	0.615	-0.010	0.473
1=HH owns plough	-0.037	0.548	-0.044	0.480
Tropical livestock units (medium/small only)	0.002	0.746	0.003	0.696
1=HH received price info through a radio	0.031	0.232	0.032	0.207
Head's education (years)	0.007	0.399	0.007	0.395
Head's age (years)	0.001	0.838	0.001	0.870
1=HH headed by a single female	-0.141	0.015	-0.151	0.008
Number of observations	2,325		2,325	
R-squared	0.8106		0.8109	

Notes: Model also includes the following explanatory variables not shown here: dummy variables for agroecological zones 5, 7, 8, 10; length of growing period (days), elevation (mm), slope (degrees), # of children age 0-4, # of children age 5-14, # of adults age 65+, and household time-average terms for each of the time-varying regressors.

We do not find either a significant positive effect of household adults age 15-64 on area cultivated or the number of adults age 65 or over. This is surprising as these variables should measure both available family labor (approximately) as well as consumption demands. We also have another unexpected result in that households that own a plough do not have significantly higher area cultivated. One potential explanation for this result could be due to the fact that there is a three-year gap between our observed survey years, it is possible that the total landholding variable is in fact picking up a positive effect of animal traction on total household area cultivated that resulted in higher total landholding sometime after 2007/08 but before the next year we observe (2010/11). That is, it is quite possible that households who did not own a plough in 2007/08 yet are observed using it in 2010/11 may have begun using animal traction in, say, 2008/09 or 2009/10, and in the process, increased their total landholding. If that scenario is relatively common among the users in 2010/11 who were not users in 2007/08, then the ostensibly positive effect of plough ownership on area cultivated would likely be captured by the household's higher total landholding observed in 2010/11. In other words, to truly measure the effect of plough ownership or animal traction use on either total landholding or total area cultivated, we would need to observe households for two consecutive years and have a reasonable number of them change from traction non-use (or use) to use (or non-use).[27] In addition, we note that plough ownership did not change much over time, and many plough owners are in Tete Province, where we did not find a significant positive increase in area cultivated.

Another surprising result is that households that that live in a village with animal traction rental available (proxied by the percentage of village households using animal traction) actually have slightly lower area cultivated. For example, a 10% increase in this percentage would lead to a 1.4% decrease in area cultivated (Table 17).[28] The negative effect of an increase in traction use among village neighbors on a household's area cultivated may well be explained by the three-year gap between our survey years, as noted in the paragraph above.[29]

7.3. Use of Temporary Hired Farm Labor for Crop Production and Cost Per Hectare

As noted above, the percentage of sample households that hired temporary farm labor increased from 20.9% in 2007/08 to 31% in 2010/11 (Table 9), with sizeable increases in every province, especially Manica. Like use of animal traction, we do not have plot- or crop-level information from the TIA survey that indicates anything about the temporary or permanent hired labor apart from the task (land-preparing, planting, weeding, harvest, etc.). We have combined all crop-related temporary labor into one category and proceed to analyze the factors driving the increase in hiring of temporary farm labor using a log-normal double-

[27] Because we are including the time-average of animal traction use, the APE that we measure in this probit regression reflects the change in household area cultivated among households that made a change (positive or negative) in use of animal traction from one year to the next.

[28] Because the percentage of village households using animal traction is a proportional variable, this means that a one-unit change in this variable (which is what OLS shows us as the partial effect) implies a change from 0 to 1 – the entire range of this variable. Thus, the partial effect of a proportional variable is typically multiplied by the standard deviation or some relatively low percentage to get a more realistic marginaleffect; in this case, we multiply -0.14 by 20%.

[29] Another possibility is that at least for some households, it's possible that the reason this effect is negative is because animal traction not only reduces the labor requirements per hectare to prepare a field but can also result in higher yields due to more timely land preparation, improved soil aeration, and better weed control. In such a case, a household that prepares its fields via animal traction instead of manually may yield gains that are high enough for them to actually cultivate less area than they would need to if they prepared their fields manually (with a hoe).

hurdle model. Thus, we first use a probit to assess the factors affecting the probability that a household hires temporary labor, and then a log-normal second stage regression to measure the effects of the same factors on the cost of labor hired per hectare, both among households that actually hire labor (the conditional quantity effect) as well as any given household (the unconditional quantity effect). Given that we are controlling separately for the village wage rate, we can consider that the cost of labor applied per hectare likely is positively correlated with the labor hours hired per hectare (which we do not observe). Hereafter, we use the term hired labor to refer to temporary hired labor only.

We first look at the effect of the price of hired farm labor (the log of village agricultural wage that season) on the probability of hiring farm labor and the cost of hired farm labor per hectare. We find that a 10% increase in the village farm wage leads to an insignificant (p=0.26) and small increase of 0.25% in the probability of hiring labor (Table 18). While we might expect a higher farm wage to discourage hiring, this may simply imply that areas with higher demand for hired farm labor are bidding up the local ag wage. As expected, we find that among households that hire labor, the village wage has a negative effect (though insignificant at p=0.27) on the cost of hired labor per hectare, as a 10% increase in the village wage leads to a decrease of 1.6% in the cost of hired labor per hectare demanded (Table 18). That is, while smallholders in villages that are more likely to demand some hired labor happen to have somewhat higher village wages, conditional on a household hiring labor, that household will tend to spend less per hectare on hired labor the higher the village wage.

Because the demand for hired labor is a derived demand,[30] we next look at the effect of expected crop (output) prices on household demand for hired ag wage labor. We find that a 10% increase in the expected price of maize leads to a nearly significant (p=0.15) increase of 2.8% in the probability that the household hires temporary ag wage labor (Table 18). There are some other prices that have a positive effect on the probability of hiring ag labor, though these effects are either insignificant and/or of small magnitude. When we look at the effect of expected crop prices on the extent of labor hired (as measured by the log of the cost of temporary labor per hectare), we also do not find significant crop price effects, we find that a 10% increase in the expected price of maize leads to a nearly significant (p=0.12) 2.6% increase in the cost of hired labor per hectare. We also find that a 1% increase in the expected cowpea price increases cost of hired labor per hectare by 5%, while a 1% increase in the tobacco price leads to a nearly significant (p=0.13) 1.6% increase in the cost of hired labor per hectare. The large cowpea effect may well be due to the fact that cowpea is often intercropped with maize, and maize is by far the most important staple crop in most of the central zones and is as important as cassava in diets rural Nampula/Zambezia. However, the effect of tobacco prices on hired labor is as we would expect given that tobacco is a labor-intensive crop with high returns. For example, we also find that the presence of a tobacco buying depot in or near the village has a rather large though insignificant (p=0.40) effect on the cost of hired labor per hectare, increasing it by 35%.

While access to output markets does not seem to have a significant effect on the probability of hiring ag labor, we find that an additional kilometer of distance to the nearest formal market reduces the cost of hired labor per hectare by 0.8% among those already hiring labor and by 1% among any given household (Table 18). The magnitude of this effect is quite large, and suggests that perhaps more of the output price variables do not have a significant

[30] Like the demand for any input in the crop production process (such as the demand for fertilizer, manure, or improved seed), the demand for hired labor is said to be 'derived demand' given that it is a function of demand for the output (crop production) for which the labor is hired to produce.

effect on the cost of hired labor per hectare because these expected prices are observed at the nearest SIMA market (for maize, rice, cowpea, beans) or the district median farmgate sales price (for other crops) and are thus not village-level expected prices. That is, because our output price variables do not account for real transport costs between the village and the location from which the output price is observed (the nearest SIMA market, or a median district farmgate price), the negative effect of distance to formal market on cost of hired labor likely indirectly indicates that demand for hired labor declines as the actual crop sales prices that farmers expect to receive in their village decline (i.e., demand for hired labor is derived from the demand for the crop output).

Table 18. Lognormal Double Hurdle Model of Log of the Household Cost of Temporary Agricultural Labor Hired Per Hectare, 2007/08 and 2010/11

	Probit		Log normal		Probit + Log normal	
	DV = 1 if HH hires temporary ag labor		DV=ln(cost of hired temp. ag labor per ha)			
			APE (Conditional) of X_j on lny, given y>0		APE (Unconditional) effect of X_j on lny	
Explanatory variables	APE	Pvalue	APE	Pvalue	APE	Pvalue
Expected main season rainfall (mm)	0.0004	0.5134	-0.0014	0.659	0.001	0.868
Expected main season rainfall - coeff. variation	0.0001	0.8756	0.0032	0.468	0.004	0.470
Year dummy (1=2011)	0.0578	0.4651	0.3300	0.727	0.692	1.000
ln(real exp price of maize (Oct-Dec)) (Mt/Kg)	0.2795	0.1479	1.1089	0.356	2.597	0.120
ln(real exp price of rice (Jan-Mar)) (Mt/Kg)	-0.0293	0.8685	-2.0854	0.136	-2.241	0.190
ln(real exp price of small g.nuts (Jul-Sep)) (Mt/K	-0.2898	0.0565	-2.3268	0.023	-3.870	0.004
ln(real exp price, common beans (Jul-Sep)) (Mt/	0.0621	0.8096	-0.2311	0.897	0.100	0.966
ln(real exp price of cowpea (Jul-Sep)) (Mt/Kg)	-0.5075	0.0637	5.0915	0.006	2.389	0.288
ln(real exp price of cassava) (Mt/kg)	0.0101	0.8258	0.3007	0.421	0.354	0.473
ln(real exp price of pigeon pea) (Mt/kg)	0.0771	0.3678	0.1664	0.761	0.577	0.436
ln(real exp price of cotton) (Mt/kg)	0.0553	0.0418	0.0270	0.878	0.321	0.178
ln(real exp price of tobacco) (Mt/kg)	-0.0070	0.6960	0.1621	0.133	0.125	0.410
ln(real exp price of sesame) (Mt/kg)	0.0626	0.3554	-0.3558	0.451	-0.023	0.970
ln(distance to nearest fertilizer retailer, km)	0.0500	0.0188	-0.3018	0.020	-0.064	0.692
ln(Distance to nearest seed retailer (km))	-0.0088	0.3553	0.0220	0.673	-0.025	0.740
ln(willage ag wage, MTN/day)	0.0252	0.2661	-0.1583	0.297	-0.024	0.902
% village households using animal traction	0.0165	0.7947	-0.2016	0.656	-0.114	0.847
Travel time to nearest town of 30k+ people (hou	0.0001	0.9818	-0.0105	0.618	-0.013	0.667
Distance to nearest formal market (km)	-0.0003	0.7061	-0.0086	0.115	-0.010	0.124
1=Village/nearby vil. had maize depot this/last	-0.0053	0.8726	-0.2488	0.172	-0.270	0.277
1=Village/nearby vil. had tobaco depot this/last	-0.0177	0.7474	0.3554	0.404	0.232	0.999
1=Village has maize mill	-0.0420	0.5019	-0.2711	0.686	-0.528	0.888
1=Nearby village has maize mill	-0.0351	0.5357	-0.0980	0.824	-0.274	0.609
Total landholding size (Ha)	0.0137	0.1243	-0.0649	0.229	0.008	0.915
# of HH members age 15-64 per hectare	-0.0038	0.8371	0.4102	0.021	0.376	0.027
1=HH owns plough	0.2334	0.0003	0.0968	0.810	1.764	1.000
Tropical livestock units	0.0028	0.5499	0.0083	0.659	0.023	0.501
1=HH received price info through a radio	0.0254	0.4462	-0.1048	0.585	0.027	0.920
Head's education (years)	-0.0163	0.0810	-0.0216	0.739	-0.108	0.242
Head's age (years)	-0.0025	0.5989	-0.0178	0.694	-0.031	0.502
1=HH headed by a single female	0.0992	0.1367	3.1933	0.233	5.374	1.000
Number of observations	2,353		676		2,353	
Wald chi2(74), Pseudo R-squared / R-squared	334 (0.000) / 0.18		0.347			

Notes: Model includes variables also omitted from Table 18 plus household time-averages of all time-varying variables.

The sign of the effect of distance to the nearest fertilizer retailer (a proxy for the price of fertilizer in the village) is hard to predict *a priori* given that on the one hand, inorganic fertilizer enables a farmer to intensify crop production (increase production per hectare) and as such is a substitute to increasing labor per hectare. On the other hand, households that inorganic fertilizer would likely have higher labor demand at harvest (if yields are higher) and if they are knowledgeable about these inputs, they will recognize that their returns to the expense of inorganic fertilizer will be higher if they both plant on time and apply timely and sufficient weeding during the growing season. We find that log of distance to the nearest fertilizer retailer has a positive and significant effect on the probability of hired labor, though the effect is relatively small as a 10% increase in this distance increases the probability of hired labor by only 0.5% (Table 18).

However, we also find that among those hiring labor, a 10% increase in the distance to the nearest fertilizer retailer reduces the cost of hired labor per hectare by 3%. While this effect implies that fertilizer is a complement to hired labor, it is likely that we do not really have a good estimate of the relationship between access to fertilizer and the demand for hired labor due the strange fact that villages that have or are near to a tobacco depot are actually further on average from a fertilizer retailer than other villages.[31] Because most fertilizer in Mozambique is linked to either tobacco or sugarcane production, this suggests that perhaps the effect of fertilizer access on the cost of hired labor per hectare is better measured by the dummy variable we noted already for presence of a tobacco buying depot in or near the village – which has a large positive (though insignificant) effect on cost of hired labor per hectare. If this interpretation is correct, this is consistent with the probit result that suggests that fertilizer and hired labor are primarily substitute means of intensification.

Apart from expected crop prices (for which we have nearly significant results), there are three fairly clear determinants of the use of hired farm labor – ownership of a plough, total landholding, and the type of household head. First, we find that ownership of a plough increases the probability of hiring farm labor by 23% (Table 18). This effect would at first seem easy to interpret if we assume that households that use animal traction are likely to have larger landholding. However, because we are already controlling separately for landholding, the effect of plough ownership may indicate that households that use a plough have higher yields on average (and thus need more labor than their family can provide to ensure a timely harvest).[32] Second, we find that one hectare increase in total landholding leads to a nearly significant (p=0.12) increase in the probability of hiring labor by 1.1%.

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[31] While this finding seems quite strange at first, it is likely explained as follows. It appears that tobacco companies that contract smallholders to grow tobacco deliver fertilizer directly to contracted farmers in their villages. Thus, this deliver of fertilizer only to contracted growers is quite correctly not recorded in the TIA village survey as a 'fertilizer retailer' nor is it a 'village fertilizer fair'.

[32] We ran this DH using a binary indicator that =1 if the household used animal traction (and dropped the variable measuring the % of village households using animal traction) and found that the APE of animal traction use on probability of hiring labor is 32%. Because there is considerably more variation in use of animal traction over the two panel waves than plough ownership, this is perhaps a better measure of animal traction use because while the time-average of both animal traction use and plough ownership should be correlated with unobserved factors that can lead to increased yields (such as plot quality, crop management knowledge and skill, etc), the increased variability of the time-varying term of animal traction use gives us more confidence in the APE of this variable as compared with plough ownership (as the number of households that owned a plough only changed by n=7 cases over time). That said, we included plow ownerhip rather than animal traction use as the latter is more likely to be endogenous with hiring temporary labor due to the simultaneity of these two decisions.

Finally, we find that households that are headed by a single female single female are 9% more likely to hire farm labor (nearly significant at p=0.13). Because we are already controlling separately for the number of household adults age 15-64 (assumed to be potentially available for own-farm crop production) as well as adults age 65 or over (who may also provide family labor), the fact that households headed by a single female are much more likely to hire labor suggests either that our proxy for available farm labor is somewhat flawed or else that there are economies of scale, flexibility, or possibly a threshold level of available adults that households with two resident spouses enjoy – and that the absence of this positive threshold level of number of adults is being picked up by the single-female-head indicator. Another explanation could be that such households may be less likely to have local social connections and/or local extended family that could provide a labor-sharing kind of arrangement (a situation that the TIA survey does not inquire about).

7.4. Use of Animal Traction

As noted in the above descriptive section, use of animal traction increased dramatically in Tete (from 26% of households to 43%) and modestly in Manica and Sofala (increasing from 12.7% to 17.5% in Manica and from 6.7% to 10.5% in Sofala). Because there are only n=3 cases of animal traction in Nampula and Zambezia, we dropped households from those areas for the following probit regression explaining household use of animal traction.[33]

Not surprisingly, we find that access to animal traction has significant and large effects on the probability of actually using it. For example, ownership of a plough (draught animal) increases the probability of using animal traction by 24% (9%), and a 10% increase in the percentage of village households that use animal traction (a proxy for access to traction rental) increases the probability of animal traction use by 1.7% (Table 19). However, given that animal traction ownership did not increase by very much in our survey area over time, it would appear that something other than access to animal traction is also driving this increase in use. Our results show that these increases in the use of animal traction over time (in the central provinces) appear to largely be driven by increases in expected crop market prices and proximity to specific crop markets. For example, the expected prices of several crops appear to have large effects on the probability of using animal traction, as a 1% effect in the expected price of maize leads to a 2.2% effect on this probability. Likewise, a 1% effect in the expected price of rice (small groundnuts, cowpeas, sesame) leads to a 6.1% (4.9%, 3.8% and 0.5%) effect on the probability of using animal traction.

We find a consistent result when looking at the effect of the presence of buying depots, as presence of a rice depot in or near the village (in the year prior and the current year) increased the probability of animal traction use by 3.5% (nearly significant at p=0.12) (Table 19). Likewise, the presence of a rice mill increased the probability of animal traction use by 10%. Similarly, we find that a one hour decrease in the travel time to the nearest town of 30,000 or more residents increases the probability of animal traction use by 0.6%. We also find a negative effect of distance to the nearest formal market on this probability, though this effect is not significant.

[33] Household ownership or use of either large livestock or animal traction is almost non-existent north of the Zambezi river, which conventional wisdom holds is due to the presence trypanosomiasis carried by the tsetse fly, which is endemic in northern provinces. Since the TIA/IAI survey series began in 2001/02, each TIA survey has found between 0 and 0.5% of small and medium-holders using animal traction in northern provinces. In our partial panel sample, which includes some districts of Zambezia and Nampula, we observed only three households that report use of animal traction.

Table 19. Probit Regression of Household Use of Animal Traction 2007/08-10/11

	Probit	
	Dep variable = 1 if HH used animal traction	
Explanatory variables	APE	p-value
1=zone 7 (wet SAT, mid-elevation north-central)	0.688	0.018
1=zone 10 (wet SAT, high altitude north-central)	0.751	0.008
Expected main season rainfall (mm)	-0.000	0.800
Expected main season rainfall - coeff. variation	0.004	0.589
Year dummy (1=2011)	-3.531	0.054
ln(real exp price of maize (Oct-Dec)) (Mt/Kg)	2.223	0.101
ln(real exp price of rice (Jan-Mar)) (Mt/Kg)	6.108	0.050
ln(real exp price of small g.nuts (Jul-Sep)) (Mt/Kg)	4.859	0.053
ln(real exp price, common beans (Jul-Sep)) (Mt/Kg)	-6.000	0.074
ln(real exp price of cowpea (Jul-Sep)) (Mt/Kg)	3.782	0.067
ln(real exp price of cassava) (Mt/kg)	-0.067	0.248
ln(real exp price of tobacco) (Mt/kg)	-0.017	0.280
ln(real exp price of sesame) (Mt/kg)	0.486	0.034
ln(distance to nearest fertilizer retailer, km)	-0.009	0.320
ln(Distance to nearest seed retailer (km))	0.010	0.205
ln(willage ag wage, MTN/day)	0.019	0.339
% village households using animal traction	0.171	0.009
1=village has land available for cultivation	0.017	0.490
Total Village TLU / total village AE	0.184	0.079
1=HH received ag extension visit	0.055	0.054
Travel time to nearest town of 30k+ people (hours)	-0.006	0.020
Distance to nearest formal market (km)	-0.001	0.348
1=Village/nearby vil. had maize depot this/last yr	0.037	0.260
1=Village/nearby vil. had rice depot this/last yr	0.035	0.120
1=Village/nearby vil. had tobaco depot this/last yr	0.059	0.179
1=Village/nearby vil. had sesame depot this/last yr	-0.032	0.416
1=Village has maize mill	-0.065	0.316
1=Nearby village has maize mill	-0.040	0.575
1=Village/nearby village has rice mill	0.103	0.021
1=Village/nearby village has oilseed press	-0.022	0.730
Total landholding size (Ha)	0.005	0.452
# of HH members age 15-64	0.023	0.132
1=HH owns plough	0.239	0.000
1=HH owns draught animal	0.085	0.056
Tropical livestock units (medium/small only)	-0.001	0.917
1=HH received price info through a radio	0.003	0.870
Head's education (years)	0.004	0.496
Head's age (years)	-0.009	0.045
1=HH headed by a single female	0.040	0.269
Number of observations	1,453	
Wald chi2(82) / pseudo R-squared	621 (0.000) / 0.587	

Notes: Model also includes variables noted in Table 19 that are not shown in either table plus household time-averages of all time-varying variables.

We also find that the receipt of a visit by an extension agent that year (related to crop production or marketing) increases the probability of animal traction use by 5% (Table 19 above). Without knowing more about what message the agent gave to the farmer, it is not possible to know why the visit appears to have a significant effect on the probability of animal traction use. However, we can speculate that the extension visit may have improved the probability of the stallholders' use of animal traction by informing the farmer of the productivity benefits of animal traction use or that the farmer received up-to-date market price information/advice from this agent – and thus the extension effect is really the effect of receipt of market price information and/or advice.

Finally, we also find that an additional household member age 15-64 has a nearly significant effect (p=0.12) of 2.3% on the probability of animal traction use (p=0.13). This is an expected result, given that a household that uses animal traction likely increases their demand for own-farm labor given that animal traction use can increase their area cultivated (which would then increase their demand for weeding, harvesting) and/or lead to increased crop yields.

7.5. Use of Organic Fertilizer

As noted above, application of organic fertilizer (manure) on food and cash crops increased dramatically in Tete (from 11% in 2007/08 to 23% in 2010/11), and although manure application to crops was almost non-existent in Manica and Sofala in 2007/08, levels there increased to 12.7% and 6.2% of households in 2010/11, respectively. In this section, we discuss results from a probit regression of household application of organic fertilizer on any annual crop. Although the percentages of households in Nampula and Zambezia applying manure to crops were quite low in both years, we do not drop observations from those provinces in this regression because unlike the case of animal traction – where households in those two provinces literally do not have that option – households in Nampula and Zambezia do have medium and small livestock and thus do have some manure available (though in small quantities on average than those in the central provinces).

Our results from this probit regression suggest that increases in the expected prices of several crops have played a key role in the increase in manure application in the central provinces over time. For example, we find that a 10% increase in the expected price of maize leads to a 5.6% increase in the probability of manure application on an annual crop (Table 20). Likewise, a 10% increase in the expected price of pigeon pea (cotton, sesame) leads to a 4.1% (0.6%, 0.9%) increase in the probability of manure application on an annual crop.

Because TIA does not record a measure of the unit price of manure, we rely on two measures to proxy for a household access to manure; the household's TLU per adult equivalent (AE) (i.e., household manure supply) and the village average TLU per AE (i.e., the total village TLU divided by the total village AE[34], which serves as a measure of the availability of manure in the village. As we would expected, household manure availability has a significant and positive effect on the probability of manure application on annual crops, as a 0.5 unit increase in this measure leads to a 0.95% increase in the probability of applying manure to any crop. While the sign on village TLU/AE is positive, this effect is not

[34] This measure is computed separately for each household and removes the households own TLU and AE from the computation of the village total TLU and total HH AE, so as to reduce the potential for this variable to be endogenous to the household's manure decision.

significant (p=0.32). However, the magnitude of the suggested effect is reasonably large, as a one unit increase in the village TLU per AE increases the probability of manure use by 4.7%.

Table 20. Probit Regression of Household Use of Organic Fertilizer, 2007/08-10/11

	Probit	
	Dep variable = 1 if HH used organic fertilizer[1]	
Explanatory variables	APE	p-value
Expected main season rainfall (mm)	0.000	0.071
Expected main season rainfall - coeff. variation	-0.002	0.626
Year dummy (1=2011)	-0.143	0.135
ln(real exp price of maize (Oct-Dec)) (Mt/Kg)	0.564	0.000
ln(real exp price of rice (Jan-Mar)) (Mt/Kg)	-0.349	0.058
ln(real exp price of small g.nuts (Jul-Sep)) (Mt/Kg)	-0.329	0.016
ln(real exp price, common beans (Jul-Sep)) (Mt/Kg)	0.077	0.646
ln(real exp price of cowpea (Jul-Sep)) (Mt/Kg)	-0.055	0.759
ln(real exp price of cassava) (Mt/kg)	0.004	0.889
ln(real exp price of pigeon pea) (Mt/kg)	0.414	0.000
ln(real exp price of cotton) (Mt/kg)	0.059	0.000
ln(real exp price of tobacco) (Mt/kg)	-0.018	0.005
ln(real exp price of sesame) (Mt/kg)	0.092	0.105
ln(distance to nearest fertilizer retailer, km)	0.007	0.052
ln(willage ag wage, MTN/day)	0.011	0.240
Total Village TLU / total village AE	0.047	0.321
1=HH received ag extension visit	0.037	0.039
Travel time to nearest town of 30k+ people (hours)	0.002	0.063
ln(Distance to nearest formal market, km)	-0.005	0.138
1=Village/nearby vil. had maize depot this/last yr	-0.032	0.007
1=Village/nearby vil. had rice depot this/last yr	0.016	0.203
1=Village/nearby vil. had tobaco depot this/last yr	-0.024	0.043
1=Village/nearby vil. had sesame depot this/last yr	0.006	0.721
1=Village has maize mill	-0.019	0.569
1=Nearby village has maize mill	0.026	0.438
1=Village/nearby village has rice mill	0.050	0.237
1=Village/nearby village has oilseed press	0.044	0.400
Total landholding size (Ha)	0.003	0.188
# of HH members age 15-64	-0.013	0.055
Tropical livestock units / Adult equivalents	0.019	0.037
1=HH received price info through a radio	-0.004	0.733
Head's education (years)	0.010	0.011
Head's age (years)	-0.002	0.210
1=HH headed by a single female	0.005	0.883
Number of observations	2,347	
Wald chi2(78) / pseudo R-squared	413 (0.000) / 0.401	

Notes: (1) use on annual crops only; model includes variables also omitted from Table 20 plus household time-averages of all time-varying variables.

We also find that an increase of 10% in the distance to the nearest inorganic fertilizer retailer increases the probability of household use of manure on any crop by 0.07%. While the magnitude of this effect is small, its sign is as expected as inorganic fertilizer is clearly a substitute to manure. The only significant effect of market access that we observe that performs as expected is that the presence of a tobacco depot reduces the probability of manure application on any crop by 2.4%, which is perhaps not surprising as tobacco growers typically have access to inorganic fertilizer on credit (that is linked to the sale of their tobacco), and thus may have less need for inorganic fertilizer.

Finally, we find that households that receive a visit from an extension agent are 3.7% more likely to apply manure to an annual crop (Table 20). As we noted in Section 7.4., we can speculate that the extension visit may have improved this probability by informing the farmer of the productivity benefits of manure application on crops and/or that the farmer received up-to-date market price information/advice from this agent – and thus the extension effect is really the effect of receipt of market price information and/or advice.

7.6. Use of Inorganic Fertilizer

As we noted above, inorganic fertilizer in Mozambique is not common, even in the medium- to high potential zones of Mozambique (which our partial panel survey included). Most fertilizer use in Mozambique is tied to either tobacco or sugarcane production, which is confined primarily to Tete, Manica, and Niassa (Table 7). Tobacco growers are able to access fertilizer via interlinked credit received from the company which purchases their harvested tobacco. That is, tobacco companies are willing to provide fertilizer on credit/loan to tobacco growers they contract, because even though contract monitoring and enforcement is difficult and costly in the rural Mozambican context, the company knows that most growers will repay the cost of the fertilizer they receive (via the value of the harvested tobacco which these growers in all likelihood will to the company), given that the company provides the only market outlet for the tobacco that these growers produce (i.e., tobacco is not a food crop, and there is typically only one buyer as tobacco companies usually are granted monopsony rights by the government, effective within a given geographic area).

Before we turn to econometric analysis of smallholder use of inorganic fertilizer, there are a few hypotheses we can make about the determinants of its use from the descriptive analysis alone. First, only in Tete do we observe more than 5% of households growing food crops applying inorganic fertilizer to crops such as maize, groundnuts and cowpeas. The fact that Tete farmers are applying fertilizer not only to tobacco but also to various food crops (even cassava) suggests that, at least in Tete, fertilizer use is profitable on these food crops. However, there are areas of Nampula and Niassa (not in the partial panel sample) that share the same general agro-ecological zone classification as much of Tete, yet outside of Tete there are few to no smallholders applying fertilizer to food crops. This suggests that fertilizer is not used on food crops outside of Tete because of the lack of affordable credit with which to obtain it (other than an interlinked credit arrangement via production under contract of a cash crop such tobacco).

It is also true that the average distance to the nearest fertilizer retailer is so large for most households in our sample (and in Mozambique in general) that even if a household could self-finance inorganic fertilizer for use on food crops, the search and transport costs to obtain fertilizer would outweigh the benefits of its use. For example, the average distance to the nearest fertilizer retailer varies from 35 km in Sofala to 65 km in Manica; and even though

Table 21. Probit Regression of Household Use of Inorganic Fertilizer, 2007/08-10/11

	Probit	
	Dept var = 1 if HH used inorganic fertilizer[1]	
Explanatory variables	APE	p-value
Expected main season rainfall (mm)	-0.000	0.714
Expected main season rainfall - coeff. variation	-0.001	0.044
Year dummy (1=2011)	-0.345	0.000
ln(real exp price of maize (Oct-Dec)) (Mt/Kg)	-0.112	0.346
ln(real exp price of rice (Jan-Mar)) (Mt/Kg)	0.331	0.073
ln(real exp price of small g.nuts (Jul-Sep)) (Mt/Kg)	0.311	0.019
ln(real exp price, common beans (Jul-Sep)) (Mt/Kg)	0.120	0.613
ln(real exp price of cowpea (Jul-Sep)) (Mt/Kg)	1.173	0.000
ln(real exp price of cassava) (Mt/kg)	0.005	0.844
ln(real exp price of pigeon pea) (Mt/kg)	0.022	0.657
ln(real exp price of cotton) (Mt/kg)	-0.045	0.035
ln(real exp price of tobacco) (Mt/kg)	0.017	0.057
ln(real exp price of sesame) (Mt/kg)	-0.080	0.362
ln(distance to nearest fertilizer retailer, km)	-0.009	0.183
1=village had a fertilizer fair that year	0.042	0.024
ln(willage ag wage, MTN/day)	0.009	0.265
% village households using animal traction	-0.029	0.372
Total Village TLU / total village AE	0.122	0.029
Travel time to nearest town of 30k+ people (hours)	0.002	0.121
Distance to nearest formal market (km)	0.001	0.167
1=Village/nearby vil. had maize depot this/last yr	-0.003	0.850
1=Village/nearby vil. had rice depot this/last yr	-0.006	0.631
1=Village/nearby vil. had tobaco depot this/last yr	0.221	0.000
1=Village/nearby vil. had sesame depot this/last yr	0.019	0.434
1=Village has maize mill	0.021	0.435
1=Nearby village has maize mill	0.007	0.826
1=Village/nearby village has rice mill	-0.006	0.803
1=Village/nearby village has oilseed press	0.201	0.001
Total landholding size (Ha)	0.006	0.101
# of HH members age 15-64	-0.005	0.578
1=HH owns plough	0.006	0.781
1=HH house has a good quality roof	0.016	0.212
1=HH owns a latrine	0.020	0.037
Tropical livestock units / total landholding (TLU/ha)	0.009	0.062
1=HH received price info through a radio	0.007	0.518
Head's education (years)	-0.007	0.195
Head's age (years)	-0.002	0.289
1=HH headed by a single female	-0.020	0.340
Number of observations	2,352	
pseudo R-squared	0.5582	

Notes: (1) use on annual crops only. Model includes variables also omitted from Table 21, plus household time-averages of all time-varying variables.

33% of Tete households use inorganic fertilizer, this appears to be concentrated in certain areas, as the average distance to the nearest fertilizer retailer in Tete is 55 km (unless perhaps the company delivers fertilizer directly to villages). While some fertilizer retailers did offer a village fertilizer fair, this only occurred in an average of 9% of villages in our sample (ranging from 7% in Manica to 12% in Nampula).

Our econometric analysis of household use of inorganic fertilizer (on any crop) shows just how important access to credit and an actual retailer is to the probability of using fertilizer. For example, households in a village with a tobacco buying depot are 22% more likely to have used fertilizer (on any crop). Another indication that fertilizer access is heavily reliant on tobacco is found in the fact that distance to either the nearest town of 30k residents or the nearest formal market has a positive and nearly significant effect (p=0.12, p=0.16) on fertilizer use (Table 20). That is, because fertilizer in Mozambique is primarily applied to tobacco – whose market is not either a formal market or the nearest town (i.e., where demand for food crops comes from) – the relevant market for most fertilizer users is not the nearest food market, but rather the nearest tobacco buying depot.

We also find that physical access to fertilizer retailers is also a determinant of its use by smallholders, as those living in a village which had a fertilizer fair are 4.2% more likely to have used it (Table 21), while an increase in 10 km in distance to the nearest retailer of fertilizer decreases the probability of fertilizer use by 9% (this effect is not far from significant at p=0.18). While presence of an oilseed press in the village or a nearby village improves the probability of fertilizer use by 20%, this appears to be a spurious correlation, given that 8.4% of small groundnut growers in Tete applied fertilizer to groundnuts, and there are no oilseed presses in our Tete sample villages. In addition, only 0.9% of small groundnut growers in Sofala used inorganic fertilizer on groundnuts and no sesame growers in our sample used inorganic fertilizer on sesame.

In addition to access to credit and fertilizer itself, expected prices also appear to play an important role in fertilizer use. For example, a 10% increase in the expected price of small groundnuts increases the probability of fertilizer use by 3.0% (Table 21). Likewise, a 10% increase in the price of cowpeas (tobacco) increases the probability of fertilizer use by 11.7% (0.2%). While it might seem as though the effect of the tobacco price on the probability of fertilizer use is quite low in magnitude, we note that most tobacco grower sin a given year (75% or more) apply fertilizer to maize. That is, where we would most likely expect to see a larger response of fertilizer use to the tobacco price would be for the quantity of fertilizer applied per hectare of tobacco (which TIA does not observe). While there is a rather large and significant positive effect of the expected price of rice on fertilizer use, it's not clear if this is a spurious effect or not given that neither inorganic nor organic fertilizer was applied to rice itself by our sample farmers.

7.7. Use of Improved Food Crop Seed that is Purchased

As noted above, there was a rather large increase among our sample smallholders in terms of use of purchased improved food crop seed, from 11.9% of smallholders in 2007/08 to 20.3% in 2010/11.[35] While there were increases in the use of purchased improved seed among

[35] We only focus on improved food crop seed that is purchased in the survey years 2007/08 and 2010/11 because that is the only measure of household use of improved food crop seed that was recorded consistently across the TIA08 and PP2011 household survey instruments. It would be ideal to study smallholder use of both improved seed that was purchased that year as well as improved seed that may have been purchased or obtained in an

nearly all food crops (for which TIA records this information – cereals, groundnuts, and legumes) and most zones, the majority of purchased improved food crop seed in 2010/11 was for maize or common bean.

Our econometric analysis of determinants of whether a household used purchased improved food crop seed in a given year shows first that physical access to seed has a large effect on household use of it. For example, a decrease of 10 kilometers in the distance between the village and the nearest seed retailer improves the probability of using purchased improved food crop seed by 2.0% (Table 22). Given that the average distance from growers to the nearest seed retailer is around 40 to 50 km, an increase of 10 kilometers is not an unreasonable large change in this distance. While we do not have information from TIA regarding the price of improved seed purchased from a retailer, it is clear that the vast distance between most smallholder households in our sample areas – among the most productive in rural Mozambique – suggest that regardless of the price of seed, the search and transport costs of acquiring seed itself are a serious constraint to use of an improved food crop variety.

However, we also have evidence that suggests that improved physical access to seed alone is not the only constraint to use of purchased improved varieties of food crops. For example, we find that farmers in villages that had a seed fair that year were not significantly more likely to have purchased improved seed (Table 22). Apart from the obvious constraint of physical access, another typical constraint to use of improved food crop varieties is lack of credit with which to purchase this input during a time of the year when many households have little access to cash (i.e., during the planting period, which is the lean season). Given the near absence of rural credit (at affordable interest rates) in rural Mozambique, this means that only wealthier households and/or those with non-farm sources of income are likely to have cash on hand to be able to purchase improved seed. We see evidence that lack of credit reduces household ability to purchase improved seed in the fact that typical indicators of household wealth such as household landholding[36], head's age, and TLU all have significant (or nearly significant at p=0.12) and positive effects on seed use. For example, an additional hectare of landholding increases the probability of improved seed purchase by 1.7%, an additional 10 years of head's age increases this probability by 7% (a large effect), while an additional unit of TLU increases it by 0.9%. While head's age may measure farming experience of the household, head's age typically has a negative effect of adoption of new technology, which suggests that in this case, head's age is praying for lifecycle wealth effects (i.e., older households tend to be wealthier per AE).

The typical third constraint to use of improved seed variety is farmer knowledge of and/or experience regarding the net benefits of their use. However, while we find that household receipt of an extension has a positive effect on this probability, it is insignificant. That said, it is important to note that in the context of rural Mozambique, extension could be measuring

earlier year, yet replanted as a recycled hybrid or an OPV. However, the latter category of improved seed use was recorded in PP2011 but not in TIA08. In addition, there is little to be gained in analyzing the determinants of *purchased seed* because such seed could be improved seed purchased from a retailer or simply grain from a market.

[36] Total household landholding has been shown to be highly correlated with total household income per AE in not only the context of rural Mozambique (Walker et al. 2004; Mather, Cunguara, and Boughton 2008) but also in many other east and southern African countries (Jayne et al. 2003). In rural Mozambique, even non-farm income/AE tends to increase in landholding (Mather, Cunguara, and Boughton 2008).

Table 22. Probit of Household Use of Purchased Improved Food Crop Seed, 2008 and 2011

	Probit	
	Dept var = 1 if HH used purchased improved food crop seed variety	
Explanatory variables	APE	p-value
Expected main season rainfall (mm)	0.000	0.801
Expected main season rainfall - coeff. variation	-0.000	0.698
Year dummy (1=2011)	-0.177	0.006
ln(real exp price of maize (Oct-Dec)) (Mt/Kg)	0.035	0.795
ln(real exp price of rice (Jan-Mar)) (Mt/Kg)	0.193	0.281
ln(real exp price of small g.nuts (Jul-Sep)) (Mt/Kg)	-0.265	0.060
ln(real exp price, common beans (Jul-Sep)) (Mt/Kg)	0.151	0.584
ln(real exp price of cowpea (Jul-Sep)) (Mt/Kg)	0.449	0.045
ln(real exp price of cassava) (Mt/kg)	-0.051	0.186
ln(real exp price of pigeon pea) (Mt/kg)	0.010	0.916
ln(real exp price of cotton) (Mt/kg)	0.057	0.019
ln(real exp price of tobacco) (Mt/kg)	-0.016	0.238
ln(real exp price of sesame) (Mt/kg)	0.220	0.000
Distance to nearest fertilizer retailer (km)	0.000	0.224
Distance to nearest seed retailer (km)	-0.002	0.002
1=village had a seed fair that year	-0.001	0.981
ln(willage ag wage, MTN/day)	0.046	0.022
Total Village TLU / total village AE	0.112	0.130
% village households using animal traction	0.078	0.344
1=HH received ag extension visit	0.047	0.232
Travel time to nearest town of 30k+ people (hours)	-0.001	0.672
Distance to nearest formal market (km)	-0.001	0.397
1=Village/nearby vil. had maize depot this/last yr	0.002	0.935
1=Village/nearby vil. had rice depot this/last yr	-0.056	0.008
1=Village has maize mill	0.019	0.698
1=Nearby village has maize mill	0.008	0.871
1=Village/nearby village has rice mill	-0.007	0.890
1=Village/nearby village has oilseed press	-0.003	0.950
Total landholding size (Ha)	0.017	0.002
# of HH members age 15-64	-0.004	0.758
1=HH owns plough	0.072	0.157
Tropical livestock units	0.009	0.123
1=HH received price info through a radio	0.020	0.400
Head's education (years)	0.006	0.496
Head's age (years)	0.007	0.057
1=HH headed by a single female	0.054	0.351
Number of observations	2,353	
Wald chi2(86) / pseudo R-squared	388 (0.000) / 0.240	

Notes: (1) crops include maize, rice, large/small groundnuts, common beans and cowpeas. Model includes variables also omitted from Table 22 plus household time-averages of all time-varying variables.

both knowledge transfer and improved access to seed, as several NGOs have promoted improved food crop varieties in various areas of Mozambique.[37] We also do not find a significant positive effect of head's education level on improved variety adoption, as is typically found (CITE). We only find one crop whose price has a positive and significant effect on the probability of purchase of improved seed use, as a 10% increase in the expected price of cowpea increases the probability of improved seed purchase by 4.5%.

We only find two significant effects of expected food crop prices on use of improved varieties. First, we find that a 10% increase in the expected price of cowpea increases the probability of improved seed purchase by 4.5%, as expected (Table 22). Second, the same increase in the expected price of small groundnuts decreases this probability by 2.7%, which is unexpected and difficult to explain. However, we do find that a reduction of ten kilometers in the distance to the nearest formal market results in an increase in the probability of improved seed purchase of 1% (though this effect is insignificant with a p-value of 0.39).

We also find that a 10% increase in the village wage reduces the probability of purchasing improve seed by 0.4%, which makes sense given that use of hired labor is a substitute means of intensification relative to use of improved seed (Table 22). By contrast, we find a positive effect of manure availability on use of seed, as a one increase in village manure availability (Village TLU/village AE) improves the probability of improved seed purchase by 1.1% (nearly significant at p=0.11). This is perhaps an expected result given that while both manure and improved seed are substitutes in that they can both help intensify production, they are complementary in that most improved seed varieties are bred to respond better when accompanied by sufficient inorganic or organic fertilizer. That said, the effects of these two indicators of substitute and/or complementary inputs are of relatively small magnitude relative to the effects related to access to a seed retailer and household wealth (as measured by head's age).

[37] Unfortunately, neither TIA08 nor the PP2011 surveys ask respondents for the source of the extension (i.e., government, NGO, outgrower scheme for cotton, tobacco, sugarcane, etc), thus any analysis we do using an indicator of household receipt of extension aggregates the extension services of very different organizations together into one indicator.

8. ECONOMETRIC ANALYSIS OF SMALLHOLDER AREA PLANTED, YIELD, AND PRODUCTION BY CROP

8.1. Introduction and Regression Diagnostics

In the following chapter, we use multivariate regression analysis of smallholder area planted to each crop to assess the role of crop prices, market access measures, and other household- and village-level factors in driving the extensification that we found in the average area planted to many different crops (computed among all households). We then use econometric analysis of crop yields to assess the role of crop prices and other factors in explaining why we observe higher average yields for many crops (and lower yields for cotton). If we find that a given crop's price has a significant and positive effect on yield of that crop on average, this implies that smallholders are intensifying their production of that crop in response to higher prices. The yield regressions also give us some evidence as to how households are intensifying, whether through increased labor application per hectare (implied by a positive effect of household labor available on yields) or through use of improved inputs. We then use econometric analysis of household crop production per household to assess the role of prices, market access and other factors in the combined extensification and intensification efforts of households for a given crop.

Before proceeding with regressions in this chapter, we first applied diagnostic tests related to functional form of each regression. For example, for our corner solution dependent variables, both area planted to a crop (hectares) and household production of a given crop (kilograms), we first tested whether to use the restricted Tobit or the Cragg double-hurdle model, using Vuong statistics presented in Appendix Tables A-1 and A-2 in the appendix section. Vuong test results of crop production suggest that the Cragg Double-Hurdle (DH) approach is always preferred to the Tobit model.

In the event that the Cragg model better fit a given corner solution dependent variable, we then tested whether the truncated normal model fit the data for a given crop regression better than the log normal model for the second stage of each DH model, and find that the former is better for most crops considered. Third, after using those diagnostic tests to find the best regression model for each corner solution dependent variable (and for our models of binary variables in the factor demand section), we tested for panel attrition bias. The results of our tests indicated that panel attrition bias exists for some of the crop models. For crop models with no evidence of attrition bias, we applied the original TIA08 sampling weights, and for crop models that showed evidence of attrition bias, we applied attrition-adjusted weights as described in Section 5.5.

Before proceeding to discussion of our econometric analysis of food and cash crop area, yields and production, we first note that in running these regressions using different quarters of the year for the expected price of the food crops covered by SIMA (maize, rice, groundnuts, common beans and cowpeas), we validated our hypothesis in Section 4.3.2. above where we anticipated that the appropriate decision price used by the majority of smallholder producers of crops such as maize and rice – within the context of semi-subsistence agriculture – is not the expected price in the 3-4 months following the main season harvest (i.e., the farm-gate sale prices that are observed in TIA07 and CAP10), but rather the expected prices of those crops in later quarters of the year (from October-December for maize, from January-March for rice, and from July-September or October-December for beans and groundnuts). These results have important methodological implications considering that were someone to use the expected price from the post-harvest period, one would erroneously conclude that Mozambican maize and rice producers respond to higher expected maize prices by reducing their maize area planted, production and yield. For more details on this point, please see Appendix B-4.

Finally, we note that that the magnitude of the effect of expected prices on crop yields should be treated with caution given that our yield regressions are technically mis-specified, given two important caveats regarding our crop-specific yield regressions. The first is that the increase in average yields over time is very likely due at least in part to the fact that agro-ecological conditions were clearly better in 2010/11 than in 2007/08, and we have imperfect controls for these time-varying conditions, as explained detail in Section 4.2. The implication is that it is possible that other time-varying variables in our regressions (expected prices) might pick up unobserved time-varying agro-ecological conditions. If conditions improved as did prices, this implies that where we find evidence of significant positive effects of prices on crop yield, the magnitude of the effect might be biased upward due to unobserved time-varying agro-ecological conditions that could be positively correlated with these prices. The second caveat is that while it is likely that households responded to higher prices by applying more family labor per hectare to crop production in 2011 (just as they clearly hired more temporary labor per hectare in 2011), we do not actually observe family labor days. Rather, we use the number of adults age 15-64 and those age 65 or older as proxies for the availability of adult labor for crop-related tasks, and the village wage as a measure of the cost of hired labor per day. The implication is that if family labor days per hectare increased over time, along with prices, it is possible that the magnitude of our price variables may have some positive bias if they are picking up an unobserved increase over time in family labor days per hectare applied to crop production.

8.2. Regression Results

8.2.1. Maize

Maize is the most important staple crop in the sampled areas, and the proportion of maize growers increased by almost 10% between the two periods covered by the panel survey. The average area planted to maize also increased among growers. The data also show increases in maize production and productivity, despite low use of external inputs. Only in Tete and Manica did we find households applying manure to maize, as these two provinces have large livestock (unlike in northern provinces).

The DH regression results show that an increase in the expected maize price by 1% results in a significant increase in area planted to maize by about .07 ha, conditional on being a maize producer (Table 23).[38] While this effect may seem small, consider that it implies that a 10% increase in the expected maize price will result in an increase in maize area of 0.7ha (among current maize growers) – which is an increase of large magnitude. We also find that smallholder maize-growers respond to a 1% increase in the expected maize price by increasing maize yield by 1.6% (Table 24) – a very large partial effect. This implies that smallholders have responded to an increase in expected maize prices over time both through extensification (area expansion) and intensification (increasing inputs applied to maize per hectare so as to increase maize yield). However, another important driver of smallholder area increases come from the effect of the presence of a maize mill in the village (or a nearby

[38] In this paper, when we say that a partial effect from a regression is ‘significant’, we mean that the p-value of its t-statistic indicates that our confidence that this effect is significantly different from zero is at the 90% level or better (i.e., a p-value of 0.10 or lower).

village) which increases the probability of planting maize by 6% (6%) while increasing area planted among growers by 0.11 ha (0.16) ha (Table 23).

Because TIA does not collect data on family or hired labor days used at a plot level, we cannot adequately explain how households achieved higher yields in 2011, as increased family and/or hired labor per hectare is the most likely way in which yield improvement can occur, given that access to inorganic fertilizer, organic fertilizer and improved seeds is very limited in all of the partial panel survey villages with the exception of those in Tete (and possibly Manica). For example, Tete Province is the only area where descriptive statistics show considerably greater use of both organic and inorganic fertilizers from 2008 to 2011.[39] However, there was considerably use of inorganic fertilizer on maize in Tete, which perhaps is what is behind our finding that households applying inorganic fertilizer to maize enjoy 44% higher maize yield (Table 23). We also find a positive effect of use of manure on maize yield, though it is not significant. Surprisingly, we find a negative though insignificant effect of use of improved maize seed variety that was purchased.

[39] We estimated a separate regression of maize production in which we add a binary indicator that =1 for households that used manure. This binary variable had a positive but non-significant effect on maize production. Those using manure increased their maize production about 50-60 kgs. While the proportion of smallholder farmers using manure more than doubled between the two panel waves, only 7% used it among the sampled households.

Table 23. DH Regression of Household Area Planted to Maize (ha), 2007/08-10/11

	Probit		Truncated normal		Probit + Trunc. N.	
	DV = 1 if HH plants maize		DV = HH area in maize (ha)			
			Growers (cond).		All HHs (uncond.)	
Explanatory variables	APE	Pvalue	APE	Pvalue	APE	Pvalue
1=zone 10 (wet SAT, high altitude north-central)	0.051	0.529	-0.125	0.103	-0.085	0.309
1=zone 5 (wet SAT, central coast)	-0.072	0.000	-0.072	0.000	-0.110	0.000
1=zone 7 (wet SAT, mid-elevation north-central)	0.014	0.313	0.138	0.000	0.136	0.000
1=zone 8 (SAT, coastal north-central)	-0.029	0.000	1.185	0.000	1.052	0.000
Elevation - meters above sea level	0.000	0.995	0.000	0.999	0.000	0.998
Expected main season rainfall - coeff. variation	0.000	0.997	0.001	0.989	0.001	0.989
Main season rainfall (mm)	0.000	0.998	0.000	0.998	0.000	0.999
Slope - measure of steepness (degrees)	-0.001	0.977	-0.031	0.704	-0.029	0.707
Length of growing period (days)	0.001	0.996	0.001	0.998	0.002	0.998
Year dummy (1=2011)	0.127	0.000	-0.006	0.960	0.077	0.501
ln(real exp price of maize (Oct-Dec)) (Mt/Kg)	-0.299	0.000	0.072	0.000	-0.119	0.000
ln(real exp price of rice (Oct-Dec)) (Mt/Kg)	-0.167	0.000	-0.806	0.000	-0.848	0.000
ln(real exp price of small g.nuts (Oct-Dec) (Mt/Kg)	0.053	0.000	-0.103	0.000	-0.063	0.000
ln(real exp price, common beans (Oct-Dec)) (Mt/K	0.092	0.001	0.415	0.000	0.440	0.000
ln(real exp price of cowpea (Oct-Dec)) (Mt/Kg)	-0.556	0.000	0.238	0.000	-0.125	0.000
ln(real exp price of pigeon pea) (Mt/kg)	-0.050	0.208	0.256	0.081	0.205	0.130
ln(real exp price of cassava) (Mt/kg)	-0.003	0.000	0.086	0.000	0.078	0.000
ln(real exp price of cotton) (Mt/kg)	0.023	0.320	0.007	0.968	0.021	0.903
ln(real exp price of tobacco) (Mt/kg)	0.019	0.659	0.035	0.827	0.044	0.766
ln(real exp price of sesame) (Mt/kg)	0.024	0.895	0.081	0.776	0.090	0.758
Distance to nearest fertilizer retailer (km)	0.001	0.000	0.001	0.000	0.001	0.000
Distance to nearest formal market (km)	0.000	0.910	0.004	0.000	0.003	0.227
Distance to nearest seed retailer (km)	0.000	0.593	0.000	0.976	0.000	0.854
Travel time to nearest town, 30k+ people (hrs)	0.000	0.263	-0.002	0.001	-0.002	0.000
1=Village/nearby had maize depot this/last yr	0.035	0.053	-0.027	0.651	-0.004	0.947
1=Village has maize mill	0.062	0.000	0.113	0.000	0.142	0.000
1=Nearby village has maize mill	0.063	0.000	0.168	0.000	0.196	0.000
1=Village/nearby village has maize mill	-0.013	0.849	-0.074	0.545	-0.076	0.526
1=HH received price info through a radio	0.031	0.529	0.094	0.366	0.107	0.265
Total landholding size (Ha)	0.010	0.948	0.183	0.642	0.175	0.634
# of HH members age 15-64	0.002	0.986	-0.032	0.900	-0.029	0.905
Tropical livestock units	0.001	0.995	-0.003	0.991	-0.002	0.994
1=HH used animal traction	-0.021	0.004	-0.019	0.435	-0.030	0.185
Head's age (years)	0.001	0.965	0.004	0.958	0.005	0.951
Head's education (years)	-0.005	0.987	0.031	0.943	0.026	0.955
1=HH headed by a single female	-0.020	0.000	-0.195	0.000	-0.191	0.000
Number of HH members age 0-4	-0.008	0.944	0.057	0.763	0.048	0.800
Number of HH members age 5-14	0.007	0.726	-0.032	0.504	-0.025	0.583
Number of HH members age 65 or above	0.136	0.000	-0.039	0.215	0.048	0.131
Number of observations	2353		2192		2353	
Pseudo R-squared / Wald chi2(69), Pr>chi2	0.3675		489.54 (0.000)			

Table 24. OLS-FE Regression of the Log of Household Maize Yield (kg/ha), 2007/08-10/11

	OLS - FE	
	DV = ln (HH maize yield (kg/ha))	
Explanatory variables	APE	Pvalue
Expected main season rainfall - coeff. variation	0.004	0.094
Main season rainfall (mm)	0.000	0.734
Year dummy (1=2011)	0.433	0.072
ln(real exp price of maize (Oct-Dec)) (Mt/Kg)	1.560	0.041
ln(real exp price of rice (Oct-Dec)) (Mt/Kg)	0.171	0.814
ln(real exp price of small g.nuts (Oct-Dec) (Mt/Kg)	-1.054	0.088
ln(real exp price, common beans (Oct-Dec)) (Mt/Kg)	-3.002	0.000
ln(real exp price of cowpea (Oct-Dec)) (Mt/Kg)	-1.500	0.080
ln(real exp price of pigeon pea) (Mt/kg)	-0.395	0.357
ln(real exp price of cassava) (Mt/kg)	0.002	0.986
ln(real exp price of cotton) (Mt/kg)	0.069	0.544
ln(real exp price of tobacco) (Mt/kg)	0.024	0.748
ln(real exp price of sesame) (Mt/kg)	0.012	0.950
1=Village/nearby had maize depot this/last yr	0.043	0.889
1=Village has maize mill	-0.009	0.966
1=Nearby village has maize mill	-0.126	0.570
1=HH received price info through a radio	-0.071	0.532
Total landholding size (Ha)	-0.117	0.000
# of HH members age 15-64	-0.033	0.688
Tropical livestock units	0.030	0.019
1=HH used animal traction	0.077	0.648
1=HH applied fertilizer to maize	0.444	0.048
1=HH applied manure to maize	0.127	0.531
1=HH used improved maize seed variety	-0.146	0.432
Head's age (years)	0.003	0.891
Head's education (years)	0.057	0.135
1=HH headed by a single female	0.324	0.179
Number of HH members age 0-4	-0.088	0.211
Number of HH members age 5-14	0.015	0.786
Number of HH members age 65 or above	0.280	0.334
Number of observations	1808	
F (33,941) p-value / R^2-within	4.33 (0.000) / 0.191	

Notes: Model includes household fixed effects.

Table 25. DH Regression of Household Maize Production (kg), 2007/08-10/11

	Probit		Truncated normal		Probit + Trunc. N.	
	DV = 1 if HH plants maize		DV = HH maize production (Kg)			
			Growers (cond).		All HHs (uncond.)	
Explanatory variables	APE	Pvalue	APE	Pvalue	APE	Pvalue
1=zone 10 (wet SAT, high altitude north-central)	0.051	0.528	764.6	0.000	748.3	0.000
1=zone 5 (wet SAT, central coast)	-0.072	0.000	37.5	0.001	-4.6	0.676
1=zone 7 (wet SAT, mid-elevation north-central)	0.014	0.314	228.8	0.000	220.5	0.000
1=zone 8 (SAT, coastal north-central)	-0.029	0.000	-565.4	0.000	-536.6	0.000
Elevation - meters above sea level	0.000	0.995	0.3	0.999	0.3	0.999
Expected main season rainfall - coeff. variation	0.000	0.997	2.1	0.990	2.0	0.989
Main season rainfall (mm)	0.000	0.998	-1.2	0.997	-1.0	0.997
Slope - measure of steepness (degrees)	-0.001	0.977	-42.4	0.918	-39.2	0.918
Length of growing period (days)	0.001	0.996	-0.3	0.999	0.1	1.000
Year dummy (1=2011)	0.127	0.000	497.1	0.005	523.7	0.001
ln(real exp price of maize (Oct-Dec)) (Mt/Kg)	-0.299	0.000	776.9	0.000	555.4	0.000
ln(real exp price of rice (Oct-Dec)) (Mt/Kg)	-0.167	0.000	-1760.8	0.000	-1702.3	0.000
ln(real exp price of small g.nuts (Oct-Dec) (Mt/Kg)	0.053	0.000	-433.9	0.000	-369.9	0.000
ln(real exp price, common beans (Oct-Dec)) (Mt/K	0.092	0.001	-1298.3	0.000	-1142.3	0.000
ln(real exp price of cowpea (Oct-Dec)) (Mt/Kg)	-0.556	0.000	67.1	0.000	-231.0	0.000
ln(real exp price of pigeon pea) (Mt/kg)	-0.050	0.208	344.6	0.046	289.8	0.066
ln(real exp price of cassava) (Mt/kg)	-0.003	0.000	305.2	0.000	278.5	0.000
ln(real exp price of cotton) (Mt/kg)	0.023	0.319	-3.5	0.994	9.0	0.983
ln(real exp price of tobacco) (Mt/kg)	0.019	0.659	62.2	0.796	66.9	0.757
ln(real exp price of sesame) (Mt/kg)	0.024	0.895	214.1	0.607	209.1	0.595
1=HH headed by a single female	-0.020	0.000	-308.6	0.000	-294.3	0.000
Head's age (years)	0.001	0.965	9.6	0.941	9.5	0.938
Head's education (years)	-0.005	0.987	-2.8	0.996	-5.3	0.992
Number of HH members age 0-4	-0.008	0.944	-43.4	0.866	-43.8	0.857
# of HH members age 15-64	0.002	0.986	-23.1	0.945	-21.2	0.945
Number of HH members age 5-14	0.007	0.725	0.8	0.992	4.4	0.949
Number of HH members age 65 or above	0.136	0.000	32.1	0.475	100.9	0.017
Total landholding size (Ha)	0.010	0.948	25.8	0.963	28.9	0.956
Tropical livestock units	0.001	0.995	11.5	0.984	11.2	0.983
1=HH used animal traction	-0.021	0.004	-98.5	0.000	-101.7	0.000
1=HH received price info through a radio	0.031	0.523	56.0	0.711	68.8	0.619
Distance to nearest fertilizer retailer (km)	0.001	0.000	2.6	0.000	2.8	0.000
Distance to nearest formal market (km)	0.000	0.910	5.4	0.045	4.7	0.156
Distance to nearest seed retailer (km)	0.000	0.592	-1.1	0.628	-1.2	0.570
Travel time to nearest town, 30k+ people (hrs)	0.000	0.264	14.5	0.000	13.1	0.000
1=Village/nearby had maize depot this/last yr	0.035	0.052	101.6	0.121	114.1	0.063
1=Village has maize mill	0.062	0.000	355.7	0.000	357.7	0.000
1=Nearby village has maize mill	0.063	0.000	347.1	0.000	360.1	0.000
1=Village/nearby village has maize mill	-0.013	0.849	-239.4	0.147	-227.5	0.146
Number of observations	2353		2170		2353	
Pseudo R-squared / Wald chi2(70), Pr>chi2	0.3675		113.84 (0.0007)			

Not surprisingly, we also find that these combination of area expansion and intensification lead to rather large responsiveness of household maize production to an expected increase in the maize price. For example, a 1% increase in the expected maize price leads to a significant 776kg increase in production among maize growers (conditional effect), and a 555 kg increase in production unconditional of being a maize grower (Table 25). The magnitude of this effect is so large that it merits discussion. The large increase in price responsiveness is not due to a change in rainfall from one year to the next, as we are already controlling separately for seasonal rainfall. Our year dummy also controls for the average effect of unobserved factors (and the magnitude of the year effect is also large at 497 kg). One potential reason explaining why this effect is so large in percentage terms is that household median production levels were considerably lower in 2008. For example, the median household quantity of maize produced was more than 50% greater in 2011.

Because maize is usually intercropped, this means that an increase in the area planted to maize may have an effect on both crops that are typically intercropped with maize (common beans, cowpeas, pigeon pea and cassava) as well as crops that are not (food crops like rice and cash crops like tobacco). An increase in the price of crops such as cowpeas, common beans, pigeon peas, and cassava also results in increased area planted to maize because those crops are usually intercropped with maize. By contrast, rice is usually grown in a monocrop system, thus we find that a 1% increase in the expected price of rice decreases the area planted to maize by 0.8ha. Thus, smallholder farmers in rice-growing areas respond to higher expected rice prices by planting less area to maize and more to rice.

Similar to the area planted to maize, an increase in the price of other crops that are usually intercropped with maize has a positive and significant effect on maize production among maize growers. This was the case of cowpeas, pigeon peas, and cassava. But common beans had a negative and significant effect. In general, the area planted to cowpeas is usually relatively smaller than that of common beans, and the latter was marketed more frequently and in greater volumes. It is possible that when prices of common beans increase considerably, smallholder farmers decide to grow them in sole cropping, thus reducing the area planted to maize, which is the result that we find in our regressions.

Access to commodity markets and agro-processors has a positive and statistically significant effect on maize production. For example, smallholder farmers whose village or nearby village had a maize buyer depot in the previous year were 3.5% more likely to grow maize (Table 23). If the village or a nearby village has a mill, this leads to an even larger increase in the probability the household plants maize (an increase of 6% for each) (Table 23).

We also find large effects of the presence of small hammer mills in or near the village on maize area planted, as a mill in the village increases maize area (among maize growers) by 0.11ha while a mill near the village increases it by 0.16ha (Table 23). The presence of small hammer mills also has significant, positive and even larger effects on maize area planted by any household (i.e., current maize growers and non-growers). In addition, having a small hammer mill in the village increases the average quantity of maize produced by smallholder farmers by about 350 kg (Table 25), and this is mostly an area effect since the OLS-FE results showed no statistically significant effect (Table 24).

There are two reasons that may explain the apparent causality of the presence of a hammer mill in (or near) the village providing an incentive for smallholders to produce more maize.[40]

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[40] We note that it is likely that the location of mills (and thus their presence in or near a village) may not be exogenous in a household regression of maize area or production, because those who invest in a mill are likely to do so in areas where they expect to find surplus maize. Thus, the causality of mill presence and high household maize production may go both ways. However, because the binary indicator of ‘village has a mill’ enters into our DH regressions of area planted and production as both a time-varying variable and the time-

First, while farmers have to pay a fee to have their maize milled, maize meal/flour sells at a considerably higher price than maize grain, thus this is one way that farmers can add value to their surplus maize production. Second, given that at present there is almost no pesticide use on maize and no post-harvest chemical treatment of harvested maize, milled maize experiences fewer storage losses than maize grain. Thus, it is also possible that the presence of a hammer mill causes farmers to produce more maize grain given that their surplus grain can be stored for long periods (as maize meal) with lower post-harvest losses relative to storing their surplus as maize grain.

While presence of agro-processing for maize (a mill) improves the probability of growing maize and the quantity of maize produced, we find unexpected effects of market access on maize production decisions. For example, a one km increase in the distance from the village to the nearest formal market leads to not a decrease in maize production (as expected) but to a significant 5 kg *increase* in maize production (Table 24). Likewise, we find that an increase in the distance from the village to the nearest town of 30k residents or more leads to a 14.5kg increase in maize production. This finding is not an unusual finding for this or earlier TIAs – we have consistently found that crop income per hectare, maize production and maize sales tend to be larger in more remote areas of Mozambique (Boughton et al. 2007; Mather et al. 2013). The reason crop income tends to be higher in more remote areas is likely because the highest returns to crop production come from farmers growing crops like cotton and tobacco, the market for which is the nearest concession area depot – not the location of consumers.

However, the finding on maize production would appear to be counter to economic logic that areas closer to markets would have a greater incentive to produce more maize, beans, etc., as they would likely receive better prices than farmers in more remote areas. Yet, there are several explanations for this seemingly counter-intuitive relationship between market access and maize production. First, some of the most productive areas of rural Mozambique in the center and north tend to have the poorest infrastructure – whether measured as roads per square km or roads per 1,000 persons. Second, farmers that are further from markets may be concentrating their crop production on maize for various reasons – one, maize is not as perishable as horticultural products, thus if the farmer in a remote village wants to produce for the market, he/she must focus on crops that are not perishable (such as maize, beans, etc.). Also, farmers in remote villages may be producing more maize than less remote villages due to poor infrastructure and thus high opportunity costs for households in remote villages of *not* producing enough grain to meet their annual consumption needs. That is, a farmer in a remote village who is a net buyer of maize will likely pay a higher price for maize grain at retain in the lean season (if the maize is shipped in from another area) than a farmer in a less remote village.

8.2.2. Rice

Although maize is the dominant cereal staple in Mozambique, rice production and consumption is quite important in the diets of both urban and rural households in Zambezia and Sofala (MPD/DEAP 2010). Given that domestic rice prices in urban areas increased more than any other food crop during the 2007 to 2008 period, it is somewhat surprising that the percentage of households in our sample growing rice did not increase from 2007/07 to

average, the time-average should control for correlation between this variable and unobserved village-level factors such as 'good agroecological conditions' that might be correlated with 'mill presence' – thus enabling us to interpret the average partial effect of the time-varying mill presence indicator on maize production as though this time-varying indicator is exogenous (i.e., not correlated with the error term).

2010/11 but stayed close to 16.5%. However, among rice growers, average area increased considerably among growers from a mean of 0.45 to 0.66 hectares from 2007/08 to 2010/11 – a change of 54% on average, and among all households from 0.07 to 0.11 hectares (an increase of 54% on average).

Table 26. DH Regression of Household Rice Area (ha), 2007/08-10/11

	Probit		Truncated normal		Probit + Trunc. N.	
	DV = 1 if HH plants paddy		DV = HH area in paddy (ha)			
			Growers (cond.)		All HHs (uncond.)	
Explanatory variables	APE	Pvalue	APE	Pvalue	APE	Pvalue
1=Agroecological zones (low)	-0.1975	0.0000	-0.104	0.872	-0.117	0.031
1=Agroecological zones (medium)	-0.2788	0.0002	0.156	0.760	-0.114	0.380
1=Agroecological zones (high)	-0.1322	0.1373	0.505	0.488	-0.005	0.974
Expected main season rainfall (mm)	0.0000	0.9527	-0.002	0.412	0.000	0.455
ln(Exp. main season rainfall - coeff. Variation)	-0.0372	0.3429	-0.110	0.556	-0.044	0.318
Year dummy (1=2011)	0.1147	0.1890	0.400	0.311	0.159	0.254
ln(real exp price of rice (Jan-Mar)) (Mt/Kg)	-0.1743	0.4241	0.301	0.778	-0.034	0.889
ln(real exp price of maize (Oct-Dec)) (Mt/Kg)	-0.0417	0.8242	-0.308	0.667	-0.088	0.613
ln(real exp price of small g.nuts (Jul-Sep)) (Mt/K	0.0652	0.7047	-0.263	0.684	-0.019	0.905
ln(real exp price, common beans (Jul-Sep)) (Mt/l	-0.2189	0.4159	0.357	0.726	-0.047	0.851
ln(real exp price of cassava) (Mt/kg)	0.0176	0.6926	0.041	0.849	0.018	0.704
ln(real exp price of pigeon pea) (Mt/kg)	-0.0556	0.5559	0.001	0.999	-0.031	0.714
ln(real exp price of cotton) (Mt/kg)	-0.0371	0.0456	-0.002	0.985	-0.021	0.298
ln(real exp price of tobacco) (Mt/kg)	0.0037	0.8538	-0.036	0.736	-0.006	0.826
ln(real exp price of sesame) (Mt/kg)	0.0560	0.3937	-0.172	0.492	-0.005	0.938
ln(distance to nearest fertilizer retailer, km)	-0.0128	0.2190	-0.009	0.869	-0.009	0.451
ln(Distance to nearest seed retailer (km))	0.0282	0.0006	-0.051	0.193	0.005	0.589
ln(willage ag wage, MTN/day)	-0.0082	0.7304	-0.199	0.050	-0.047	0.055
Travel time to nearest town, 30k+ people (hrs)	0.0017	0.6205	0.035	0.045	0.009	0.041
Distance to nearest formal market (km)	-0.0022	0.0504	0.006	0.273	0.000	0.987
1=Village/nearby had maize depot this/last yr	-0.0201	0.6510	0.201	0.462	0.027	0.631
1=Village has maize mill	-0.0520	0.3836	-0.002	0.995	-0.029	0.670
1=Nearby village has maize mill	-0.0004	0.9941	-0.119	0.556	-0.025	0.626
Total landholding size (Ha)	0.0171	0.1961	0.067	0.207	0.022	0.108
# of HH members age 15-64	0.0241	0.1780	-0.096	0.133	-0.007	0.671
1=HH used animal traction	-0.0300	0.6682	0.035	0.915	-0.010	0.878
Tropical livestock units	-0.0089	0.1447	-0.036	0.101	-0.013	0.033
1=HH received price info through a radio	-0.0307	0.3521	-0.052	0.656	-0.028	0.370
Head's education (years)	0.0158	0.1212	-0.010	0.798	0.007	0.466
Head's age (years)	0.0000	0.9964	0.010	0.577	0.003	0.486
1=HH headed by a single female	0.0086	0.8931	-0.357	0.007	-0.074	0.024
Number of HH members age 0-4	-0.0214	0.3140	0.000	0.999	-0.012	0.531
Number of HH members age 5-14	0.0230	0.1445	0.127	0.072	0.040	0.023
Number of HH members age 65 or above	-0.0098	0.9293	-0.379	0.395	-0.085	0.428
Number of observations	1,848		331			
Psuedo R-squared / Wald chi2 (74), Pr>chi2	0.2459		222.7 (0.000)			

Notes: Model includes elevation (mm), slope, length of growing period, and household time-averages of all time-varying variables. Model excludes all observations from Tete Province.

Table 27. OLS-FE Regression of the Log of Household Rice Yield (kg/ha), 2007/08-10/11

	OLS-FE	
	DV = ln(HH paddy yield (kg/ha))	
Explanatory variables	APE	Pvalue
Main season rainfall, rice (mm)	-0.016	0.382
ln(Exp. main season rainfal, rice - coeff. var)	-0.531	0.512
Year dummy (1=2011)	2.511	0.335
ln(real exp price of rice (Jan-Mar)) (Mt/Kg)	4.751	0.471
ln(real exp price of maize (Oct-Dec)) (Mt/Kg)	1.722	0.736
ln(real exp price of small g.nuts (Jul-Sep)) (Mt/Kg)	-6.367	0.161
ln(real exp price of cowpea (Jul-Sep)) (Mt/Kg)	-17.928	0.003
ln(real exp price of cassava) (Mt/kg)	0.916	0.420
ln(real exp price of pigeon pea) (Mt/kg)	-2.422	0.104
ln(real exp price of cotton) (Mt/kg)	0.698	0.228
ln(real exp price of tobacco) (Mt/kg)	-0.298	0.662
ln(real exp price of sesame) (Mt/kg)	0.169	0.920
ln(willage ag wage, MTN/day)	-0.461	0.341
1=Village/nearby had maize depot this/last yr	-3.956	0.115
1=Village has maize mill	0.494	0.709
1=Nearby village has maize mill	-0.585	0.545
Total landholding size (Ha)	0.088	0.618
# of HH members age 15-64	0.629	0.047
1=HH used animal traction	0.116	0.863
Tropical livestock units	-0.415	0.071
1=HH received price info through a radio	0.482	0.342
Head's education (years)	-0.225	0.081
Head's age (years)	-0.086	0.152
1=HH headed by a single female	-0.440	0.565
Number of HH members age 0-4	0.612	0.033
Number of HH members age 5-14	0.869	0.006
Number of HH members age 65 or above	-0.070	0.926
Number of observations	331	
F(30, 253) p-value / R2-within	4.98 (0.000) / 0.602	

Notes: Model includes household fixed effects, and excludes all observations from Tete Province.

Turning to our double-hurdle regression of household area planted to rice (Table 26), given that there was little change in participation in rice production across the two panel years, it is not surprising that very few variables are significant in the probit model explaining whether or not a given household planted the crop. One significant factor affecting rice participation includes distance to the nearest formal market, as a 10 km decrease in this distance results in a 2.2% increase in the probability of growing rice (Table 26). Given the rather large increase in average rice area planted over time among rice growers, it is perhaps surprising that there are no significant effects of expected prices on rice area planted (among growers), although we note that the coefficient on the expected rice price is positive as we would expect (Table 26). We also note that because our expected prices of food staples such as maize, rice, groundnuts, cowpeas, and common beans come from the nearest SIMA rural or urban retail

Table 28. DH Regression of Household Rice Production (kg), 2007/08-10/11

	Probit		Truncated normal		Probit + Trunc. N.	
	DV = 1 if HH plants paddy		DV = HH paddy production (kg)			
			Growers (cond.)		All HHs (uncond.)	
Explanatory variables	APE	Pvalue	APE	Pvalue	APE	Pvalue
1=Agroecological zones (low)	-0.2080	0.0000	-226.51	0.670	-115.05	0.590
1=Agroecological zones (medium)	-0.3737	0.0000	191.41	0.665	-39.21	0.747
1=Agroecological zones (high)	-0.2092	0.0017	1124.32	0.130	44.57	0.564
Main season rainfall (mm)	0.0005	0.4136	-2.74	0.137	-0.50	0.235
ln(Exp. main season rainfall - coeff. Variation)	-0.0306	0.4350	216.01	0.061	40.95	0.127
Year dummy (1=2011)	0.0809	0.3698	-264.21	0.488	-30.61	0.692
ln(real exp price of rice (Jan-Mar)) (Mt/Kg)	-0.2423	0.2497	469.89	0.470	57.87	0.697
ln(real exp price of maize (Oct-Dec)) (Mt/Kg)	-0.1779	0.4498	27.98	0.966	-25.58	0.869
ln(real exp price of small g.nuts (Jul-Sep)) (Mt/I	0.0460	0.7910	-485.99	0.339	-96.19	0.413
ln(real exp price, common beans (Jul-Sep)) (Mt/	0.0737	0.8027	1205.86	0.158	272.02	0.164
ln(real exp price of cassava) (Mt/kg)	-0.0136	0.7850	-218.90	0.168	-49.41	0.175
ln(real exp price of pigeon pea) (Mt/kg)	0.0577	0.4888	710.24	0.008	162.76	0.009
ln(real exp price of cotton) (Mt/kg)	-0.0048	0.8317	134.75	0.057	28.08	0.094
ln(real exp price of tobacco) (Mt/kg)	-0.0295	0.2620	10.06	0.901	-3.08	0.868
ln(real exp price of sesame) (Mt/kg)	0.0624	0.3322	-136.37	0.450	-18.19	0.659
ln(distance to nearest fertilizer retailer, km)	-0.0099	0.3479	84.43	0.011	16.37	0.030
ln(Distance to nearest seed retailer (km))	0.0223	0.0062	-15.74	0.313	0.58	0.879
ln(willage ag wage, MTN/day)	0.0014	0.9530	-48.50	0.374	-10.17	0.430
Travel time to nearest town, 30k+ people (hrs)	0.0021	0.5453	-20.52	0.095	-4.06	0.171
Distance to nearest formal market (km)	-0.0015	0.1451	1.91	0.402	0.13	0.820
1=Village/nearby had maize depot this/last yr	-0.0222	0.6366	-272.40	0.001	-57.79	0.001
1=Village has maize mill	-0.0495	0.4088	70.75	0.714	7.77	0.864
1=Nearby village has maize mill	-0.0147	0.7836	43.72	0.753	6.38	0.838
Total landholding size (Ha)	0.0181	0.1499	17.37	0.485	6.70	0.258
# of HH members age 15-64	0.0203	0.2605	29.93	0.345	9.81	0.192
1=HH used animal traction	-0.0397	0.5805	-1.43	0.991	-7.29	0.724
Tropical livestock units	-0.0077	0.2304	0.14	0.987	-1.33	0.565
1=HH received price info through a radio	-0.0318	0.3191	4.45	0.940	-4.76	0.724
Head's education (years)	0.0121	0.2201	6.14	0.746	3.46	0.449
Head's age (years)	-0.0025	0.5752	-0.24	0.980	-0.48	0.835
1=HH headed by a single female	-0.0451	0.5508	-73.27	0.844	-22.09	0.572
Number of HH members age 0-4	-0.0154	0.4818	-21.54	0.583	-7.36	0.434
Number of HH members age 5-14	0.0157	0.2961	3.23	0.918	3.49	0.637
Number of HH members age 65 or above	-0.0042	0.9691	-8.75	0.963	-2.62	0.957
Number of observations	1,848		331		1,848	
Psuedo R-squared / Wald chi2 (74), Pr>chi2	0.2459		227.7 (0.000)			

Notes: Model includes elevation (mm), slope, length of growing period, and household time-averages of all time-varying variables. Model excludes all observations from Tete Province.

market (as we do not have data on village prices in the previous year), we are not able to model the effect of household area decisions as a function of the actual expected village-level prices that they would face.[41]

It appears that increases in rice area during this period were driven in part by the availability of hired labor, as a 1% increase in the village agricultural wage reduced area planted by 0.2 hectares – a rather large marginal effect. We also find that an additional household member age 15-64 reduces rice area by 0.09 ha (among growers) – an effect we would have expected to be positive given that rice production is quite labor intensive, and rice yields are particular sensitive to quick transplanting as soon as the main season rains begin. The combination of these two results suggests that rice growing households do not have enough adult family labor (on average) at periods of peak labor demand during field preparation and/or transplanting, and have to rely on hired labor during these stages.

We also find that an additional household member age 5-14 increases area planted to rice (among growers) by 0.12 ha – a rather large marginal effect (Table 26). This could be interpreted in two ways – first, that households with higher consumption requirements drive increases in area planted to a staple grain like rice, or perhaps that some of these children participate in rice production, perhaps during periods of peak labor demand such as transplanting. Finally, we find that households headed by a single female plants 0.36 ha less rice than the average household, which is likely due to the fact that single female households tend to have less overall adult labor, income with which to hire additional labor, and/or social connections through which they might enjoy some kind of labor-sharing arrangement.

Although area planted among rice growers increased considerably over the two panel years, average rice yields did not as they fell from 498 kg/ha in 2007/08 to 472 kg/ha in 2010/11, a decline of 5% (Table 16). Turning to the OLS-FE regression of log rice yields, we note that unlike rice area, rice yields do appear to be affected to some extent by expected prices, at least those of competing crops, as increase in the expected prices small groundnuts, cowpea, and pigeon pea all lead to significant (or nearly significant) negative effects on rice yield (Table 27). Market access of the main alternative staple grain – maize – also affects rice yields, as the presence of a maize buying depot in the village in the prior year has a nearly significant (p=0.11) and large negative effect on rice yields (Table 27). We also note that we are somewhat limited in assessing the effect of market access on crop yields, as most of our market access variables do not vary over time, thus within a OLS household fixed effects regression, such variables drop out.[42]

Unlike rice area, rice yields do appear to depend heavily on available household adult labor, and less on hired labor. For example, an additional household member age 15-64 increases rice yield by 63% (Table 27), while the effect of a 1% increase in village wages on rice yield is negative by insignificant (p-value = 0.341). While this effect is quite large, we note that increasing labor per hectare (timely transplanting, effective weeding, timely work to facilitate adequate irrigation) is likely one of the only means by which rural Mozambique rice growers in these areas can increase yields, as almost none of them (in this sample) use any improved

[41] Though our hope is that the market access variable measuring 'travel time (in hours) to the nearest town of 30,000 or more residents help control for village remoteness and thus proxies for the likely differences in transportation costs (and thus village-level expected rice prices) between more and less remote villages.

[42] Any observed or unobserved explanatory variable that is fixed over time within an OLS-FE regression is 'controlled for' by this method and thus is not necessarily excluded from the regression, but we are not able to measure the partial effect of these fixed factors within an OLS-FE framework.

inputs on rice, such as inorganic or organic fertilizer or improved rice seed. This perhaps explains why household education has a negative and not a positive effect on household rice yields (Table 27).[43] Household consumption demands also appear to have a large effect on household rice yields, as an additional child age 0-4 (15-64) increase rice yield by 61% (87%) (Table 27).

Household rice production is a function of area planted and yields, and although rice yields were stagnant (or fell a bit) over time, rice area increased quite a bit. Thus, we find that average (median) rice production per household increased from 132 to 202 kg (72 to 84) (Table 28). Although we are controlling separately for several village-level agro-ecological factors such as rice-specific seasonal rainfall and its expected coefficient of variation, elevation, slope, and length of growing period, we nevertheless find a large and nearly significant effect (p=0.11) of the dummy for the high potential agroecological zone on rice production, as growers in this area produce 1,125 kg more rice per household on average (Table 28). We also find that although there are not significant effects of rice or other grain prices on rice production, we find that an increase of one hour in the travel time to the nearest town of 30,000 residents or more leads to a 20 kg decrease in household rice production (Table 28). As noted above, because our expected prices of most food come from the nearest SIMA rural or urban retail market, this might suggest that rice production is more responsive to variation in rice prices than the results from this production might suggest, given that households further from towns would likely receive lower prices than those closer to towns – yet we are limited in that we do not have expected prices at the village level.

Based on the descriptive and econometric findings on rice area and yields across the two panel years, it is clear that although expected rice prices increased dramatically over time, the number of smallholders in our sample areas who grew rice did not change. However, those who did grow rice increased their average and median production, primarily via extensification (by increasing their area planted to rice). That said, variation in rice yields across households appears to primarily be due to the availability of family adult labor – as there is virtually no use of improved inputs in rice production in these zones – and appears to be driven in part by household consumption requirements of children.

8.2.3. Cassava

Cassava is generally known to be a key staple crop in Nampula and Zambezia, as we see that in our sample of central and northern districts, 75% of smallholders in Nampula and 74% in Zambezia grew cassava in 2007/08. By contrast, Tete had little cassava (10% of growers) and it was important yet still not a major crop in Manica (26%) and Sofala (28%) in 2007/08. However, the percentage of growers in Manica and Sofala more than doubled in both Manica (54%) and Sofala (65%) in 2010/11, and there were even increases in participation in Nampula and Zambezia (increasing to 86% and 83% of households, respectively). However, although there were dramatic increases in participation, the average area planted to cassava only increased from 0.227 ha to 0.251 ha, and the average area among growers actually fell from 0.467ha to 0.392ha. The reason for this is that most of the increase in participation came from Manica and Sofala, where the average area planted to cassava is around 0.25ha, which is half the average of that in Zambezia and a third that of Nampula.

[43] Typically one finds a positive effect of head’s years of education on crop yields, both because more educated farmers are more likely to know and apply improved crop management practices (Foster and Rosenzweig 1995) and because head’s education is often a proxy for household wealth (which may mean the household has better plots, easier access to hired labor, etc).

When we turn to econometric analysis of smallholder participation in cassava, we clearly see that the large price increases in rice, common beans, and groundnuts played a key role in driving increased participation in this crop. For example, we find that a 10% increase in the price of rice (common beans, groundnuts) led to a 4.5% (4.1%, 6.6%) increase in the probability that a smallholder planted cassava (Table 29). We also find that households headed by a single female were 15% more likely to have planted cassava than other households, *ceteris paribus* (i.e., after separately controlling for other factors such expected prices, agroecological factors, total landholding, number of adult laborers, etc.).

However, when we next look at the determinants of the area planted to cassava, we find that a 1% increase in the expected price of maize led to a 0.68ha increase in cassava planted among current growers (a very large marginal effect) (Table 29). Among all households, we find that both maize and rice prices led to increased area, as a 1% increase in the expected price of maize (rice) led to a 0.28ha (0.21) increase in area planted to cassava (the rice effect is not far from significant at a p-value of 0.15). While households headed by a single female are more likely to plant cassava, they plant 0.20ha less of it on average, controlling separately for total area (Table 29).[44]

The descriptive results show that along with a large increase in participation in cassava production, average household cassava yields increased from 6,694 kg/ha in 2007/08 to 9,045 kg/ha, an increase of 30% (22%) (Table 16). Our econometric analysis of cassava yield shows a large positive but insignificant effect of expected maize and rice prices on cassava yield, though a 1% increase in the common bean price leads to a nearly significant 2.9% increase in cassava yield (p-value of 0.18) (Table 30). By contrast, a 1% increase in the expected pigeon pea price (an emerging cash crop in Zambezia and perhaps a competitor for cassava area) leads to a 1.3% decline in cassava yield (Table 31). Another key driver of cassava yield appear to be available labor from members age 65 or above, as an additional member this age increases yields by 114% (Table 31). The magnitude of this effect and the fact that the effect of children age 5-14 (some of whom may be laborers, but who would require significant calories) suggests that these adults over 65 may be enabling households to increase cassava yields via increased labor hours per hectare.

[44] Please see Section 7.2. for potential explanations of why single-headed households are more likely to hire labor, tend to cultivate less area, etc even after we control separately for availability of household members age 15-64 and those over 65.

Table 29. DH Regression of Household Cassava Area (ha), 2007/08-10/11

	Probit		Truncated normal		Probit + Trunc N.	
	DV = 1 if HH plants cassava		DV = HH area in cassava (ha)			
			Growers (cond.)		All HHs (uncond.)	
Explanatory variables	APE	Pvalue	APE	Pvalue	APE	Pvalue
1=Agroecological zones (low)	-0.1000	0.2396	-0.121	0.344	-0.093	0.155
1=Agroecological zones (medium)	-0.1048	0.1284	0.016	0.923	-0.028	0.764
1=Agroecological zones (high)	-0.1721	0.0480	0.185	0.437	0.021	0.853
Year dummy (1=2011)	0.0421	0.5283	-0.243	0.062	-0.113	0.122
Expected main season rainfall (mm)	-0.0005	0.3983	-0.002	0.125	-0.001	0.087
ln(Exp. main season rainfall - coeff. Variation)	0.0157	0.6288	-0.035	0.437	-0.014	0.616
ln(real exp price of cassava) (Mt/kg)	-0.1413	0.0002	0.017	0.766	-0.040	0.212
ln(real exp price of maize (Oct-Dec)) (Mt/Kg)	-0.2458	0.1161	0.689	0.006	0.284	0.045
ln(real exp price of rice (Jan-Mar)) (Mt/Kg)	0.4534	0.0044	0.097	0.697	0.210	0.157
ln(real exp price of small g.nuts (Oct-Dec) (Mt/Kg	0.4061	0.0001	-0.162	0.290	0.054	0.525
ln(real exp price, common beans (Jul-Sep)) (Mt/K	0.6572	0.0078	-0.190	0.619	0.127	0.560
ln(real exp price of cowpea (Jul-Sep)) (Mt/Kg)	-0.6106	0.0228	0.258	0.607	-0.074	0.791
ln(real exp price of pigeon pea) (Mt/kg)	-0.1111	0.2729	0.130	0.297	0.031	0.665
ln(real exp price of cotton) (Mt/kg)	-0.0580	0.0240	0.010	0.798	-0.015	0.520
ln(real exp price of tobacco) (Mt/kg)	-0.0108	0.5434	0.113	0.095	0.057	0.124
ln(real exp price of sesame) (Mt/kg)	0.0157	0.7982	-0.059	0.343	-0.026	0.493
Travel time to nearest town, 30k+ people (hrs)	0.0089	0.0125	0.001	0.679	0.003	0.078
Distance to nearest formal market (km)	0.0022	0.0114	0.002	0.172	0.002	0.026
1=Village/nearby had rice depot this/last yr	0.0254	0.4863	0.089	0.439	0.058	0.372
1=Village/nearby had tobaco depot this/last yr	0.0253	0.6481	-0.068	0.385	-0.029	0.557
1=Village/nearby had maize depot this/last yr	-0.0246	0.5571	0.011	0.905	-0.003	0.957
1=Village/nearby had sesame depot this/last yr	-0.0443	0.3695	-0.023	0.814	-0.028	0.617
1=Village has maize mill	-0.1155	0.0433	0.026	0.765	-0.025	0.625
1=Nearby village has maize mill	-0.2287	0.0001	-0.032	0.671	-0.098	0.009
1=Village/nearby has cassava processing equip.	0.0129	0.8538	0.017	0.864	0.014	0.819
ln(distance to nearest fertilizer retailer, km)	0.0195	0.1108	0.019	0.265	0.017	0.107
ln(Distance to nearest seed retailer (km))	-0.0002	0.9825	0.009	0.489	0.005	0.550
ln(willage ag wage, MTN/day)	0.0122	0.3658	0.009	0.666	0.009	0.463
Total landholding size (Ha)	0.0014	0.8889	0.091	0.000	0.049	0.000
# of HH members age 15-64	-0.0053	0.7927	-0.057	0.144	-0.032	0.126
1=HH used animal traction	0.0465	0.4443	0.284	0.328	0.176	0.294
Tropical livestock units	0.0071	0.0931	-0.027	0.053	-0.012	0.114
1=HH received price info through a radio	0.0498	0.0926	0.029	0.595	0.033	0.291
Head's education (years)	-0.0022	0.8168	-0.006	0.787	-0.004	0.746
Head's age (years)	0.0093	0.0722	-0.008	0.427	-0.001	0.807
1=HH headed by a single female	0.1520	0.0289	-0.204	0.025	-0.071	0.171
Number of HH members age 0-4	-0.0014	0.9421	-0.068	0.035	-0.037	0.052
Number of HH members age 5-14	0.0462	0.0059	0.005	0.839	0.019	0.183
Number of HH members age 65 or above	-0.0133	0.8373	-0.075	0.490	-0.045	0.471
Number of observations	2,347		533		2,347	
Psuedo R-squared / Wald chi2 (74), Prob > chi2	0.3138		626 (0.000)			

Notes: Model includes elevation (mm), slope, length of growing period, and household time-averages of all time-varying variables.

Table 30. OLS-FE Regression of the Log of Household Cassava Yield (kg/ha), 2007/08-10/11

	OLS-FE	
	DV = ln(cassava yield (kg/ha))	
Explanatory variables	APE	Pvalue
Year dummy (1=2011)	1.334	0.172
Main season rainfall (mm)	-0.001	0.809
ln(Exp. main season rainfall - coeff. Variation)	-0.530	0.134
ln(real exp price of cassava) (Mt/kg)	0.173	0.532
ln(real exp price of maize (Jul-Sep)) (Mt/Kg)	0.647	0.786
ln(real exp price of rice (Jan-Mar)) (Mt/Kg)	1.253	0.402
ln(real exp price of small g.nuts (Oct-Dec) (Mt/Kg)	-0.312	0.768
ln(real exp price, common beans (Jul-Sep)) (Mt/Kg)	3.258	0.147
ln(real exp price of cowpea (Jul-Sep)) (Mt/Kg)	-1.526	0.662
ln(real exp price of pigeon pea) (Mt/kg)	-1.271	0.061
ln(real exp price of cotton) (Mt/kg)	-0.053	0.834
ln(real exp price of tobacco) (Mt/kg)	-0.556	0.181
ln(real exp price of sesame) (Mt/kg)	-0.185	0.666
1=Village/nearby had maize depot this/last yr	0.856	0.596
ln(willage ag wage, MTN/day)	-0.010	0.959
1=Village has maize mill	-0.452	0.432
1=Nearby village has maize mill	-0.023	0.966
ln(Total landholding (Ha))	-0.229	0.329
# of HH members age 15-64	0.163	0.326
1=HH used animal traction	2.702	0.081
1=HH applied manure to this crop	1.797	0.064
Tropical livestock units	0.247	0.001
1=HH received price info through a radio	-0.855	0.006
Head's education (years)	-0.015	0.865
Head's age (years)	0.026	0.696
1=HH headed by a single female	0.369	0.656
Number of HH members age 0-4	0.228	0.166
Number of HH members age 5-14	-0.104	0.425
Number of HH members age 65 or above	1.169	0.041
Number of observations	1,122	
F(30, 737) and p-value / R2-within	3.39 (0.000) / 0.226	

Note: Model includes household fixed effects.

Table 31. DH Regression of Household Cassava Production (ha), 2007/08-10/11

	Probit		Log normal		Probit + Log Norm	
	DV = 1 if HH harvests cassava		DV = ln(HH cassava production (kg))			
			Growers (cond.)		All HHs (uncond.)	
Explanatory variables	APE	Pvalue	APE	Pvalue	APE	Pvalue
1=Agroecological zones (low)	-0.1356	0.0708	-0.293	0.516	-0.592	0.232
1=Agroecological zones (medium)	-0.0788	0.2345	-0.360	0.498	-0.578	0.334
1=Agroecological zones (high)	-0.2296	0.0081	0.123	0.875	-0.684	0.537
Year dummy (1=2011)	0.1314	0.1371	1.046	0.467	1.985	0.530
Main season rainfall (mm)	0.0000	0.9596	0.002	0.510	0.002	0.522
ln(Exp. main season rainfall - coeff. Variation)	-0.0104	0.7001	-0.506	0.027	-0.538	0.027
ln(real exp price of cassava) (Mt/kg)	-0.1213	0.0070	0.158	0.546	-0.226	0.412
ln(real exp price of maize (Jul-Sep)) (Mt/Kg)	-0.3151	0.1613	0.067	0.971	-0.930	0.623
ln(real exp price of rice (Jan-Mar)) (Mt/Kg)	0.2635	0.0973	0.336	0.777	1.170	0.348
ln(real exp price of small g.nuts (Oct-Dec) (Mt/Kg	0.3479	0.0008	0.253	0.772	1.354	0.134
ln(real exp price, common beans (Jul-Sep)) (Mt/K	0.7863	0.0008	2.789	0.137	5.279	0.006
ln(real exp price of cowpea (Jul-Sep)) (Mt/Kg)	-0.7736	0.0171	-1.335	0.612	-3.785	0.163
ln(real exp price of pigeon pea) (Mt/kg)	0.0647	0.4929	-0.713	0.152	-0.509	0.365
ln(real exp price of cotton) (Mt/kg)	-0.0309	0.2079	-0.018	0.917	-0.116	0.559
ln(real exp price of tobacco) (Mt/kg)	-0.0259	0.1780	-0.076	0.694	-0.158	0.408
ln(real exp price of sesame) (Mt/kg)	0.0524	0.3885	-0.081	0.803	0.085	0.823
Travel time to nearest town, 30k+ people (hrs)	0.0066	0.0613	0.002	0.915	0.022	0.292
ln(Distance to nearest formal market, km)	0.0134	0.2490	-0.065	0.342	-0.023	0.769
1=Village/nearby had maize depot this/last yr	-0.0514	0.1548	0.130	0.692	-0.036	0.913
1=Village/nearby had rice depot this/last yr	-0.0198	0.5700	-0.183	0.442	-0.237	0.344
1=Village has maize mill	-0.0617	0.2682	0.409	0.339	0.230	0.634
1=Nearby village has maize mill	-0.1771	0.0047	0.765	0.237	0.035	0.945
1=Village/nearby has cassava processing equip.	-0.0226	0.7307	0.044	0.907	-0.028	0.953
ln(distance to nearest fertilizer retailer, km)	0.0238	0.0399	0.035	0.686	0.110	0.245
ln(Distance to nearest seed retailer (km))	0.0058	0.4855	0.094	0.179	0.112	0.142
ln(willage ag wage, MTN/day)	0.0273	0.0392	0.173	0.084	0.259	0.018
ln(Total landholding (Ha))	0.0249	0.3155	0.264	0.119	0.370	0.029
# of HH members age 15-64	0.0008	0.9594	-0.001	0.990	0.001	0.994
1=HH used animal traction	0.0721	0.1546	0.133	0.898	0.401	0.767
Tropical livestock units	0.0047	0.2259	0.041	0.372	0.056	0.219
1=HH received price info through a radio	0.0598	0.0382	-0.080	0.764	0.113	0.717
Head's education (years)	-0.0047	0.6141	-0.107	0.142	-0.121	0.142
Head's age (years)	0.0045	0.2951	-0.026	0.520	-0.012	0.789
1=HH headed by a single female	0.1023	0.1116	0.185	0.855	0.605	0.706
Number of HH members age 0-4	-0.0082	0.6602	0.070	0.602	0.044	0.764
Number of HH members age 5-14	0.0498	0.0032	-0.087	0.349	0.071	0.515
Number of HH members age 65 or above	-0.0371	0.5818	0.620	0.240	0.502	0.412
Number of observations	2,347		1,195		2,347	
Psuedo R-squared / R-squared	0.3410		0.1819			

Notes: Model includes elevation (mm), slope, length of growing period, and household time-averages of all time-varying variables.

We find two interesting and encouraging positive effects of animal traction and livestock on cassava production. First, we find that households that use animal traction achieve cassava yields that are 270% higher than average. Given that there is essentially no animal traction in Nampula or Zambezia, this effect would appear to be caused by growers in Sofala and Manica with animal traction who may be new growers of cassava. This effect is significant to note because since the dependent variable is yield, this obviously implies that animal traction is improving yields, perhaps via more timely planting, better weed control, better soil aeration, etc. That said, we cannot claim causality in the case of positive or negative effects of animal traction on crop yields as TIA collects information on animal traction use at the farm and not the plot-level, thus we do not know for certain whether the fields on which cassava were grown were in fact prepared by animal traction.

The second important finding linked to large livestock is that the application of manure increases cassava yield by 179%, and our descriptive chapter above noted that manure application on crops is essentially only found in sample areas where large livestock are found (Tete, Manica, and Sofala), and not in areas such as Zambezia or Tete where the presence of tsetse fly is believed to provide the main constraint to adoption of large livestock. The large effect of manure highlights a very import by-product of large livestock, which can be of use to the household not only for use as draught animals, but which also provide manure, in addition to potentially meat and/or dairy products, depending on the animal. Third, we find that an additional unit of TLU (i.e., a cow) increases cassava yield by 25% (Table 30). Because we are separately controlling for manure use and animal traction already, this suggests that TLU in this case is capturing a positive effect of household wealth on cassava yields. The way in which a wealthier household might increase cassava yield could either be through a higher probability of hiring labor or perhaps accessing borrowed or shared labor. Finally, we also find that some of the large increase in cassava yields is due to the average effect of unobserved factors, as the year dummy is nearly significant (p=0.13) and the magnitude of the effect is quite large (133%) (Table 30).

Given that both average cassava area and yields increased over time, it is not surprising that we also find that average household production (among growers) increased 2,502 to 2,876 kg, an increase of 15%. From our econometric analysis of household cassava production (per household) we again see increased expected food crop prices as an important driver of this change. For example, among all households, an increase of 1% in the expected price of common beans leads to a 5.3% increase in cassava production, while a 1% increase in the expected price of small groundnuts leads to a nearly significant 1.3% increase in cassava production (p-value of 0.13) (Table 31). The effect of rice prices on cassava production is positive and of similar magnitude though not significant (p-value of 0.348). The other main factor explaining the increase in household cassava production is increased total land holding (as noted above), as a 10% increase in total area increased cassava production by 2.6% among cassava growers and by 2.7% among all households.

Our descriptive and econometric analysis shows that cassava production increased on average by 15% due to a combination of both extensification (a large increase in the percentage of households growing cassava) and intensification (an increase in cassava yields). The increase in cassava participation seems to have been primarily driven by increases in the expected prices of rice, beans and groundnuts, while increases in area planted were primarily driven by increases in the expected price of maize. Increases in cassava yields appear to be driven by various factors, one being an increase in labor applied by adults over 65, use of animal traction, and the average effect of unobserved factors (i.e., the year dummy).

8.2.4. Cowpeas

Cowpea is an important food crop grown by smallholder farmers in Mozambique for both leaf and grain harvesting. Farmers usually grow speading varieties, which have low grain yields but have high biomass for leaf harvesting over a long period for both home consumptions and the market. In many parts of the country farmers actually give higher importance to leaves than the grain (CIAT/ICRISAT/IITA 2013).

The proportion of farmers growing cowpeas increased by 13% between 2008 (35.3%) and 2011 (39.9%), but the average area remained unchanged although some provinces experienced an increase (Nampula and Sofala). Average yields and total production of grain are still quite low in part because cowpeas are mostly consumed as a leaf crop. Other than in Tete Province where about 5.6% (13.2%) of farmers applied manure in 2008 (2011) to cowpea, the use of manure and other yield-enhancing technologies such as use of improved varieties is practically non-existent.

Since maize is the most important staple food crop in Mozambique, many production decisions involving other crops are influenced by a household's decisions regarding its maize production. For example, households in the partial panel sample cultivated more than 5,700 machambas in 2008, yet only 11 machambas had cowpeas grown in a monocrop system. That is, in the vast majority of machambas which included cowpea, it was intercropped with maize and/or a combination of other crops. This positive correlation between maize and cowpea area perhaps explains why we find that a 10% increase in the expected maize price increases the probability of growing cowpeas by 2% and increases area planted to cowpea by 1.7 ha (among cowpea growers) (Table 32). Likewise, the presence of a maize mill in the village leads to a 1.6% increase in cowpea yield (Table 33). It appears that the primary rival crop of cowpeas in an intercropped system is small groundnuts, as a 10% increase in the expected price of small groundnuts leads to a 2.8% decrease in the probability that a household plants cowpeas.

We do find an unexpectedly negative and significant effect of the expected cowpea price on the probability of planting cowpea and cowpea area (Table 32). However, we also find that a 1% increase in the expected price of cowpea leads to a positive (yet not significant) effect on cowpea yield (Table 33) and a positive and significant increase in cowpea production of 129 kg (Table 34).[45] Given that increases in the expected cowpea price have a negative effect on cowpea area, the significant positive increase in cowpea production per household appears to be achieved through agricultural intensification, given that we find a positive and large (though not significant p=0.38) effect of this price on cowpea yield (Table 34).

[45] While the magnitude of the APE of the expected cowpea price on conditional quantity of cowpea produced is quite large, investigation of the distribution of cowpea production in the two years suggests that the large manigutde of this APE is due to the fact that there was a rather large percentage increase in the mean quantity of cowpea produced among growers over time (from a mean of 49 kg in 2007/08 to 67 kg in 2010/11) (Table 15)

Table 32. DH Regression of Household Area Planted to Cowpeas (ha), 2007/08-10/11

	Probit		Truncated normal		Probit + Trunc. N.	
	DV = 1 if HH plants cowpea		DV = HH area in cowpeas (ha)			
			Growers (cond).		All HHs (uncond.)	
Explanatory variables	APE	Pvalue	APE	Pvalue	APE	Pvalue
1=zone 10 (wet SAT, high altitude north-central)	-0.147	0.039	-0.040	0.466	-0.049	0.110
1=zone 5 (wet SAT, central coast)	0.047	0.000	0.026	0.002	0.022	0.000
1=zone 7 (wet SAT, mid-elevation north-central)	-0.109	0.000	-0.039	0.025	-0.040	0.000
1=zone 8 (SAT, coastal north-central)	-0.302	0.000	0.014	0.000	-0.074	0.000
Elevation - meters above sea level	0.000	0.999	0.000	0.998	0.000	0.999
Expected main season rainfall - coeff. variation	-0.001	0.983	0.001	0.989	0.000	0.998
Expected main season rainfall (mm)	0.000	0.999	0.001	0.995	0.000	0.996
Slope - measure of steepness (degrees)	0.009	0.870	-0.015	0.806	-0.003	0.887
Length of growing period (days)	-0.003	0.970	0.000	1.000	-0.001	0.983
Year dummy (1=2011)	0.080	0.236	0.060	0.219	0.043	0.094
ln(real exp price of maize (Jul-Sep)) (Mt/Kg)	0.216	0.000	0.177	0.000	0.119	0.000
ln(real exp price of rice (Jul-Sep)) (Mt/Kg)	0.066	0.000	-0.519	0.000	-0.179	0.000
ln(real exp price of small g.nuts (Jul-Sep)) (Mt/Kg)	-0.279	0.000	0.020	0.000	-0.060	0.000
ln(real exp price, common beans (Jul-Sep)) (Mt/Kg	0.066	0.153	0.108	0.001	0.057	0.000
ln(real exp price of cowpea (Jul-Sep)) (Mt/Kg)	-1.414	0.000	-0.409	0.000	-0.496	0.000
ln(real exp price of pigeon pea) (Mt/kg)	-0.009	0.920	0.114	0.080	0.041	0.245
ln(real exp price of cassava) (Mt/kg)	0.067	0.000	0.029	0.000	0.027	0.000
ln(real exp price of cotton) (Mt/kg)	0.036	0.694	-0.052	0.378	-0.011	0.738
ln(real exp price of tobacco) (Mt/kg)	0.024	0.813	0.011	0.832	0.010	0.768
ln(real exp price of sesame) (Mt/kg)	0.119	0.695	-0.046	0.868	0.012	0.925
Distance to nearest fertilizer retailer (km)	0.000	0.649	0.000	0.000	0.000	0.000
Distance to nearest formal market (km)	0.001	0.092	0.001	0.325	0.001	0.064
Distance to nearest seed retailer (km)	0.000	0.774	0.000	0.768	0.000	0.679
Travel time to nearest town, 30k+ people (hrs)	-0.008	0.000	0.000	0.825	-0.001	0.000
1=Village/nearby had maize depot this/last yr	-0.063	0.073	-0.031	0.207	-0.026	0.024
1=Village has maize mill	-0.012	0.605	-0.010	0.561	-0.007	0.423
1=Nearby village has maize mill	0.017	0.374	-0.043	0.005	-0.012	0.111
1=Village/nearby village has maize mill	0.096	0.298	-0.081	0.229	-0.014	0.653
1=HH received price info through a radio	0.045	0.542	-0.036	0.561	-0.003	0.900
Total landholding size (Ha)	0.004	0.991	0.036	0.905	0.014	0.920
# of HH members age 15-64	0.059	0.753	0.021	0.900	0.022	0.769
Tropical livestock units	0.010	0.968	-0.002	0.994	0.002	0.984
1=HH used animal traction	0.065	0.000	-0.001	0.898	0.015	0.000
Head's age (years)	-0.006	0.880	-0.002	0.958	-0.002	0.904
Head's education (years)	-0.031	0.912	-0.003	0.989	-0.009	0.935
1=HH headed by a single female	-0.057	0.000	-0.029	0.000	-0.024	0.000
Number of HH members age 0-4	0.005	0.959	-0.004	0.966	0.000	0.996
Number of HH members age 5-14	0.051	0.093	-0.008	0.751	0.010	0.394
Number of HH members age 65 or above	0.245	0.000	-0.060	0.002	0.037	0.000
Number of observations	2353		896		2353	
Pseudo R-squared / Wald chi2(69), Pr>chi2	0.087		134.9 (0.0000)			

Table 33. OLS-FE Regression of the Log of Household Cowpea Yield (kg/ha), 2007/08-10/11

	OLS-FE	
	DV = ln(HH cowpea yield (kg/ha))	
Explanatory variables	Coeff.	Pvalue
Expected main season rainfall - coeff. variation	-0.010	0.362
Main season rainfall (mm)	-0.002	0.498
Year dummy (1=2011)	0.797	0.485
ln(real exp price of maize (Jul-Sep)) (Mt/Kg)	-4.217	0.124
ln(real exp price of rice (Jul-Sep)) (Mt/Kg)	6.466	0.110
ln(real exp price of small g.nuts (Jul-Sep)) (Mt/Kg)	2.790	0.177
ln(real exp price, common beans (Jul-Sep)) (Mt/Kg)	1.029	0.739
ln(real exp price of cowpea (Jul-Sep)) (Mt/Kg)	1.926	0.566
ln(real exp price of pigeon pea) (Mt/kg)	-1.340	0.248
ln(real exp price of cassava) (Mt/kg)	0.131	0.775
ln(real exp price of cotton) (Mt/kg)	-0.425	0.212
ln(real exp price of tobacco) (Mt/kg)	0.234	0.386
ln(real exp price of sesame) (Mt/kg)	-0.343	0.590
1=Village/nearby had maize depot this/last yr	1.003	0.595
1=Village has maize mill	1.632	0.048
1=Nearby village has maize mill	0.281	0.710
1=HH received price info through a radio	-0.239	0.576
Total landholding size (Ha)	-0.121	0.004
Total landholding size (Ha) - squared	-0.623	0.324
# of HH members age 15-64	1.147	0.003
# of HH members age 15-64, squared	-0.095	0.021
Tropical livestock units	0.016	0.704
1=HH used animal traction	-0.244	0.677
1=household applied manure to cowpeas	-0.977	0.146
1=household used improved cowpea seed variety	-2.384	0.000
1=HH used manure/improved cowpea seed (interaction)	2.072	0.089
Head's age (years)	-0.132	0.582
Head's age (years), squared	0.000	0.911
Head's education (years)	-0.011	0.917
1=HH headed by a single female	-0.480	0.454
Number of HH members age 0-4	0.386	0.139
Number of HH members age 5-14	0.240	0.174
Number of HH members age 65 or above	1.612	0.112
Constant	-22.502	0.247
Number of observations	719	
F (32,558) p-value / R^2-within	4.53 (0.000) / 0.318	

Notes: Model includes household fixed effects.

Table 34. DH Regression of Household Cowpea Production (kg), 2007/08-10/11

	Probit		Truncated		Probit + Trunc. N.	
	DV = 1 if HH plants cowpeas		DV = HH cowpea production (Kg)			
			Growers (cond.)		All HHs (uncond.)	
Explanatory variables	APE	Pvalue	APE	Pvalue	APE	Pvalue
1=zone 10 (wet SAT, high altitude north-central)	-0.150	0.035	-37.750	0.318	-26.620	0.117
1=zone 5 (wet SAT, central coast)	0.049	0.000	44.649	0.000	24.339	0.000
1=zone 7 (wet SAT, mid-elevation north-central)	-0.109	0.000	-39.436	0.000	-24.433	0.000
1=zone 8 (SAT, coastal north-central)	-0.282	0.000	-20.025	0.000	-19.750	0.000
Elevation - meters above sea level	0.000	0.999	0.035	0.998	0.012	0.999
Expected main season rainfall - coeff. variation	-0.001	0.981	-0.925	0.989	-0.472	0.986
Main season rainfall (mm)	0.000	0.998	0.011	1.000	-0.014	1.000
Slope - measure of steepness (degrees)	0.009	0.859	-6.631	0.785	-2.287	0.846
Length of growing period (days)	-0.004	0.974	0.416	0.997	-0.033	0.999
Year dummy (1=2011)	0.034	0.608	-10.850	0.662	-2.711	0.804
ln(real exp price of maize (Jul-Sep)) (Mt/Kg)	0.259	0.000	-34.298	0.000	0.489	0.789
ln(real exp price of rice (Jul-Sep)) (Mt/Kg)	0.220	0.000	-54.555	0.000	-10.409	0.000
ln(real exp price of small g.nuts (Jul-Sep)) (Mt/Kg)	-0.266	0.000	77.658	0.000	17.584	0.000
ln(real exp price, common beans (Jul-Sep)) (Mt/Kg)	-0.005	0.904	138.542	0.000	58.808	0.000
ln(real exp price of cowpea (Jul-Sep)) (Mt/Kg)	-1.319	0.000	129.037	0.000	-22.020	0.000
ln(real exp price of pigeon pea) (Mt/kg)	-0.002	0.981	53.631	0.126	22.761	0.116
ln(real exp price of cassava) (Mt/kg)	0.066	0.000	20.323	0.000	12.553	0.000
ln(real exp price of cotton) (Mt/kg)	0.034	0.712	-11.772	0.844	-3.065	0.905
ln(real exp price of tobacco) (Mt/kg)	0.030	0.763	17.452	0.766	9.226	0.755
ln(real exp price of sesame) (Mt/kg)	0.117	0.706	-26.017	0.840	-4.247	0.937
Distance to nearest fertilizer retailer (km)	0.000	0.937	0.199	0.000	0.085	0.000
Distance to nearest formal market (km)	0.001	0.133	0.155	0.785	0.135	0.557
Distance to nearest seed retailer (km)	0.000	0.809	0.172	0.594	0.059	0.670
Travel time to nearest town, 30k+ people (hrs)	-0.008	0.000	0.843	0.000	0.010	0.885
1=Village/nearby had maize depot this/last yr	-0.062	0.072	6.300	0.579	-1.153	0.833
1=Village has maize mill	-0.020	0.395	13.112	0.070	4.598	0.147
1=Nearby village has maize mill	0.008	0.663	7.850	0.238	4.056	0.185
1=Village/nearby village has maize mill	0.082	0.376	4.560	0.938	7.196	0.762
1=HH received price info through a radio	0.043	0.556	9.142	0.918	6.733	0.810
Total landholding size (Ha)	0.016	0.970	7.849	0.962	4.028	0.954
# of HH members age 15-64	0.056	0.772	10.090	0.903	7.483	0.829
Tropical livestock units	0.010	0.968	1.474	0.988	1.243	0.976
1=HH used animal traction	0.065	0.000	15.760	0.001	11.684	0.000
Head's age (years)	-0.006	0.882	0.959	0.964	0.025	0.998
Head's education (years)	-0.029	0.926	-3.886	0.979	-3.369	0.956
1=HH headed by a single female	-0.054	0.000	40.470	0.000	12.039	0.000
Number of HH members age 0-4	0.004	0.969	-2.723	0.950	-0.925	0.961
Number of HH members age 5-14	0.052	0.091	-2.098	0.872	2.117	0.710
Number of HH members age 65 or above	0.246	0.000	-9.295	0.299	10.406	0.008
Number of observations	2353		822		2336	
Pseudo R-squared / Wald chi2(69), Pr>chi2	0.088		10.5(1.0)			

Average cowpea yield in the sample increase by 21%, and it appears that yield increases were driven by two main factors. First, an additional household member age 15-64 increases cowpea yield by 114% an additional member age 65 or older increases yield by 161% (nearly significant p=0.11) (Table 33), suggesting that additional family labor per hectare (in weeding, harvesting, etc.) may partly explain the average increase in cowpea yield. While we surprisingly find that use of an improved cowpea variety has a negative and significant effect on cowpea yield, when an improved cowpea variety is used together with manure, this leads to a 200% increase in yields. That said, this interaction effect of use of an improved variety and manure does not likely explain that much of the average yield increase given that the percentage of cowpea growers using either of those improved inputs on cowpea increased over time but is not high. A third form of intensification of cowpea grain (our dependent variable), relates to the dual-product nature of cowpea production – that is, it produces both grain and edible leaves. . There is some degree of trade-off in production of those two by-products, as a study conducted in Kenya shows that leaf harvesting in cowpea can result in about 50% loss in cowpea grain yield (Saidi et al. 2010). Thus, it is possible that cowpea growers are reducing cowpea leaf harvesting for consumption in response to an increase in cowpea grain prices.

In general, market access variables do not appear to have a significant effect on smallholder area planted to cowpeas, cowpea yields or cowpea production. This may simply be due to that fact that cowpea appears to primarily be retained by growers, as only 13% of smallholders in the sample who grow cowpea also sell some of their production. Thus, the only marketing infrastructure that has a significant and expected effect on cowpea production is the presence of a maize mill, which indirectly increases cowpea production because of the tendency of many smallholder maize producers to intercrop maize with a legume such as cowpea.

8.2.5. Common Beans

As we saw above, the province where common bean is most commonly grown is Tete (67.5% or households grew it in 2010/11), and while participation in this crop did not change over time in Tete, there were sizeable increases from 2007/08 to 2010/11 in the percentage of growers in Manica (8% to 19.9%) and Sofala (5.6% to 8.8%) (Table 7). This increase in participation appears to be driven by an increase in the expected common bean price, as we find that a 10% increase in this price has a significant though small (0.6%) effect on the probability of growing common beans, yet a larger effect on area planted (raising it by 1.0 hectare among current growers and by 0.5 ha among any given household, *ceteris paribus*) (Table 35). When prices of the main food crop (maize) that is usually intercropped with common beans increases, the probability of growing beans and the area planted to beans also increases. For example, a 10% increase in the expected maize price increases the probability of growing common beans by 2.1% and common bean area by 1.2 ha among any given household (the unconditional effect) (Table 35). Yet, in some cases, maize competes with common bean for area planted, as the presence of a maize buying depot reduces the probability of growing common bean by 6.3% (Table 35) – possibly because cowpea is more often grown in inter-crop with maize than common bean and/or that the presence of a buying depot results in farmers in that village receiving a significantly better maize price.

We also find that for smallholders in the partial panel villages, the main competition for common bean area comes from other pulse crops, specifically small groundnuts and cowpea, as a 10% increase in the price of those crops decreases the probability of growing common bean by 2.8% and 14% respectively (Table 35). The evidence from the area regression already suggests that smallholders are responding to higher expected common bean prices via extensification. Further evidence to support this conclusion is that use of animal traction increases the probability of growing common bean by 6.5% (Table 35), and we noted above that there was a large increase in animal traction use in the area where most farmer grow common bean (Tete) and smaller increases in the other two areas where participation increased (Manica and Sofala). However, there is also some evidence of intensification as animal traction use increases common bean yields by 88% (Table 36). It also increases common bean production per household by 102 kg (Table 37).

Table 35. DH Regression of Household Area Planted to Common Beans (ha), 2007/08-10/11

	Probit		Truncated normal		Probit + Trunc. N.	
	DV = 1 if HH plants beans		DV = HH area in beans (ha)			
			Growers (cond).		All HHs (uncond.)	
Explanatory variables	APE	Pvalue	APE	Pvalue	APE	Pvalue
1=zone 10 (wet SAT, high altitude north-central)	-0.147	0.001	-0.040	0.540	-0.049	0.038
1=zone 5 (wet SAT, central coast)	0.047	0.000	0.026	0.259	0.022	0.000
1=zone 7 (wet SAT, mid-elevation north-central)	-0.109	0.000	-0.039	0.317	-0.040	0.000
1=zone 8 (SAT, coastal north-central)	-0.302	0.000	0.014	0.057	-0.074	0.000
Elevation - meters above sea level	0.000	0.999	0.000	1.000	0.000	1.000
Expected main season rainfall - coeff. variation	-0.001	0.972	0.001	0.998	0.000	0.999
Expected main season rainfall (mm)	0.000	0.999	0.001	0.999	0.000	0.999
Slope - measure of steepness (degrees)	0.009	0.859	-0.015	0.920	-0.003	0.915
Length of growing period (days)	-0.003	0.977	0.000	1.000	-0.001	0.998
Year dummy (1=2011)	0.080	0.157	0.060	0.900	0.043	0.664
ln(real exp price of maize (Jul-Sep)) (Mt/Kg)	0.216	0.000	0.177	0.000	0.119	0.000
ln(real exp price of rice (Jul-Sep)) (Mt/Kg)	0.066	0.000	-0.519	0.000	-0.179	0.000
ln(real exp price of small g.nuts (Jul-Sep)) (Mt/Kg)	-0.279	0.000	0.020	0.000	-0.060	0.000
ln(real exp price, common beans (Jul-Sep)) (Mt/Kg	0.066	0.002	0.108	0.102	0.057	0.000
ln(real exp price of cowpea (Jul-Sep)) (Mt/Kg)	-1.414	0.000	-0.409	0.000	-0.496	0.000
ln(real exp price of pigeon pea) (Mt/kg)	-0.009	0.824	0.114	0.651	0.041	0.414
ln(real exp price of cassava) (Mt/kg)	0.067	0.000	0.029	0.000	0.027	0.000
ln(real exp price of cotton) (Mt/kg)	0.036	0.570	-0.052	0.865	-0.011	0.907
ln(real exp price of tobacco) (Mt/kg)	0.024	0.760	0.011	0.979	0.010	0.943
ln(real exp price of sesame) (Mt/kg)	0.119	0.342	-0.046	0.913	0.012	0.907
Distance to nearest fertilizer retailer (km)	0.000	0.391	0.000	0.030	0.000	0.000
Distance to nearest formal market (km)	0.001	0.476	0.001	0.857	0.001	0.510
Distance to nearest seed retailer (km)	0.000	0.628	0.000	0.945	0.000	0.811
Travel time to nearest town, 30k+ people (hrs)	-0.008	0.000	0.000	0.956	-0.001	0.000
1=Village/nearby had maize depot this/last yr	-0.063	0.009	-0.031	0.478	-0.026	0.063
1=Village has maize mill	-0.012	0.451	-0.010	0.781	-0.007	0.484
1=Nearby village has maize mill	0.017	0.210	-0.043	0.181	-0.012	0.144
1=Village/nearby village has maize mill	0.096	0.121	-0.081	0.553	-0.014	0.729
1=HH received price info through a radio	0.045	0.435	-0.036	0.811	-0.003	0.946
Total landholding size (Ha)	0.004	0.979	0.036	0.981	0.014	0.963
# of HH members age 15-64	0.059	0.465	0.021	0.969	0.022	0.846
Tropical livestock units	0.010	0.954	-0.002	0.999	0.002	0.995
1=HH used animal traction	0.065	0.000	-0.001	0.951	0.015	0.001
Head's age (years)	-0.006	0.868	-0.002	0.989	-0.002	0.951
Head's education (years)	-0.031	0.854	-0.003	0.997	-0.009	0.953
1=HH headed by a single female	-0.057	0.000	-0.029	0.043	-0.024	0.000
Number of HH members age 0-4	0.005	0.945	-0.004	0.993	0.000	0.998
Number of HH members age 5-14	0.051	0.002	-0.008	0.935	0.010	0.631
Number of HH members age 65 or above	0.245	0.000	-0.060	0.052	0.037	0.000
Number of observations	2353		503		2352	
Pseudo R-squared / Wald chi2(69), Pr>chi2	0.398		163.4 (0.000)			

Table 36. OLS-FE Regression of the Log of Household Common Bean Yield (kg/ha), 2007/08-10/11

	OLS-FE	
	DV = ln(HH beans yield (kg/ha))	
Explanatory variables	Coeff.	Pvalue
Expected main season rainfall - coeff. variation	-1.475	0.079
Main season rainfall (mm)	-0.116	0.431
Year dummy (1=2011)	-7.512	0.574
ln(real exp price of maize (Jul-Sep)) (Mt/Kg)	-32.660	0.327
ln(real exp price of rice (Jul-Sep)) (Mt/Kg)	-19.131	0.531
ln(real exp price of small g.nuts (Jul-Sep)) (Mt/Kg)	68.338	0.448
ln(real exp price, common beans (Jul-Sep)) (Mt/Kg)	-5.772	0.912
ln(real exp price of pigeon pea) (Mt/kg)	12.819	0.043
ln(real exp price of cassava) (Mt/kg)	0.523	0.809
ln(real exp price of cotton) (Mt/kg)	-6.372	0.532
ln(real exp price of tobacco) (Mt/kg)	-0.286	0.575
1=Village/nearby had maize depot this/last yr	1.756	0.001
1=Village has maize mill	1.177	0.007
1=Village/nearby village has maize mill	0.012	0.989
1=HH received price info through a radio	0.334	0.136
Total landholding size (Ha)	-0.153	0.283
Total landholding size (Ha) - squared	0.005	0.207
# of HH members age 15-64	-0.817	0.109
# of HH members age 15-64, squared	0.092	0.204
Tropical livestock units	0.208	0.001
1=HH used animal traction	0.865	0.004
1=HH applied manure to common beans	0.001	0.999
1=HH used improved common beans seed variety	-0.147	0.832
1=HH applied fertilizer to common beans	0.190	0.896
1=HH applied fertilizer to common beans interactio	-0.005	0.448
1=HH applied manure and improved common bean	0.310	0.765
Head's age (years)	0.065	0.780
Head's age (years), squared	0.000	0.870
Head's education (years)	-0.520	0.046
Head's education (years) - squared	0.092	0.013
1=HH headed by a single female	0.355	0.630
Number of HH members age 0-4	0.048	0.840
Number of HH members age 5-14	-0.110	0.570
Number of HH members age 65 or above	0.662	0.306
Constant	-104.926	0.492
Number of observations	465	
F (36,327) p-value / R^2-within	4.53 (0.000) / 0.500	

Notes: Model includes household fixed effects.

Table 37. DH Regression of Household Production of Common Beans (kg), 2007/08-10/11

	Probit		Truncated normal		Probit + Trunc. N.	
	DV = 1 if HH plants beans		DV = HH beans production (ha)			
			Growers (cond).		All HHs (uncond.)	
Explanatory variables	APE	Pvalue	APE	Pvalue	APE	Pvalue
1=zone 10 (wet SAT, high altitude north-central)	0.070	0.116	32.855	0.403	15.379	0.275
1=zone 5 (wet SAT, central coast)	-0.062	0.000	-82.436	0.000	-19.255	0.000
1=zone 7 (wet SAT, mid-elevation north-central)	0.028	0.090	54.552	0.005	15.097	0.001
1=zone 8 (SAT, coastal north-central)	-0.065	0.000	-93.187	0.000	-21.726	0.000
Elevation - meters above sea level	0.000	0.995	0.178	0.999	0.068	0.999
Expected main season rainfall - coeff. variation	-0.002	0.964	1.287	0.988	0.087	0.993
Main season rainfall (mm)	0.000	1.000	0.114	1.000	0.025	1.000
Slope - measure of steepness (degrees)	-0.013	0.810	-7.883	0.851	-3.071	0.851
Length of growing period (days)	0.000	0.998	-0.720	0.998	-0.117	0.999
Year dummy (1=2011)	-0.172	0.005	-676.888	0.002	-277.962	0.000
ln(real exp price of maize (Jul-Sep)) (Mt/Kg)	0.317	0.000	1008.664	0.000	238.765	0.000
ln(real exp price of rice (Jul-Sep)) (Mt/Kg)	0.400	0.000	-305.505	0.000	-15.696	0.000
ln(real exp price of small g.nuts (Jul-Sep)) (Mt/Kg)	-0.011	0.000	-231.047	0.000	-47.672	0.000
ln(real exp price, common beans (Jul-Sep)) (Mt/Kg)	-0.409	0.000	-1036.431	0.000	-254.873	0.000
ln(real exp price of cowpea (Jul-Sep)) (Mt/Kg)	0.547	0.000	514.948	0.000	165.911	0.000
ln(real exp price of pigeon pea) (Mt/kg)	-0.082	0.046	-4.118	0.989	-10.144	0.788
ln(real exp price of cassava) (Mt/kg)	0.036	0.000	127.174	0.000	29.683	0.000
ln(real exp price of cotton) (Mt/kg)	-0.037	0.553	-6.539	0.947	-5.544	0.734
ln(real exp price of tobacco) (Mt/kg)	-0.015	0.858	19.706	0.443	2.209	0.727
ln(real exp price of sesame) (Mt/kg)	-0.090	0.720	-129.046	0.794	-36.192	0.728
Distance to nearest fertilizer retailer (km)	-0.001	0.000	1.441	0.000	0.213	0.000
Distance to nearest formal market (km)	0.000	0.908	0.035	0.989	-0.026	0.970
Distance to nearest seed retailer (km)	0.001	0.195	-1.189	0.361	-0.153	0.570
Travel time to nearest town, 30k+ people (hrs)	0.002	0.000	5.837	0.000	1.332	0.000
1=Village/nearby had maize depot this/last yr	-0.057	0.015	-48.198	0.013	-15.331	0.005
1=Village has maize mill	0.117	0.000	-454.256	0.000	-37.590	0.000
1=Nearby village has maize mill	0.129	0.000	-194.217	0.000	-21.725	0.000
1=Village/nearby village has maize mill	0.171	0.007	-122.385	0.022	-18.562	0.190
1=HH received price info through a radio	0.053	0.357	31.547	0.818	12.775	0.751
Total landholding size (Ha)	0.004	0.989	-6.738	0.993	-0.876	0.996
# of HH members age 15-64	0.003	0.983	-5.549	0.990	-0.738	0.994
Tropical livestock units	0.000	0.999	5.761	0.994	1.140	0.994
1=HH used animal traction	0.051	0.000	102.601	0.000	29.829	0.000
Head's age (years)	0.004	0.907	-4.440	0.936	-0.510	0.966
Head's education (years)	-0.006	0.984	3.343	0.996	0.023	1.000
1=HH headed by a single female	0.050	0.000	95.987	0.000	28.848	0.000
Number of HH members age 0-4	0.031	0.665	-10.847	0.949	1.364	0.969
Number of HH members age 5-14	-0.004	0.817	11.865	0.854	1.891	0.885
Number of HH members age 65 or above	0.023	0.066	165.332	0.000	35.866	0.000
Number of observations	2353		493		2350	
Pseudo R-squared / Wald chi2(70), Pr>chi2	0.400					

We also find that tropical livestock units had a positive and significant effect on common beans yields (Table 36), which may also suggest an intensification effect (likely due to livestock in Tete where many households also grow common beans) via manure application to common beans. We also find that a 1% increase in the expected price of common bean increases common bean yield by 30.5%. While this effect is too large to be credible, it is not apparent what is causing it as average and median bean yields among most of the growers in our sample (from Tete) do not appear to change much across the two panels. Nevertheless, it suggests an intensification response that does not appear to be through increased labor use per hectare, as the partial effect on our proxy for available family labor is negative though insignificant.

There are also some results from the common bean production regression which at first appear to be contradictory. For example, we find that a 1% increase in the common bean price leads to a very large (1036 kg) decrease in common bean production per household. One explanation for this seemingly contradictory finding is that in the provinces where cowpea participation increased, average quantity produced per household fell over time (from 134 to 123 kg in Tete, from 155 to 112 kg in Manica, and from 52 to 32 kg in Sofala) Table 15 – perhaps because the new common bean growers planted less area or received lower yields due to their inexperience with common bean production. Another explanation may be that although a reasonably large percentage of common bean growers sell some of their production (37% in 2008), because common bean is typically grown intercropped with maize, it may be that maize prices are what is really driving common bean production – as we find significant and large effects of the expected maize price on both common bean area and production per household (Table 35 and 37).

Unlike for cowpeas and most other food crops, we find a significant and negative effect of travel time to the nearest town of 30,000+ residents. That said, this effect is rather small in magnitude, as a 10 hour decrease in travel time to this size town only increases the probability of growing common bean by 0.8% (Table 35). In addition, there is no effect of distance to a formal market on cowpea area or production. The only market access variables that have a sizeable effect on common bean production are related to maize, as presence of a maize depot or maize mill increases the probability of common bean planting (Table 35) but only increases yields by 1-2 kg/ha (Table 36). Again, it appears that common bean area and production are being driven indirectly by the demand for the maize, the crop with which it is generally intercropped.

8.2.6. Pigeon Peas

Given that the expected price of pigeon pea increased from an average of 5.9 MTN/kg in 2007/08 to an average of 8.1 MTN/kg in 2010/11 (in real prices) and the percentage of growers increased from 26.4 to 41% across the two waves (Table 7), it is, therefore, surprising that the effect of a 10% increase in the expected price of pigeon peas is quite small, as it only increases the probability of growing pigeon peas by 1.1% (Table 38). Even more surprising is that there is no significant effect of the pigeon pea price on area planted to pigeon pea, though the direction of the effect is positive. One explanation for this result might be that anecdotal evidence during the 2010/11 survey suggested that there were many traders buying pigeon pea that season that had not been active in earlier years – yet they apparently did not have temporary buying depots (at least, none were recorded in our community survey in 2010/11). Thus, it is possible that although average prices increased dramatically, we are not able to explain variation across households and over time in pigeon pea area cultivated because we do not have a measure of which villages were targeted by traders interested in pigeon pea (assuming this occurred in 2009/10, which would have generated the expectation of a market for pigeon pea in 2010/11).

Table 38. DH Regression of Household Area Planted to Pigeon Peas (ha), 2007/08-10/11

	Probit		Truncated normal		Probit + Trunc. N.	
	DV = 1 if HH plants pigeonpea		DV = HH area in pigeonpeas (ha)			
			Growers (cond).		All HHs (uncond.)	
Explanatory variables	APE	Pvalue	APE	Pvalue	APE	Pvalue
1=zone 10 (wet SAT, high altitude north-central)	-0.036	0.269	0.035	0.894	-0.014	0.736
1=zone 5 (wet SAT, central coast)	0.003	0.589	0.126	0.002	0.023	0.000
1=zone 7 (wet SAT, mid-elevation north-central)	-0.136	0.000	-0.180	0.004	-0.100	0.000
1=zone 8 (SAT, coastal north-central)	0.141	0.000	2.463	0.000	1.011	0.000
Elevation - meters above sea level	0.000	0.993	0.000	0.999	0.000	1.000
Expected main season rainfall - coeff. variation	-0.001	0.974	0.060	0.791	0.007	0.869
Expected main season rainfall (mm)	0.000	1.000	-0.002	0.999	0.000	1.000
Slope - measure of steepness (degrees)	0.000	0.996	0.020	0.990	0.002	0.987
Length of growing period (days)	-0.001	0.993	0.002	0.999	0.000	1.000
Year dummy (1=2011)	-0.165	0.000	-0.269	0.476	-0.164	0.005
ln(real exp price of maize (Oct-Dec)) (Mt/Kg)	0.137	0.000	1.075	0.000	0.211	0.000
ln(real exp price of rice (Oct-Dec)) (Mt/Kg)	0.217	0.000	-2.047	0.000	-0.156	0.000
ln(real exp price of small g.nuts (Oct-Dec) (Mt/Kg)	0.014	0.000	-0.868	0.000	-0.106	0.000
ln(real exp price, common beans (Oct-Dec)) (Mt/Kg	-0.005	0.810	-0.760	0.000	-0.102	0.000
ln(real exp price of cowpea (Oct-Dec)) (Mt/Kg)	-0.277	0.000	1.433	0.000	0.045	0.000
ln(real exp price of pigeon pea) (Mt/kg)	0.110	0.026	0.169	0.954	0.079	0.826
ln(real exp price of cassava) (Mt/kg)	0.043	0.000	0.040	0.000	0.027	0.000
ln(real exp price of cotton) (Mt/kg)	0.006	0.911	-0.006	0.999	0.002	0.997
ln(real exp price of tobacco) (Mt/kg)	0.003	0.957	0.099	0.977	0.014	0.979
ln(real exp price of sesame) (Mt/kg)	0.047	0.717	0.234	0.855	0.055	0.772
Distance to nearest fertilizer retailer (km)	0.000	0.000	-0.001	0.200	0.000	0.000
Distance to nearest formal market (km)	0.002	0.445	0.006	0.859	0.002	0.733
Distance to nearest seed retailer (km)	0.000	0.592	-0.002	0.686	0.000	0.549
Travel time to nearest town, 30k+ people (hrs)	0.002	0.000	0.014	0.000	0.004	0.000
1=Village/nearby had maize depot this/last yr	-0.017	0.354	-0.016	0.845	-0.011	0.470
1=Village has maize mill	0.016	0.158	-0.168	0.002	-0.019	0.064
1=Nearby village has maize mill	-0.033	0.001	-0.148	0.006	-0.037	0.000
1=Village/nearby village has maize mill	-0.034	0.584	-0.130	0.620	-0.032	0.562
1=HH received price info through a radio	0.000	0.995	-0.001	0.999	0.000	0.999
Total landholding size (Ha)	0.006	0.973	0.104	0.979	0.017	0.975
# of HH members age 15-64	0.018	0.831	0.085	0.897	0.019	0.849
Tropical livestock units	0.004	0.972	-0.007	0.997	0.001	0.996
1=HH used animal traction	-0.005	0.370	-0.156	0.000	-0.025	0.000
Head's age (years)	0.000	0.997	0.005	0.990	0.001	0.990
Head's education (years)	0.004	0.979	0.022	0.988	0.005	0.982
1=HH headed by a single female	0.046	0.000	0.112	0.000	0.048	0.000
Number of HH members age 0-4	-0.002	0.977	-0.003	0.993	-0.001	0.984
Number of HH members age 5-14	0.010	0.639	0.005	0.969	0.006	0.781
Number of HH members age 65 or above	0.071	0.000	0.033	0.805	0.041	0.058
Number of observations	2353		342		2352	
Pseudo R-squared / Wald chi2(69), Pr>chi2	0.354		7489.6 (0.0000)			

Table 39. OLS-FE Regression of the Log of Household Pigeon Pea Yield (kg/ha), 2007/08-10/11

	OLS-FE	
	DV = ln(HH pigeonpea yield (kg/ha))	
Explanatory variables	APE	Pvalue
Main season rainfall (mm)	-0.003	0.59
Year dummy (1=2011)	2.144	0.086
ln(real exp price of maize (Oct-Dec)) (Mt/Kg)	3.841	0.367
ln(real exp price of rice (Oct-Dec)) (Mt/Kg)	-6.464	0.096
ln(real exp price of small g.nuts (Oct-Dec) (Mt/Kg	-2.754	0.298
ln(real exp price, common beans (Oct-Dec)) (Mt/	4.799	0.259
ln(real exp price of cowpea (Oct-Dec)) (Mt/Kg)	-1.883	0.582
ln(real exp price of pigeon pea) (Mt/kg)	1.182	0.209
ln(real exp price of cassava) (Mt/kg)	1.728	0.026
ln(real exp price of cotton) (Mt/kg)	0.412	0.243
ln(real exp price of tobacco) (Mt/kg)	-0.133	0.89
ln(real exp price of sesame) (Mt/kg)	0.987	0.312
1=Village/nearby had maize depot this/last yr	-2.721	0.002
1=Village has maize mill	-0.576	0.366
1=Nearby village has maize mill	-0.413	0.449
1=Village/nearby village has maize mill	1.169	0.049
1=HH received price info through a radio	-0.406	0.159
Total landholding size (Ha)	-0.002	0.985
# of HH members age 15-64	0.063	0.755
Tropical livestock units	0.037	0.648
1=HH used animal traction	0.05	0.936
Head's age (years)	0.018	0.539
Head's education (years)	0.035	0.825
1=HH headed by a single female	-0.421	0.62
Number of HH members age 0-4	-0.105	0.471
Number of HH members age 5-14	0.099	0.604
Number of HH members age 65 or above	-0.64	0.213
Number of observations	643	
F(30,463) p-value / R2-within	6.1 (0.000) / 0.230	

Table 40. DH Regression of Household Production of Pigeon Peas (kg), 2007/08-10/11

	Probit		Truncated normal		Probit + Trunc. N.	
	DV = 1 if HH plants pigeonpea		DV = HH pigeonpea production (Kg)			
			Growers (cond.)		All HHs (uncond.)	
Explanatory variables	APE	Pvalue	APE	Pvalue	APE	Pvalue
1=zone 10 (wet SAT, high altitude north-central)	0.090	0.176	268.525	0.238	119.006	0.119
1=zone 5 (wet SAT, central coast)	-0.089	0.000	371.065	0.000	98.077	0.000
1=zone 7 (wet SAT, mid-elevation north-central)	-0.079	0.000	-2.371	0.922	-11.388	0.204
1=zone 8 (SAT, coastal north-central)	0.029	0.000	-133.915	0.000	-47.754	0.000
Elevation - meters above sea level	0.000	0.996	0.021	1.000	-0.014	0.999
Expected main season rainfall - coeff. variation	0.001	0.979	0.428	0.999	0.283	0.997
Main season rainfall (mm)	0.000	0.995	0.856	0.998	0.256	0.998
Slope - measure of steepness (degrees)	-0.024	0.597	4.651	0.969	-1.334	0.979
Length of growing period (days)	0.002	0.984	-0.281	0.999	0.166	0.999
Year dummy (1=2011)	0.065	0.167	428.445	0.021	175.977	0.009
ln(real exp price of maize (Oct-Dec)) (Mt/Kg)	0.240	0.000	2398.607	0.000	901.637	0.000
ln(real exp price of rice (Oct-Dec)) (Mt/Kg)	0.121	0.000	-3185.858	0.000	-1140.940	0.000
ln(real exp price of small g.nuts (Oct-Dec) (Mt/Kg)	-0.163	0.000	-1304.693	0.000	-494.547	0.000
ln(real exp price, common beans (Oct-Dec)) (Mt/Kg	0.021	0.405	-940.826	0.000	-338.786	0.000
ln(real exp price of cowpea (Oct-Dec)) (Mt/Kg)	-0.655	0.000	488.797	0.000	93.225	0.000
ln(real exp price of pigeon pea) (Mt/kg)	-0.098	0.140	476.673	0.000	160.432	0.000
ln(real exp price of cassava) (Mt/kg)	0.083	0.000	765.617	0.000	288.553	0.000
ln(real exp price of cotton) (Mt/kg)	0.025	0.687	135.645	0.072	52.453	0.061
ln(real exp price of tobacco) (Mt/kg)	0.029	0.672	128.799	0.519	50.494	0.465
ln(real exp price of sesame) (Mt/kg)	0.099	0.535	257.221	0.727	106.147	0.699
Distance to nearest fertilizer retailer (km)	0.000	0.000	0.292	0.025	0.165	0.001
Distance to nearest formal market (km)	0.002	0.001	0.111	0.875	0.269	0.303
Distance to nearest seed retailer (km)	-0.001	0.092	-0.183	0.848	-0.197	0.571
Travel time to nearest town, 30k+ people (hrs)	-0.009	0.000	0.458	0.497	-0.927	0.000
1=Village/nearby had maize depot this/last yr	-0.006	0.806	52.281	0.090	17.898	0.119
1=Village has maize mill	-0.021	0.260	90.380	0.000	30.305	0.000
1=Nearby village has maize mill	-0.043	0.002	14.124	0.474	-0.819	0.909
1=Village/nearby village has maize mill	-0.030	0.652	340.201	0.008	110.723	0.024
1=HH received price info through a radio	-0.026	0.651	-23.257	0.803	-11.754	0.749
Total landholding size (Ha)	0.012	0.949	13.998	0.989	6.788	0.985
# of HH members age 15-64	0.029	0.789	-3.235	0.994	2.417	0.987
Tropical livestock units	0.005	0.978	0.100	1.000	0.654	0.998
1=HH used animal traction	-0.068	0.000	55.032	0.000	8.449	0.043
Head's age (years)	0.008	0.816	-0.273	0.999	1.028	0.989
Head's education (years)	-0.012	0.951	-19.780	0.974	-8.676	0.969
1=HH headed by a single female	0.030	0.000	-40.460	0.000	-11.582	0.000
Number of HH members age 0-4	-0.007	0.941	38.631	0.874	13.118	0.883
Number of HH members age 5-14	0.012	0.539	5.953	0.922	3.754	0.868
Number of HH members age 65 or above	-0.008	0.635	-158.272	0.001	-58.499	0.001
Number of observations	2353		631		2334	
Pseudo R-squared / Wald chi2(69), Pr>chi2	0.489		59.9 (0.775)			

Another explanation for this result may be found in the response of pigeon pea area to other food crops. For example, a 1% increase in the expected price of maize leads to an increase of 1 ha of pigeon pea among current growers and a 0.22 ha increase in pigeon pea area among any given household. Because pigeon pea is often grown in intercrop with maize, it is possible that the increase in maize price may be driving increases in pigeon prices in two ways – one, by increasing area planted to a maize/pigeon pea intercrop (from the household's desire to increase maize production; and two, because many of these households are likely net buyers of maize, increasing pigeon pea production (at a time when this is becoming a cash crop in Zambezia and other areas, thus anecdotal demand for pigeon pea *and* expected pigeon pea prices are rising rapidly) provides these net maize-buying households with a source of cash with which they can purchase maize in the lean season. Likewise, we see the expected prices of groundnuts and common bean – crops that compete with pigeon pea as the companion to maize within a maize intercrop, as well as competitors in terms of cash sales value and household source of vegetable protein – have a large and significant negative effect on pigeon pea area. Increases in the price of rice, which is not grown in intercrop with pigeon pea, have a large and significant negative effect on pigeon pea area, while a 1% increase in the expected price of cassava – which is grown in intercrop with pigeon pea – leads to a 0.04 ha increase in area planted to pigeon pea. Thus, while we do not appear to see a direct link between improved pigeon pea market access and rising expected prices for pigeon pea, it appears that increases in pigeon pea participation and area planted are being driven by not only pigeon pea's emergence as a new food staple cash crop in central and northern Mozambique, but also as a higher-value intercrop companion for maize.

While we did not find a significant effect of expected pigeon pea price on pigeon pea area, a 1% increase in this price has a 1.2% increase in pigeon pea yield (Table 39). This implies that pigeon pea producers are responding to higher pigeon pea and other food crop prices by increasing their pigeon pea area (extensification) but also by pigeon pea intensification. We also find that increases in the price of maize and cassava have large, positive and significant effects on pigeon pea yields, while an increase in the price of a competitor food cash crop and protein source (small groundnuts) has a negative effect on pigeon pea yield while an increase of a crop which is not intercropped with pigeon pea (rice) also has a significant negative effect on pigeon pea yield. These results are consistent with our findings above regarding how increases in expected prices of maize, cassava, rice, and groundnuts appear to be driving increases in pigeon pea area.

The rather large positive effects of expected pigeon pea and cassava prices on pigeon pea yield suggest that, in addition to the obvious increase in pigeon pea production via extensification (as seen in the large increase in % of households growing pigeon pea and a doubling of the average area grown to pigeon pea, among all households), there appears to be intensification as well. However, the lack of a significant effect of available family adults on pigeon pea yield suggests that the large observed increases in average pigeon pea yield are not due to increased family labor per hectare (Table 39). In addition, the animal traction effect is positive yet insignificant, which suggests that perhaps the producers may be intensifying pigeon pea production via higher seeding rates.

When we turn to the regression of pigeon pea production, we find that a 1% increase in the expected pigeon pea has a large effect (485 kg) on household production (Table 40). We also see that use of animal traction increases production by 55 kg, which might be an intensification effect, but since this variable is not significant in the regression of pigeon pea yield, it is likely that animal traction is increasing pigeon pea production via increased area cultivated to pigeon pea (extensification). However, the yield regression results also demonstrate that some of the increase in average pigeon pea production appears to be due to intensification (of some kind), as a 1% increase in the expected pigeon pea price increases pigeon pea yield by 2.4% (Table 39).

The only significant infrastructure result that appears to be linked to pigeon pea is the finding that presence of a maize depot leads to a 52 kg increase in pigeon pea production, if one assumes that maize depots can be used to buy other commodities. Total production of pigeon peas was also higher among smallholder farmers in villages that possess a maize mill, though it is not clear why this would stimulate pigeon pea production unless pigeon pea is also intercropped with maize.

8.2.7. Large Groundnuts

Although the real expected price of large groundnuts increased by about 11% on average over our two panel years, there was only a slight increase in the percentage of large groundnut growers from 14.2% of our sample in 2007/08 to 17.4% in 2010/11, with the primary increases in participation coming from Sofala (an increase from 8% to 14%) and Nampula (from 13% to 19%). Anecdotal evidence suggests that these rather large increases in Sofala and Nampula were due to aflotoxin reduction programs. Among growers, average area planted to large groundnuts only increased slightly from 0.33 to 0.40, though there was some variation by province.

Econometric analysis of smallholder large groundnut cropping shows that changes in participation among growers appears to largely be driven by changes in expected prices. For example, a 10% increase in the expected price of large (small) groundnuts increased the probability of planting the crop by 4.2% (4.0%) (Table 41). Likewise, increases in competing crops have the opposite effect, as a 10% increase in the price of maize (pigeon pea, cotton) led to a 5.2% (1.4%, 0.7%) decrease in the probability of planting large groundnuts. The negative effect of cash crops like pigeon pea and cotton on large groundnut planting is perhaps not surprising as both large and small groundnuts are sold by approximately 30-40% of growers in any given year, making it one of the more widely commercialized food crops in Mozambique (along with common beans, and, in recent years, pigeon pea). Likewise, the presence of a tobacco buying depot in the village (or nearby village) reduces the probability of growing large groundnut by 8.8%. However, while prices of groundnut and competing crops seem to pre-dominate smallholders' decision regarding whether to grow it or not, they do not have a significant effect on the area planted. In fact, it is difficult to find a factor that has a significant effect on area planted to large groundnut.[46]

While participation in large groundnut and area planted to it did not increase very much, yields among current growers did increase dramatically, as the mean yield increased from 319 kg/ha in 2007/08 to 421 kg/ha (223 kg/ha) in 2010/11 (Table 16). Our econometric analysis of large groundnut yield shows that the increase in mean yields appear to be driven in large part by changes in expected prices, as an increase of 1% in the expected price of small groundnut (whose price is positively correlated with that of large groundnut) increased yields by 10%, while that of large groundnut had a large positive but insignificant effect on large groundnut yield (Table 42). As in the area regression, competing crops had the opposite effect, as a 1% increase in the expected price of pigeon pea (sesame) led to an 8% (2.7%) decrease in large groundnut yield (Table 42). As we found with cassava, an additional household member aged 15-64 has a large though insignificant effect on groundnut yield. Given that large groundnuts do not receive improved inputs such as inorganic fertilizer, manure or improved seed (with the exception of some growers in Tete and recently Manica), yield increases are likely derived from increases in labor application per hectare. Given that the village wage appears to not have a significant effect on groundnut yields, this suggests

[46] The presence of an oilseed press in the village (or nearby village) actually reduces area planted to large groundnut by 0.24 ha (Table 41). However, these presses were likely due to efforts to promote sesame thus unless they can be used for groundnuts as well, this is likely a spurious correlation.

Table 41. DH Regression of Household Large Groundnut Area (ha), 2007/08-10/11

	Probit		Truncated normal		Probit + Trunc. N.	
	DV=1 if HH plants large groundnuts		DV=HH area in large gr.nuts (ha)			
			Growers (cond.)		All HHs (uncond.)	
Explanatory variables	APE	Pvalue	APE	Pvalue	APE	Pvalue
1=Agroecological zones (low)	-0.0155	0.8324	-0.071	0.929	-0.016	0.902
1=Agroecological zones (medium)	-0.0587	0.4338	0.065	0.903	-0.008	0.932
1=Agroecological zones (high)	0.0770	0.3534	-0.166	0.653	-0.005	0.951
Expected main season rainfall (mm)	-0.0004	0.2955	0.000	0.860	0.000	0.612
ln(Exp. main season rainfall - coeff. Variation)	-0.0096	0.7245	0.146	0.045	0.023	0.126
Year dummy (1=2011)	0.0942	0.1018	-0.025	0.973	0.026	0.881
ln(real exp price of large g.nuts (Jul-Sep)) (Mt/Kg)	0.4254	0.0014	-0.423	0.492	0.061	0.620
ln(real exp price of small g.nuts (Oct-Dec) (Mt/Kg	0.4069	0.0000	-0.177	0.650	0.099	0.214
ln(real exp price of maize (Oct-Dec)) (Mt/Kg)	-0.5201	0.0008	-0.044	0.951	-0.173	0.244
ln(real exp price of rice (Jan-Mar)) (Mt/Kg)	0.1591	0.2316	-0.300	0.560	-0.002	0.984
ln(real exp price, common beans (Jul-Sep)) (Mt/Kg	-0.0209	0.9250	0.675	0.498	0.112	0.575
ln(real exp price of cowpea (Jul-Sep)) (Mt/Kg)	-0.1889	0.5071	-0.093	0.949	-0.077	0.801
ln(real exp price of cassava) (Mt/kg)	-0.1187	0.0004	0.030	0.824	-0.033	0.232
ln(real exp price of pigeon pea) (Mt/kg)	-0.1484	0.0451	0.108	0.739	-0.028	0.666
ln(real exp price of cotton) (Mt/kg)	-0.0765	0.0038	0.128	0.167	-0.002	0.921
ln(real exp price of tobacco) (Mt/kg)	-0.0090	0.5774	0.025	0.608	0.001	0.895
ln(real exp price of sesame) (Mt/kg)	-0.0975	0.2332	-0.011	0.975	-0.033	0.640
ln(distance to nearest fertilizer retailer, km)	-0.0095	0.2963	-0.004	0.869	-0.004	0.516
ln(Distance to nearest seed retailer (km))	0.0013	0.8745	0.028	0.237	0.005	0.293
ln(willage ag wage, MTN/day)	0.0017	0.8754	-0.052	0.139	-0.009	0.246
Travel time to nearest town, 30k+ people (hrs)	0.0019	0.4563	0.005	0.302	0.001	0.312
Distance to nearest formal market (km)	-0.0007	0.3864	-0.003	0.178	-0.001	0.139
1=Village/nearby had maize depot this/last yr	-0.0059	0.8934	0.180	0.370	0.030	0.516
1=Village/nearby had rice depot this/last yr	-0.0198	0.5201	0.002	0.987	-0.006	0.805
1=Village/nearby had tobaco depot this/last yr	-0.0882	0.0031	-0.084	0.500	-0.039	0.051
1=Village/nearby had sesame depot this/last yr	0.0027	0.9622	-0.160	0.176	-0.026	0.317
1=Village has maize mill	0.0539	0.1979	-0.111	0.529	0.001	0.976
1=Nearby village has maize mill	0.1092	0.0569	-0.124	0.422	0.006	0.883
1=Village/nearby village has oilseed press	0.0376	0.5873	-0.236	0.014	-0.034	0.133
Total landholding size (Ha)	0.0132	0.0505	0.022	0.234	0.008	0.057
# of HH members age 15-64	-0.0020	0.9064	0.023	0.639	0.003	0.743
1=HH used animal traction	0.0366	0.3967	0.056	0.718	0.023	0.518
Tropical livestock units	-0.0031	0.3493	-0.006	0.444	-0.002	0.267
1=HH received price info through a radio	0.0060	0.8151	0.034	0.671	0.008	0.628
Head's education (years)	-0.0009	0.9088	0.046	0.138	0.008	0.244
Head's age (years)	0.0066	0.1270	-0.003	0.872	0.001	0.674
1=HH headed by a single female	-0.0963	0.0191	0.299	0.676	-0.003	0.961
Number of HH members age 0-4	0.0220	0.1547	0.075	0.174	0.020	0.089
Number of HH members age 5-14	-0.0112	0.4526	0.061	0.119	0.007	0.392
Number of HH members age 65 or above	0.0320	0.4348	-0.045	0.787	0.002	0.946
Number of observations	2,358		526		2,358	
Psuedo R-squared / Wald chi2 (76), Pr>chi2	0.1910		288.6 (0.000)			

Notes: Model includes elevation, slope, length of growing period, and HH time-averages.

Table 42. OLS-FE Regression of the Log of Household Large Groundnut Yield (kg/ha), 2007/08-10/11

	OLS-FE	
	DV = ln(HH large groundnut yield (kg/ha))	
Explanatory variables	APE	Pvalue
Year dummy (1=2011)	5.564	0.369
Main season rainfall (mm)	-0.008	0.586
ln(Exp. main season rainfall - coeff. Variation)	0.441	0.776
ln(real exp price of large g.nuts (Jul-Sep)) (Mt/Kg)	8.008	0.596
ln(real exp price of small g.nuts (Oct-Dec) (Mt/Kg)	10.855	0.000
ln(real exp price of maize (Oct-Dec)) (Mt/Kg)	-14.112	0.029
ln(real exp price of rice (Jan-Mar)) (Mt/Kg)	2.804	0.612
ln(real exp price, common beans (Jul-Sep)) (Mt/Kg)	-22.622	0.186
ln(real exp price of cowpea (Jul-Sep)) (Mt/Kg)	-0.541	0.984
ln(real exp price of cassava) (Mt/kg)	-0.272	0.704
ln(real exp price of pigeon pea) (Mt/kg)	-8.972	0.011
ln(real exp price of cotton) (Mt/kg)	-0.342	0.830
ln(real exp price of tobacco) (Mt/kg)	0.341	0.377
ln(real exp price of sesame) (Mt/kg)	-2.634	0.050
ln(willage ag wage, MTN/day)	0.083	0.733
1=Village has maize mill	-0.986	0.200
1=Nearby village has maize mill	-1.258	0.090
ln(Total landholding (Ha))	-0.407	0.043
# of HH members age 15-64	0.031	0.863
1=HH used animal traction	-0.180	0.747
1=HH applied manure to this crop	1.927	0.001
1=HH used improved seed (purchased that yr)	0.697	0.278
Tropical livestock units	-0.003	0.945
1=HH received price info through a radio	-0.240	0.548
Head's education (years)	-0.092	0.605
Head's age (years)	-0.100	0.507
1=HH headed by a single female	0.062	0.919
Number of HH members age 0-4	-0.789	0.011
Number of HH members age 5-14	-0.373	0.071
Number of HH members age 65 or above	1.336	0.023
Number of observations	421	
F(34, 329) p-value / R2-within	7.85 (0.000) / 0.585	

Notes: Model includes household fixed effects.

that perhaps our proxy for family labor use (number of adults age 15-64 in the household) perhaps is not capturing an increase in family labor per hectare. That said, we also find that an additional household member age 65 or older had a large and significant effect (104%) on large groundnut yield. Given that the effects of other dependenthousehold members (children 14 or younger) have a negative effect on groundnut yields, this suggests that adults 65 or older may be the primary source of additional labor per hectare that would appear to be leading to increased large groundnut yields.

Table 43. DH Regression of Household Large Groundnut Production (ha), 2007/08-10/11

	Probit		Log normal		Probit + Log Norm	
	DV=1 if HH plants large groundnuts		DV=ln(HH lar. grnut production (kg))			
			Growers (cond.)		All HHs (uncond.)	
Explanatory variables	APE	Pvalue	APE	Pvalue	APE	Pvalue
1=Agroecological zones (low)	0.0313	0.6546	0.106	0.957	0.412	0.919
1=Agroecological zones (medium)	-0.0296	0.6365	-0.374	0.758	-0.685	0.794
1=Agroecological zones (high)	0.0986	0.2014	-0.615	0.701	0.231	0.997
Main season rainfall (mm)	0.0000	0.9967	0.003	0.589	0.003	0.644
ln(Exp. main season rainfall - coeff. Variation)	-0.0005	0.9853	-0.285	0.383	-0.290	0.542
Year dummy (1=2011)	0.1003	0.0884	-2.133	0.896	-0.584	0.932
ln(real exp price of large g.nuts (Jul-Sep)) (Mt/Kg	0.3188	0.0177	2.388	0.252	5.132	0.041
ln(real exp price of small g.nuts (Oct-Dec) (Mt/K	0.3394	0.0007	0.020	0.988	2.942	0.094
ln(real exp price of maize (Oct-Dec)) (Mt/Kg)	-0.4156	0.0083	2.234	0.379	-1.344	0.663
ln(real exp price of rice (Jan-Mar)) (Mt/Kg)	0.0972	0.4691	-0.529	0.806	0.308	0.905
ln(real exp price, common beans (Jul-Sep)) (Mt/I	-0.0004	0.9986	-2.943	0.447	-2.947	0.504
ln(real exp price of cowpea (Jul-Sep)) (Mt/Kg)	-0.2310	0.4004	1.102	0.812	-0.887	0.868
ln(real exp price of cassava) (Mt/kg)	-0.0977	0.0026	0.039	0.947	-0.803	0.228
ln(real exp price of pigeon pea) (Mt/kg)	-0.1060	0.1663	1.702	0.211	0.790	0.605
ln(real exp price of cotton) (Mt/kg)	-0.0534	0.0385	-0.404	0.288	-0.864	0.082
ln(real exp price of tobacco) (Mt/kg)	-0.0197	0.2643	0.125	0.574	-0.044	0.872
ln(real exp price of sesame) (Mt/kg)	-0.0742	0.3252	0.504	0.682	-0.135	0.928
ln(distance to nearest fertilizer retailer, km)	-0.0106	0.2585	0.108	0.298	0.017	0.898
ln(Distance to nearest seed retailer (km))	0.0027	0.7414	-0.130	0.131	-0.107	0.391
ln(willage ag wage, MTN/day)	0.0053	0.6353	0.255	0.025	0.300	0.043
Travel time to nearest town, 30k+ people (hrs)	0.0026	0.3230	0.068	0.001	0.099	0.004
Distance to nearest formal market (km)	-0.0009	0.2434	0.001	0.853	-0.007	0.508
1=Village/nearby had maize depot this/last yr	-0.0067	0.8832	0.129	0.795	0.067	0.927
1=Village/nearby had rice depot this/last yr	-0.0132	0.6858	0.094	0.802	-0.027	0.958
1=Village/nearby had tobaco depot this/last yr	-0.0820	0.0087	1.484	0.244	0.010	0.989
1=Village/nearby had sesame depot this/last yr	-0.0117	0.8381	-0.569	0.134	-0.667	0.450
1=Village has maize mill	0.0568	0.1824	-0.061	0.913	0.418	0.553
1=Nearby village has maize mill	0.0969	0.0895	0.208	0.734	1.304	0.433
1=Village/nearby village has oilseed press	0.0241	0.7041	0.035	0.991	0.257	0.965
Total landholding size (Ha)	0.0139	0.0377	-0.091	0.086	0.029	0.720
# of HH members age 15-64	-0.0111	0.4570	0.067	0.738	-0.031	0.899
1=HH used animal traction	0.0448	0.3081	-0.027	0.949	0.371	0.662
Tropical livestock units	-0.0038	0.2600	-0.012	0.712	-0.044	0.306
1=HH received price info through a radio	-0.0035	0.8867	-0.541	0.059	-0.566	0.126
Head's education (years)	-0.0015	0.8454	-0.123	0.276	-0.136	0.287
Head's age (years)	0.0054	0.2273	-0.001	0.995	0.050	0.677
1=HH headed by a single female	-0.0859	0.0429	-0.417	0.423	-1.034	0.330
Number of HH members age 0-4	0.0208	0.1666	-0.210	0.264	-0.031	0.897
Number of HH members age 5-14	-0.0100	0.4541	-0.102	0.474	-0.188	0.340
Number of HH members age 65 or above	0.0039	0.9125	0.363	0.523	0.397	0.553
Number of observations	2,358		401		2,358	
Psuedo R-squared / R-squared	0.1815		0.380			

Notes: Model includes elevation (mm), slope, length of growing period, and household time-averages of all time-varying variables.

Average (median) production of large groundnut per household increased less than yields did (by 16% and 48% respectively). Our econometric analysis of smallholder production of large groundnut shows again that the primary driver of increased production is primarily due to price changes, in this case, higher expected prices of groundnuts. For example, a 1% increase in the expected price of large (small) groundnut increased the production of large groundnut by any given household by 5% (2.9%) (Table 43).

Our descriptive and econometric analysis shows that production of large groundnut increased by cassava production increased on average by 16% due to a combination of both extensification (an increase in growers primarily in Sofala and Nampula) and intensification (an increase in yields that appears to be due to increased family labor applied per hectare, particularly from older adults). The increase in cassava participation seems to have been primarily driven by increases in the expected prices of rice, beans and groundnuts, while increases in area planted were primarily driven by increases in the expected price of maize. Increases in cassava yields appear to be driven by various factors, one being an increase in labor applied by adults over 65, use of animal traction, and the average effect of unobserved factors (i.e., the year dummy).

8.2.8. Small Groundnuts

The real expected price of small groundnuts rose about 5% between 2007/08 and 2009/10, though participation increased slightly from (from 19.7% to 23.9%, with increases primarily seen in Tete, Manica and Sofala. However, the average area planted to groundnuts among all growers increased only from 0.06 to 0.07 ha, while the average area planted computed among growers increased from 0.31 to 0.33 ha. Our econometric analysis of smallholder participation in small groundnut production shows no significant effects of any crop prices on area planted to this crop except that a 1% increase in the price of rice decreases the probability of planting groundnut by 0.36%, while a 1% increase in the expected price of small groundnuts leads to a surprising 0.2% decline in probability of planting this crop (Table 44). The only other significant factors affecting the probability of growing small groundnuts are the presence of an oilseed press in or near the village (which increases probability of planting the crop by 18%) and receipt of market price information via radio (which increases this probability by 5%).[47] Although the presence of a maize mill in the village increases this probability by 11%, this may be a spurious effect (due to the large number of villages with a maize mill) given that our other evidence suggests that maize competes with small groundnuts.

Apart from total landholding, only the presence of a rice buying depot appears to have a significant effect on area planted to small groundnut, as it reduces it by 0.11 ha (Table 44). The lack of significant effects of prices or market access is perhaps due to the fact that the price of this crop did not vary much over time (on average), and thus participation and average area planted to the crop also did not change much.

The average small groundnut yield increased from 293 in 2008 to 387 kg/ha in 2011, an increase of 33% (Table 16). Our econometric analysis of household small groundnut yield suggests that there are three primary determinants of yield variation. First, we find a positive yet insignificant effect of small groundnut prices on small groundnut yield, yet a 1% increase in the expected price of large groundnuts increases small groundnut yield by 2.8%. One

[47] Because many oilseed presses in rural areas of Mozambique are the result of sesame promotion, unless they can also be used for groundnuts, this correlation is likely spurious.

Table 44. DH Regression of Household Small Groundnut Area (ha), 2007/08-10/11

	Probit		Truncated normal		Probit + Trunc. N.	
	DV=1 if HH plants small groundnuts		DV = HH area in small gr.nuts (ha)			
			Growers (cond.)		All HHs (uncond.)	
Explanatory variables	APE	Pvalue	APE	Pvalue	APE	Pvalue
1=Agroecological zones (low)	-0.1702	0.0000	0.039	0.802	-0.050	0.010
1=Agroecological zones (medium)	-0.1259	0.0802	0.014	0.928	-0.035	0.393
1=Agroecological zones (high)	-0.1811	0.0036	0.113	0.504	-0.038	0.268
Expected main season rainfall (mm)	-0.0003	0.5462	0.004	0.012	0.001	0.041
ln(Exp. main season rainfall - coeff. Variation)	-0.0250	0.3767	-0.038	0.561	-0.016	0.328
Year dummy (1=2011)	0.0820	0.2428	0.043	0.710	0.034	0.368
ln(real exp price of large g.nuts (Jul-Sep)) (Mt/Kg	0.0202	0.8851	-0.292	0.323	-0.058	0.441
ln(real exp price of small g.nuts (Oct-Dec) (Mt/K	-0.2117	0.0542	0.000	0.999	-0.063	0.323
ln(real exp price of maize (Oct-Dec)) (Mt/Kg)	0.1350	0.4164	0.105	0.727	0.063	0.461
ln(real exp price of rice (Jan-Mar)) (Mt/Kg)	-0.3616	0.0340	0.142	0.644	-0.077	0.352
ln(real exp price, common beans (Jul-Sep)) (Mt/I	-0.0319	0.9066	-0.314	0.513	-0.078	0.531
ln(real exp price of cowpea (Jul-Sep)) (Mt/Kg)	0.1555	0.5353	0.666	0.148	0.192	0.134
ln(real exp price of cassava) (Mt/kg)	0.0562	0.1727	-0.030	0.414	0.010	0.487
ln(real exp price of pigeon pea) (Mt/kg)	-0.0132	0.8942	-0.013	0.949	-0.007	0.887
ln(real exp price of cotton) (Mt/kg)	0.0081	0.7855	0.014	0.844	0.005	0.756
ln(real exp price of tobacco) (Mt/kg)	-0.0128	0.5247	0.005	0.896	-0.003	0.818
ln(real exp price of sesame) (Mt/kg)	0.0599	0.3056	-0.087	0.247	-0.001	0.962
ln(distance to nearest fertilizer retailer, km)	-0.0092	0.4078	-0.006	0.761	-0.004	0.441
ln(Distance to nearest seed retailer (km))	-0.0038	0.7090	-0.014	0.439	-0.004	0.385
ln(willage ag wage, MTN/day)	0.0230	0.1108	0.030	0.189	0.013	0.046
Travel time to nearest town, 30k+ people (hrs)	-0.0014	0.6310	0.004	0.295	0.000	0.995
Distance to nearest formal market (km)	0.0007	0.4900	0.000	0.867	0.000	0.539
1=Village/nearby had maize depot this/last yr	-0.0294	0.4364	-0.048	0.550	-0.019	0.328
1=Village/nearby had rice depot this/last yr	0.0086	0.7934	-0.110	0.027	-0.022	0.088
1=Village/nearby had tobaco depot this/last yr	-0.0591	0.1941	0.052	0.634	-0.009	0.715
1=Village/nearby had sesame depot this/last yr	0.0414	0.4134	0.082	0.416	0.033	0.277
1=Village has maize mill	0.1151	0.0106	0.021	0.808	0.038	0.066
1=Nearby village has maize mill	0.0540	0.3800	0.068	0.452	0.033	0.266
1=Village/nearby village has oilseed press	0.1803	0.0205	0.107	0.270	0.090	0.034
Total landholding size (Ha)	0.0110	0.2279	0.040	0.031	0.012	0.013
# of HH members age 15-64	-0.0223	0.2097	0.001	0.973	-0.006	0.456
1=HH used animal traction	0.0060	0.8980	-0.098	0.059	-0.020	0.226
Tropical livestock units	0.0047	0.2563	-0.005	0.560	0.000	0.847
1=HH received price info through a radio	0.0520	0.0665	0.025	0.643	0.021	0.206
Head's education (years)	0.0075	0.3790	0.011	0.476	0.005	0.238
Head's age (years)	-0.0033	0.3746	-0.007	0.505	-0.003	0.343
1=HH headed by a single female	0.0790	0.1871	0.137	0.385	0.062	0.239
Number of HH members age 0-4	0.0111	0.5475	0.016	0.592	0.007	0.437
Number of HH members age 5-14	-0.0149	0.3791	0.016	0.513	-0.001	0.890
Number of observations	2,358		533		2,358	
Psuedo R-squared / Wald chi2 (74), Pr>chi2	0.1580		76.9 (0.127)			

Notes: Model includes elevation (mm), slope, length of growing period, and household time-averages of all time-varying variables.

Table 45. OLS-FE Regression of the Log of Household Small Groundnut Yield (kg/ha), 2007/08-10/11

	OLS-FE	
	DV = ln(small groundnut yield (kg/ha))	
Explanatory variables	APE	Pvalue
Year dummy (1=2011)	-0.385	0.576
Main season rainfall (mm)	-0.015	0.019
ln(Exp. main season rainfall - coeff. Variation)	0.427	0.420
ln(real exp price of large g.nuts (Jul-Sep)) (Mt/Kg)	2.870	0.064
ln(real exp price of small g.nuts (Oct-Dec) (Mt/Kg)	0.641	0.801
ln(real exp price of maize (Oct-Dec)) (Mt/Kg)	-1.435	0.532
ln(real exp price of rice (Jan-Mar)) (Mt/Kg)	1.691	0.300
ln(real exp price, common beans (Jul-Sep)) (Mt/Kg)	2.606	0.630
ln(real exp price of cowpea (Jul-Sep)) (Mt/Kg)	0.493	0.906
ln(real exp price of cassava) (Mt/kg)	-0.063	0.743
ln(real exp price of pigeon pea) (Mt/kg)	0.371	0.892
ln(real exp price of cotton) (Mt/kg)	-0.346	0.345
ln(real exp price of tobacco) (Mt/kg)	0.431	0.085
ln(real exp price of sesame) (Mt/kg)	0.723	0.227
ln(willage ag wage, MTN/day)	-0.013	0.951
1=Village has maize mill	-1.604	0.006
1=Nearby village has maize mill	-1.624	0.002
ln(Total landholding (Ha))	-0.694	0.003
# of HH members age 15-64	0.398	0.010
1=HH used animal traction	-1.050	0.003
1=HH applied manure to this crop	-0.147	0.709
1=HH used improved seed (purchased that yr)	0.660	0.143
Tropical livestock units	0.067	0.025
1=HH received price info through a radio	0.035	0.907
Head's education (years)	0.026	0.716
Head's age (years)	-0.004	0.960
1=HH headed by a single female	0.525	0.508
Number of HH members age 0-4	0.181	0.273
Number of HH members age 5-14	0.031	0.834
Number of HH members age 65 or above	2.196	0.000
Number of observations	533	
F(34, 421) and p-value / R2-within	4.63 (0.000) / 0.451	

Notes: Model includes household fixed effects.

explanation for this result may be that as we noted above, the prices of large groundnuts increased by 11% on average, while that of small groundnuts increased less (by 5%), and these crops are grown in every area of our sample, and sometimes the same household grows both kinds of groundnuts. Therefore, perhaps this result indicates that as large groundnuts become more expensive, this drives up the incentive to produce the closest substitute to this food crop (small groundnuts).

Table 46. DH Regression of Household Small Groundnut Production (ha), 2007/08-10/11

	Probit		Log normal		Probit + Log Norm	
	DV=1 if HH plants small groundnuts		DV=ln(HH small g.nut prod. (kg))			
			Growers (cond.)		All HHs (uncond.)	
Explanatory variables	APE	Pvalue	APE	Pvalue	APE	Pvalue
1=Agroecological zones (low)	-0.1457	0.0001	2.733	0.319	0.087	0.934
1=Agroecological zones (medium)	-0.0261	0.6661	1.585	0.268	1.263	1.000
1=Agroecological zones (high)	-0.1344	0.0390	0.607	0.618	-0.325	0.736
Main season rainfall (mm)	-0.0003	0.4421	-0.009	0.040	-0.011	0.033
ln(Exp. main season rainfall - coeff. Variation)	-0.0242	0.3534	0.310	0.349	0.167	0.667
Year dummy (1=2011)	0.0952	0.1757	0.401	0.435	37.550	1.000
ln(real exp price of large g.nuts (Jul-Sep)) (Mt/Kg	0.0668	0.6176	2.612	0.059	3.008	0.067
ln(real exp price of small g.nuts (Oct-Dec) (Mt/Kg	-0.2242	0.0454	1.061	0.417	-0.269	0.860
ln(real exp price of maize (Oct-Dec)) (Mt/Kg)	0.1673	0.2819	-1.354	0.343	-0.362	0.836
ln(real exp price of rice (Jan-Mar)) (Mt/Kg)	-0.4244	0.0124	-0.300	0.821	-2.817	0.109
ln(real exp price, common beans (Jul-Sep)) (Mt/K	-0.1991	0.4577	-1.166	0.651	-2.346	0.442
ln(real exp price of cowpea (Jul-Sep)) (Mt/Kg)	0.3874	0.1404	-0.251	0.918	2.047	0.485
ln(real exp price of cassava) (Mt/kg)	0.0648	0.0949	0.027	0.896	0.411	0.214
ln(real exp price of pigeon pea) (Mt/kg)	-0.0047	0.9611	-0.665	0.534	-0.693	0.575
ln(real exp price of cotton) (Mt/kg)	-0.0007	0.9813	-0.553	0.058	-0.557	0.108
ln(real exp price of tobacco) (Mt/kg)	-0.0092	0.6797	0.340	0.075	0.286	0.254
ln(real exp price of sesame) (Mt/kg)	0.0421	0.4705	0.244	0.538	0.494	0.378
ln(distance to nearest fertilizer retailer, km)	-0.0069	0.5607	-0.125	0.099	-0.167	0.127
ln(Distance to nearest seed retailer (km))	-0.0091	0.3829	0.113	0.168	0.059	0.575
ln(willage ag wage, MTN/day)	0.0231	0.1242	0.052	0.633	0.189	0.196
Travel time to nearest town, 30k+ people (hrs)	-0.0007	0.8155	0.001	0.974	-0.005	0.854
Distance to nearest formal market (km)	0.0007	0.4531	0.004	0.527	0.008	0.387
1=Village/nearby had maize depot this/last yr	-0.0427	0.2550	0.141	0.729	-0.156	1.000
1=Village/nearby had rice depot this/last yr	-0.0145	0.6546	-0.236	0.406	-0.305	0.429
1=Village/nearby had tobaco depot this/last yr	-0.0250	0.6337	1.260	0.233	0.936	0.967
1=Village/nearby had sesame depot this/last yr	0.0493	0.3259	-0.420	0.286	-0.185	1.000
1=Village has maize mill	0.1006	0.0329	0.237	0.615	0.814	1.000
1=Nearby village has maize mill	0.0575	0.3578	-0.179	0.694	0.235	1.000
1=Village/nearby village has oilseed press	0.1312	0.0476	-0.269	0.522	278.634	1.000
Total landholding size (Ha)	0.0156	0.1245	-0.251	0.001	-0.165	0.080
# of HH members age 15-64	-0.0034	0.8337	0.119	0.435	0.089	0.650
1=HH used animal traction	-0.0037	0.9381	-0.071	0.838	-0.091	0.999
Tropical livestock units	0.0058	0.1750	0.018	0.594	0.053	0.265
1=HH received price info through a radio	0.0614	0.0365	-0.279	0.165	0.085	1.000
Head's education (years)	0.0051	0.5710	0.006	0.928	0.036	0.699
Head's age (years)	-0.0039	0.2650	0.040	0.405	0.010	0.850
1=HH headed by a single female	0.0895	0.1469	-0.178	0.796	4.607	1.000
Number of HH members age 0-4	0.0168	0.3794	-0.162	0.308	-0.062	0.704
Number of HH members age 5-14	-0.0087	0.5694	0.015	0.916	-0.037	0.816
Number of HH members age 65 or above	0.0285	0.5690	-0.007	0.991	0.162	0.788
Number of observations	2,358		516		2,358	
Psuedo R-squared / R-squared	0.1441		0.276			

Notes: Model includes elevation, slope, length of growing period, and household time-average terms.

Second, an additional adult age 15-64 increases small groundnut yield by 39%, while an additional adult 65 or older increases this yield by 219% (Table 45). Because the effects of children on small groundnut yields are insignificant and/or negative, this suggests that the family adult variables may indicate that households with larger amounts of available family labor obtain higher small groundnut yields (rather than these adult variables acting as a measure of household consumption needs). The third main determinant appears to be the presence of a maize mill in or near the village, either of which decreases small groundnut yield by 160%. As all but 10% of our sample villages either have a maize mill or are near one, it's not clear if this suggests that groundnut yields decline due to demand for maize or if this simply implies that in those few areas of our sample that lack access to a maize mill, groundnut yields are considerably higher (as demand for maize is likely much lower).

Surprisingly, we find that households that used animal traction had 109% lower small groundnut yield (Table 45). Because our animal traction use variable is collected at the farm and not plot-level, we do not observe whether the field on which a given crop is grown was actually prepared by animal traction or manually. However, it is possible that this strange effect is a spurious correlation, given that Mather (2009) found that animal traction use improved smallholder net crop income by 33% in central provinces, using data from the TIA2002-05 panel of smallholder households.[48] We also find that a 1 unit increase in TLU (i.e., one cow) has a positive and significant effect on small groundnut yield, increasing it by 6.7%. Because we are separately controlling for application of manure on small groundnuts, this suggests that TLU in this case implies that households with more wealth are obtaining somewhat higher yields – perhaps through the ability to hire labor. However, because there is no significant effect of village wages on small groundnut yield, perhaps this labor is borrowed/shared labor.

Average small groundnut production increased slightly from 54 to 71 kg, among growers, and from 11 to 17 kg among all households. As in our yield analysis, our econometric analysis of small groundnut production finds that a 1% increase in the expected price of large groundnuts leads to a 2.6% increase among current growers (Table 46). This again suggests that the increase in small groundnut area and production, though not large, appear to be driven more by increases in prices of large rather than small groundnut. We also find a positive and large effect of small groundnut price on small groundnut production, though this effect is not significant (p=0.417).

In summary, we do not find large changes in small groundnut participation, area planted, yields, or production, perhaps because the price of this crop only increased about 5%. However, while yields stayed stagnant on average, some households did respond to higher prices of a close substitute crop (large groundnuts) by a combination of increased participation and intensifying their small groundnut production (raising their yield) of that crop.

8.2.9. Sesame

The overall proportion of smallholder farmers growing sesame remained practically the same, but the data show a considerable reduction in sesame participation in Nampula (from 22.4%

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[48] Like the analysis in this paper, the analysis by Mather (2009a) used panel household-level an econometric technique to control for time-constant unobserved household level factors, and also controlled separately for total household landholding, thus the effect of animal traction use would ostensibly imply a positive effect on smallholder crop productivity.

in 2008 to 12.8% in 2011) and an increase in Sofala (from 35.3% to 43.3%). Our regression results of the probability of planting sesame suggest that these changes in participation in Nampula and Sofala are likely driven by changes in relative prices between our panel years. Although the average expected price of sesame has a positive effect on participation in sesame growing, it is not significant and is of relatively small magnitude. Interestingly, we also see that while the expected price of sesame increased on average by 65% across our two panel years, the largest increase was in Nampula (where we see declining participation) and the lowest in Sofala (where we see the highest). This suggests that perhaps other changes in the prices of other crops are perhaps influencing sesame participation. In fact, our econometric analysis of the probability that a household grows sesame shows that a 10% increase in the price of the two main cereal staples maize and rice leads to 1.2% and 2% increase in sesame participation, respectively, in the probability of growing sesame (Table 47). We then note that the average expected price of maize in the 4th quarter (Oct-December) fell by 13% from 2008 to 2011 in Nampula but increased by 75% in Sofala. This suggests that rapidly increasing maize prices in Sofala drew more households into production of a high-return crop like sesame (the proceeds of which can buy more maize for net buyers of maize).

We also find that a 10% increase in the price of cowpea leads to 3% decrease in sesame participation (Table 47). As sesame is a higher-value cash crop that is sold by nearly 75% of its growers, cowpea does not likely compete directly with sesame. Rather, the negative effect of cowpea price increases on sesame participation may be linked to the regular intercropping of cowpea with maize. Thus, given that we found sizeable increases in maize participation in Nampula in 2011 (and a huge increase in cowpea production), it would appear that area previously planted to sesame is being switched into a maize-cowpea intercrop.

The average area planted to sesame declined only slightly between the two panel years. Econometric analysis of household area planted to sesame shows that a 10% increase in the expected sesame price has a positive and nearly significant effect (p=0.13) effect on area planted (increase of 2.9 ha) among current growers (Table 47). However, among all households, a 10% increase in the sesame price increases area planted by 0.6 ha. As with participation, an increase in the expected maize has a positive and significant effect on area planted to sesame, as a 1% increase in the maize price leads to a 1.1ha increase in area planted to sesame among current growers (conditional effect) and an 0.2 ha increase in are planted among any household. This suggests that in some areas (such as Sofala), increased sesame participation and area planted are responding not just to increases in sesame prices but primarily because these households perhaps use the high relative returns per hectare of sesame as a way to increase their cash income to purchase maize during the lean season.

Surprisingly, the presence of an oilseed press in or near the village has a negative but insignificant effect on both sesame participation and area planted (Table 47). The receipt of price information also results in a significant increase in the area planted to sesame. While sesame prices are not broadcast by SIMA, the prices of cooking oil are, as well as all the key grain and legume staple crops. This positive effect of market information on unconditional sesame area planted perhaps indicates that smallholders growing sesame and who recognize that oil prices (and perhaps those of food crops which they use sesame sales to buy) are increasing in their district/province and responding by increasing their area planted to sesame.

We next turn to econometric analysis of sesame yield, noting first that average sesame yields increased by 51% from 2008 to 2011. These increased yields appear to be driven in large part by access to an oilseed press in or near the village, which increases yields by 460% (Table 48). In addition, the large increase in sesame price appears to also have increased yields, though this positive effect on the sesame price variable is not significant (p=0.226). Prices of other crops also influence sesame yield, with the price of maize having a large positive yet insignificant effect on sesame yield, while that of cowpea, cassava and pigeon pea have large positive effects on sesame yield. Increases in the expected price of common beans have a large negative effect on sesame yield. Use of animal traction does not have a significant effect on sesame, and we do not include fertilizer or manure application in the yield regression as these inputs are rarely if at all applied to sesame.

Table 47. DH Regression of Household Area Planted to Sesame (Ha), 2007/08-10/11

	Probit		Truncated		Probit + Trunc. N.	
	DV = 1 if HH plants sesame		DV = HH area in sesame (ha)			
			Growers (cond).		All HHs (uncond.)	
Explanatory variables	APE	Pvalue	APE	Pvalue	APE	Pvalue
1=zone 10 (wet SAT, high altitude north-central)	-0.040	0.000	-0.236	0.000	-0.043	0.000
1=zone 5 (wet SAT, central coast)	-0.002	0.956	0.086	0.793	0.010	0.840
1=zone 7 (wet SAT, mid-elevation north-central)	-0.137	0.000	-0.191	0.000	-0.085	0.000
1=zone 8 (SAT, coastal north-central)	0.128	0.000	1.106	0.000	0.329	0.000
Elevation - meters above sea level	0.000	0.994	0.001	0.999	0.000	1.000
Expected main season rainfall - coeff. variation	-0.001	0.974	0.028	0.852	0.003	0.917
Main season rainfall (mm)	0.000	1.000	0.002	0.998	0.000	0.999
Slope - measure of steepness (degrees)	-0.001	0.985	-0.037	0.966	-0.005	0.958
Length of growing period (days)	-0.001	0.995	0.002	0.999	0.000	1.000
Year dummy (1=2011)	-0.160	0.000	0.306	0.022	-0.034	0.093
ln(real exp price of maize (Oct-Dec)) (Mt/Kg)	0.121	0.000	1.112	0.000	0.203	0.000
ln(real exp price of rice (Oct-Dec)) (Mt/Kg)	0.206	0.000	-4.136	0.000	-0.450	0.000
ln(real exp price of small g.nuts (Oct-Dec) (Mt/Kg)	0.022	0.000	-1.367	0.000	-0.170	0.000
ln(real exp price, common beans (Oct-Dec)) (Mt/Kg	0.002	0.926	-0.003	0.977	0.001	0.976
ln(real exp price of cowpea (Oct-Dec)) (Mt/Kg)	-0.290	0.000	1.293	0.000	0.036	0.000
ln(real exp price of pigeon pea) (Mt/kg)	0.110	0.029	0.242	0.908	0.083	0.700
ln(real exp price of cassava) (Mt/kg)	0.040	0.000	0.262	0.000	0.053	0.000
ln(real exp price of cotton) (Mt/kg)	0.006	0.911	0.118	0.951	0.018	0.937
ln(real exp price of tobacco) (Mt/kg)	0.004	0.938	-0.049	0.978	-0.004	0.984
ln(real exp price of sesame) (Mt/kg)	0.046	0.288	0.298	0.137	0.061	0.035
Distance to nearest fertilizer retailer (km)	-0.001	0.000	0.000	0.704	0.000	0.001
Distance to nearest formal market (km)	0.001	0.536	0.003	0.906	0.001	0.793
Distance to nearest seed retailer (km)	0.000	0.671	-0.001	0.848	0.000	0.722
Travel time to nearest town, 30k+ people (hrs)	0.002	0.000	0.014	0.000	0.003	0.000
1=Village/nearby had maize depot this/last yr	-0.018	0.580	-0.004	0.986	-0.009	0.814
1=Village has maize mill	0.018	0.803	-0.088	0.858	-0.003	0.980
1=Nearby village has maize mill	-0.029	0.013	-0.084	0.082	-0.023	0.006
1=Village/nearby village has maize mill	-0.030	0.002	-0.077	0.082	-0.022	0.004
1=Village/nearby village has oilseed press	-0.028	0.634	-0.143	0.513	-0.029	0.522
1=HH received price info through a radio	0.001	0.757	0.035	0.009	0.005	0.018
Total landholding size (Ha)	0.012	0.920	0.098	0.925	0.017	0.917
# of HH members age 15-64	0.016	0.928	0.085	0.977	0.018	0.962
Tropical livestock units	0.004	0.959	-0.006	0.992	0.001	0.991
1=HH used animal traction	-0.002	0.897	-0.041	0.527	-0.007	0.612
Head's age (years)	0.000	0.999	0.002	0.999	0.000	0.999
Head's education (years)	0.004	0.973	0.012	0.992	0.003	0.984
1=HH headed by a single female	0.049	0.000	0.501	0.000	0.109	0.000
Number of HH members age 0-4	-0.003	0.920	0.026	0.935	0.002	0.968
Number of HH members age 5-14	0.011	0.863	0.024	0.936	0.008	0.881
Number of HH members age 65 or above	0.074	0.000	-0.001	0.990	0.034	0.072
Number of observations	2353		342		2351	
Pseudo R-squared / Wald chi2(69), Pr>chi2	0.355		275.6 (0.000)			

Table 48. OLS-FE Regression of the Log of Household Sesame Yield (kg/ha), 2007/08-10/11

	OLS-FE DV = ln(HH sesame yield (kg/ha))	
Explanatory variables	APE	Pvalue
Expected main season rainfall - coeff. variation	0.632	0.010
Main season rainfall (mm)	-0.006	0.557
Year dummy (1=2011)	-6.322	0.289
ln(real exp price of maize (Oct-Dec)) (Mt/Kg)	10.440	0.219
ln(real exp price of rice (Oct-Dec)) (Mt/Kg)	3.483	0.781
ln(real exp price of small g.nuts (Oct-Dec) (Mt/Kg)	-1.302	0.660
ln(real exp price, common beans (Oct-Dec)) (Mt/Kg	-17.076	0.017
ln(real exp price of cowpea (Oct-Dec)) (Mt/Kg)	10.246	0.076
ln(real exp price of pigeon pea) (Mt/kg)	3.770	0.015
ln(real exp price of cassava) (Mt/kg)	2.670	0.354
ln(real exp price of cotton) (Mt/kg)	0.348	0.611
ln(real exp price of tobacco) (Mt/kg)	-0.026	0.978
ln(real exp price of sesame) (Mt/kg)	2.268	0.286
1=Village/nearby had maize depot this/last yr	-1.898	0.205
1=Village has maize mill	3.009	0.006
1=Nearby village has maize mill	4.139	0.000
1=Village/nearby village has oilseed press	4.575	0.039
1=HH received price info through a radio	0.094	0.766
Total landholding size (Ha)	-0.231	0.011
# of HH members age 15-64	-0.339	0.134
Tropical livestock units	-0.018	0.668
1=HH used animal traction	-0.042	0.928
Head's age (years)	-0.149	0.063
Head's education (years)	-0.059	0.658
Number of HH members age 0-4	-1.207	0.000
Number of HH members age 5-14	0.240	0.273
Number of HH members age 65 or above	-4.203	0.000
Number of observations	344	
F(27, 197) p-value / R2-within	5.92 (0.001) / 0.703	

Although average production of sesame per household increased (among those growing sesame), when computed across the full sample, the average production per household actually decreased by 19%. Increases in production among growers appear to be driven by increases in the prices of maize and cowpea, while increases in prices of common bean, small groundnuts and rice decreased household sesame production (among growers (Table 49). In addition, household receipt of market price information increased quantity grown among growers by 50kg.

Table 49. DH Regression of Household Production of Sesame (kg), 2007/08-10/11

	Probit		Truncated normal		Probit + Trunc. N.	
	DV = 1 if HH plants sesame		DV = HH sesame production (kg)			
Explanatory variables			Growers (cond).		All HHs (uncond.)	
1=zone 10 (wet SAT, high altitude north-central)	-0.040	0.000	-30.413	0.000	-9.830	0.000
1=zone 5 (wet SAT, central coast)	-0.002	0.956	-17.004	0.917	-2.779	0.911
1=zone 7 (wet SAT, mid-elevation north-central)	-0.137	0.000	-81.892	0.000	-29.265	0.000
1=zone 8 (SAT, coastal north-central)	0.128	0.000	-89.849	0.000	-3.112	0.418
Elevation - meters above sea level	0.000	0.994	0.157	0.999	-0.003	1.000
Expected main season rainfall - coeff. variation	-0.001	0.974	0.128	0.998	-0.154	0.989
Main season rainfall (mm)	0.000	1.000	-0.424	1.000	-0.057	1.000
Slope - measure of steepness (degrees)	-0.001	0.985	-16.776	0.974	-2.475	0.947
Length of growing period (days)	-0.001	0.995	-2.043	0.998	-0.425	0.998
Year dummy (1=2011)	-0.160	0.000	-8.564	0.901	-26.748	0.019
ln(real exp price of maize (Oct-Dec)) (Mt/Kg)	0.121	0.000	362.848	0.000	69.302	0.000
ln(real exp price of rice (Oct-Dec)) (Mt/Kg)	0.206	0.000	-594.529	0.000	-47.997	0.000
ln(real exp price of small g.nuts (Oct-Dec) (Mt/Kg)	0.022	0.000	-188.987	0.000	-22.349	0.000
ln(real exp price, common beans (Oct-Dec)) (Mt/Kg	0.002	0.926	-495.942	0.000	-67.614	0.000
ln(real exp price of cowpea (Oct-Dec)) (Mt/Kg)	-0.290	0.000	765.696	0.000	57.839	0.000
ln(real exp price of pigeon pea) (Mt/kg)	0.110	0.031	313.017	0.896	60.655	0.872
ln(real exp price of cassava) (Mt/kg)	0.040	0.000	-29.074	0.000	2.434	0.000
ln(real exp price of cotton) (Mt/kg)	0.006	0.912	-14.491	0.995	-1.034	0.997
ln(real exp price of tobacco) (Mt/kg)	0.004	0.938	34.336	0.988	5.406	0.984
ln(real exp price of sesame) (Mt/kg)	0.046	0.290	-108.308	0.610	-7.413	0.742
Distance to nearest fertilizer retailer (km)	-0.001	0.000	1.658	0.000	0.130	0.000
Distance to nearest formal market (km)	0.001	0.532	-0.216	0.985	0.207	0.909
Distance to nearest seed retailer (km)	0.000	0.669	-1.342	0.350	-0.220	0.357
Travel time to nearest town, 30k+ people (hrs)	0.002	0.000	4.358	0.000	0.956	0.000
1=Village/nearby had maize depot this/last yr	-0.018	0.580	-65.385	0.419	-11.880	0.354
1=Village has maize mill	0.018	0.807	-129.359	0.111	-13.022	0.439
1=Nearby village has maize mill	-0.029	0.013	-75.626	0.003	-14.942	0.000
1=Village/nearby village has maize mill	-0.030	0.002	-112.885	0.000	-18.148	0.000
1=Village/nearby village has oilseed press	-0.028	0.634	-55.176	0.647	-10.877	0.583
1=HH received price info through a radio	0.001	0.757	53.445	0.000	7.712	0.000
Total landholding size (Ha)	0.012	0.920	-0.183	1.000	1.557	0.981
# of HH members age 15-64	0.016	0.928	27.160	0.986	5.818	0.978
Tropical livestock units	0.004	0.959	3.212	0.992	1.097	0.983
1=HH used animal traction	-0.002	0.896	5.629	0.898	0.416	0.957
Head's age (years)	0.000	0.999	8.705	0.986	1.246	0.987
Head's education (years)	0.004	0.973	-8.762	0.989	-0.557	0.995
1=HH headed by a single female	0.049	0.000	-117.567	0.000	-13.616	0.000
Number of HH members age 0-4	-0.003	0.920	-37.132	0.755	-5.591	0.767
Number of HH members age 5-14	0.011	0.864	-1.516	0.991	1.534	0.953
Number of HH members age 65 or above	0.074	0.000	-113.234	0.062	-3.572	0.719
Number of observations	2353		347		2348	
Pseudo R-squared / Wald chi2(69), Pr>chi2	0.355		92.0 (0.04)			

8.2.10. Cotton

We note that for both cotton and tobacco regressions, we only include observations from villages where at least one smallholder produced the crop in at least one of the two years.[49] Since there are not very many producers of either tobacco or cotton (compared to the food crops), this means that there is not a large number of observations that we can use for our cotton regressions and tobacco regressions – especially the yield regressions that clearly are only run using observations from cotton and tobacco growers. One consequence of the relatively small sample size of smallholders in cotton or tobacco-growing villages is that our degrees of freedom are considerably smaller. In addition, because cotton and tobacco tend to be grown in select areas within a few provinces of rural Mozambique (and thus our sample of villages)– this means that we do not have very much spatial variation in the prices of competing crops that face households. Because of both our relatively small sample size for the cotton and tobacco regressions and the lack of spatial variation in prices, we are not able to include as many variables as we do in modeling the area planted, yield, and production of other crops, as this lack of spatial price variation leads to high multicollinearity among price variables.

As we noted in the empirical modeling section, we assume that the actual cotton price paid in 2008 and 2011 is closer to the indicative price (given to growers in October before planting, and on which growers make their production and input decisions) as opposed to last year's actual price paid, thus we use the actual village price of cotton that year (in 2007/08 and 2010/11) as an estimate of the farmer's expected price of cotton that season. Although the real expected price of cotton increased by 8% between our panel years, the percentage of cotton growers remained about the same across the two years (4.9% of our sample), although average area increased by about 9% (Table 8). However, there was some change in participation in cotton production, as Nampula and Sofala saw small increases, Zambezia had a slight decrease, and the percentage in Tete stayed constant over time.

Although the overall percentage of households growing cotton did not change much from 2008 to 2011, there was a small increase in Nampula and small decrease in Zambezia. This change in participation appears to be driven by the maize price, as a 1% increase in the price of maize (cowpea) led to a 1.2% (3.2%) decrease in the probability of planting cotton (cowpea is often intercropped with maize) (Table 50). However, we also find a negative and significant effect of the cotton price on cotton participation. This may be driven by the fact that the expected cotton price in Zambezia (where participation fell) only increased by 6% over time (a small increase relative to prices of most other crops).

Given that participation across the sample did not change much (in aggregate terms), it is perhaps not surprising that average area planted (computed among all households) did not increase. However, average area computed among cotton growers only increased by 9%. Turning to our econometric analysis of cotton area planted, we again see that among consistent growers, maize has a positive (though insignificant) effect on cotton area, while cowpea has a positive and significant effect on cotton area (Table 50). This perhaps implies

[49] The reason that we restrict the sample of households/villages used for the cotton and tobacco regressions is because unlike edible cash crops, tobacco and cotton do not have a market apart from buying depots organized by the existing cotton and tobacco companies in Mozambique. Thus, in studying the decision of a smallholder regarding whether or not to plant one of these crops, it makes no sense to include observations from villages in which smallholders do not realistically have the opportunity of growing this crop.

that cotton is grown as a relay crop[50] with cotton, as the planting season for cowpea precedes that of cotton by several months.

Table 50. DH Regression of Household Area Planted to Cotton (ha), 2007/08-10/11

	Probit		Truncated normal		Probit + Trunc. N.	
	DV = 1 if HH plants cotton		DV = HH area in cotton (ha)			
			Growers (cond).		All HHs (uncond.)	
Explanatory variables	APE	Pvalue	APE	Pvalue	APE	Pvalue
1=zone 10 (wet SAT, high altitude north-central)	0.622	0.000	11.758	0.000	11.762	0.000
1=zone 5 (wet SAT, central coast)	-0.041	0.931	0.546	0.997	0.109	0.999
1=zone 7 (wet SAT, mid-elevation north-central)	0.468	0.000	-0.930	0.000	0.273	0.272
1=zone 8 (SAT, coastal north-central)	0.539	0.000	2.306	0.000	2.346	0.000
Elevation - meters above sea level	0.001	0.998	0.001	1.000	0.001	1.000
Expected main season rainfall - coeff. variation	-0.032	0.887	-0.191	0.999	-0.090	0.999
Main season rainfall (mm)	0.002	0.989	0.003	1.000	0.003	1.000
Slope - measure of steepness (degrees)	-0.249	0.111	-0.371	0.998	-0.363	0.995
Length of growing period (days)	0.007	0.981	0.030	1.000	0.016	1.000
Year dummy (1=2011)	0.478	0.017	-0.859	0.981	0.265	0.984
ln(real exp price of maize (Jul-Sep)) (Mt/Kg)	-1.267	0.000	3.321	0.795	-0.268	0.959
ln(real exp price of small g.nuts (Jul-Sep)) (Mt/Kg)	0.070	0.000	-0.520	0.323	-0.087	0.627
ln(real exp price of cowpea (Jul-Sep)) (Mt/Kg)	-3.223	0.000	4.876	0.000	-1.764	0.000
ln(real exp price of pigeon pea) (Mt/kg)	-1.344	0.000	-0.726	0.000	-1.572	0.000
ln(real exp price of cassava) (Mt/kg)	-0.283	0.084	0.380	0.974	-0.170	0.977
ln(real exp price of cotton) (Mt/kg)	-0.174	0.000	-0.950	0.000	-0.462	0.000
ln(real exp price of sesame) (Mt/kg)	0.639	0.630	0.323	0.999	0.740	0.994
Distance to nearest fertilizer retailer (km)	-0.004	0.000	0.001	0.987	-0.004	0.900
Distance to nearest formal market (km)	-0.015	0.791	0.075	0.958	0.008	0.986
Distance to nearest seed retailer (km)	-0.002	0.793	-0.066	0.748	-0.022	0.797
Travel time to nearest town, 30k+ people (hrs)	-0.005	0.001	-0.001	0.997	-0.004	0.979
1=Village/nearby had depot this/last yr for alt. crops	0.105	0.514	-1.352	0.019	-0.382	0.747
1=Village has maize mill	0.238	0.248	1.422	0.985	0.710	0.987
1=Nearby village has maize mill	0.268	0.000	2.825	0.000	1.811	0.000
1=Village/nearby village has maize mill	0.486	0.000	2.744	0.000	2.517	0.000
1=Village/nearby village has oilseed press	0.090	0.676	0.227	0.959	0.178	0.919
1=HH received price info through a radio	-0.015	0.501	0.297	0.693	0.075	0.813
Total landholding size (Ha)	0.012	0.987	0.232	0.999	0.077	0.999
# of HH members age 15-64	0.049	0.692	0.160	0.977	0.101	0.960
Tropical livestock units	0.004	0.976	0.011	0.998	0.008	0.997
1=HH used animal traction	-0.038	0.506	0.225	0.544	0.025	0.914
Head's age (years)	0.025	0.886	-0.084	0.998	0.000	1.000
Head's education (years)	0.046	0.748	-0.103	0.986	0.015	0.998
1=HH headed by a single female	-0.020	0.551	2.946	0.000	0.846	0.000
Number of HH members age 0-4	0.037	0.979	-0.180	1.000	-0.017	1.000
Number of HH members age 5-14	0.032	0.929	0.224	0.998	0.100	0.998
Number of HH members age 65 or above	0.045	0.954	0.863	0.983	0.306	0.982
Number of observations	425		120		420	
Pseudo R-squared / Wald chi2(59), Pr>chi2	0.430					

[50] Relay cropping can be considered a type of double-cropping where farmers grow more than one crop in the same area, but one of the crops is planted earlier than the other, the second crop is planted later but before the first crop is harvested. For example, farmers growing groundnuts or cowpeas and cotton on the same field will first plant groundnuts and cowpeas, but before harvesting those legume crops, they will plant cotton.

Table 51. OLS-FE Regression of the Log of Household Cotton Yield (kg/ha), 2007/08-10/11

	OLS-FE	
	DV = ln(HH cotton yield (kg/ha))	
Explanatory variables	PE	Pvalue
Year dummy (1=2011)	1.454	0.296
Main season rainfall (mm)	-0.008	0.040
Expected main season rainfall - coeff. variation	0.113	0.262
1=drought shock affected many villagers in main season	-2.656	0.000
1=crop disease affected many villagers in main season	-1.381	0.018
ln(real exp price of cotton) (Mt/kg)	-0.003	0.994
ln(real exp price of maize (Oct-Dec)) (Mt/Kg)	1.735	0.251
ln(real exp price of rice (Jan-Mar)) (Mt/Kg)	12.426	0.006
ln(real exp price of sesame) (Mt/kg)	-5.919	0.000
Total landholding size (Ha)	-0.280	0.000
Number of adults age 15 or over	1.043	0.002
Tropical livestock units	0.183	0.038
1=HH used animal traction	-1.250	0.015
1=HH applied pesticide to cotton	1.236	0.001
Head's education (years)	-0.118	0.455
Head's age (years)	-1.279	0.000
Number of HH members age 0-4	0.271	0.325
Number of HH members age 5-14	-0.065	0.748
Number of observations	121	
F(19, 83) p-value / R2-within	21(0.000)/0.865	

Notes: Model includes household fixed effects and squared terms for head's age.

We again find the unexpected result that an increase expected price of cotton results in a statistically significant decrease in cotton area. Although there were changes in cotton participation over time among growers from three different provinces in our sample, this result is unexpected given that overall participation did not fall, and there was a 25% increase in the expected cotton price in Nampula, where participation and average area planted among growers increased. It may be that the expected price of cotton – while increasing over time – is simply picking up an unobserved factor (that has changed over time), such as a decline in the quality of the general management of the cotton subsector by cotton companies.

Our econometric analysis of cotton yield finds no significant effect of cotton prices on cotton yield, though a strong positive effect of the expected price of rice on cotton (Table 51). This suggests that although average yields fell 25% from 2008 to 2011, growers who attained higher yields on average were in areas where rice prices rose more rapidly, which could indicate that such households were incentivized to improve their cotton yields so as to have more cash income from cotton with which to buy rice. We also find a strong negative effect of sesame prices on cotton; this is as we would expect given that sesame is one of the main cash crops grown in the same areas as cotton.

Although smallholder cotton yield fell 25% on average from 2008 to 2011, there is still obviously inter-household variation in cotton yields. Two key household-level factors that have a significant positive effect on cotton yield are access to family labor and pesticides. For example, an additional adult age 15 or old increases cotton yield by 100% while application of pesticide to cotton increases yield by 123%. Surprisingly, we find that households that used animal traction had 88% lower cotton yields (Table 51).[51]

Given the average increase in cotton prices over time, it is surprising to find that average household cotton yields fell by 25%. Our econometric analysis of cotton yields shows that some of this may be explained by the fact that a drought (incidence of crop disease) affecting a large number of villagers reduces cotton yield by 265% (138%) (Table 51). However, given the incidence of drought and disease shocks in cotton-growing districts actually fell somewhat over time, this may highlight the limitation of a shock variable that does not actually measure the extent of the shock (just whether or not it occurs and the prevalence in the village).[52] That is, it is possible that these variables are picking up something we do not actually observe, such as the possibility that drought and disease shocks in 2011 were worse than those in 2008 (even if the prevalence of such shocks was somewhat lower in 2011).

There are a few more potential explanations for the decline in cotton yields. First, about one-third of cotton growers in 2008 were not growing in 2011, thus it could be that the growers in 2010/11 have poorer soils, less experience with cotton, etc. than those who were growing cotton in 2007/08 but stopped. However, when we run the OLS-FE cotton yield regression using only growers who grew cotton in both years, we still find the negative effect of cotton price on cotton yields, and those growers experienced a 19% (17%) loss in mean (median) cotton yield. Second, it is possible that there is a time-varying factor that is partly responsible for lower yields that is missing from our model – such as a decline in the prevalence or quality of cotton company extension messages/visits to contracted growers, timeliness of pesticide/seed delivery to farmers, etc. Third, given that pesticide use typically improves cotton yields (as noted above), the fact that only 18% of cotton growers used pesticide in 2008 (and 12% in 2011), suggests that either they did not receive this input at all or that perhaps they did receive it but applied it to crops instead. Unfortunately, our second and third explanations above are not consistent with the fact that the year dummy is positive and not far from significant, which implies that the effect of unobserved time-varying factors has resulted in 145% higher yields in 2011. The fact that we do not appear to have an explanation for the average lower yields within our regression analysis of cotton yields suggests we likely have a misspecification problem (i.e., a missing variable).

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[51] Because our observation of animal traction use is at the farm- and not the crop-level, it is possible that this negative effect is a spurious correlation (i.e., that animal traction was not used on the field where cotton was grown).

[52] The TIA08 and PP11 community surveys asked the village leader whether the village had suffered from a specific kind of production-related shock that main season (drought, flood, cyclone, or crop disease) and if yes, to indicate the proportion of growers affected (options included less than half, half, more than half, most households). While these variables are better than no village-level shock information, there are two potential problems with using them. First, what is considered a 'drought' in a given year by one village leader may not be a drought from the perspective of the leader of a different village, thus this is a somewhat subjective measure of an adverse shock. Second, even though the village leader gives an estimate of how many villagers were affected by the given shock, we have no measure of the extent of the damage – that is, many areas of Mozambique (even in medium to high potential zones) may receive some type of drought in a given season, but for the purposes of measuring the effect of this event on yields, we ideally need a measure of the extent of the drought (i.e., days of drought), not simply whether what a village leader defines as 'drought' occurred or not that year.

Table 52. DH Regression of Household Production of Cotton (kg), 2007/08-10/11

Explanatory variables	Probit: DV = 1 if HH plants cotton		Truncated normal: DV = HH cotton production (kg), Growers (cond.)		Probit + Trunc. N.: All HHs (uncond.)	
	APE	Pvalue	APE	Pvalue	APE	Pvalue
1=zone 10 (wet SAT, high altitude north-central)	0.419	0.000	-758.0	0.011	-147.5	0.645
1=zone 5 (wet SAT, central coast)	-0.053	0.739	-375.0	0.871	-142.0	0.923
1=zone 7 (wet SAT, mid-elevation north-central)	0.301	0.000	-1512.2	0.000	-94.1	0.798
1=zone 8 (SAT, coastal north-central)	0.169	0.000	197.8	0.048	186.4	0.204
Elevation - meters above sea level	0.001	0.999	1.1	1.000	0.7	1.000
Expected main season rainfall - coeff. variation	-0.032	0.897	99.7	0.999	16.0	1.000
Main season rainfall (mm)	0.002	0.993	-6.1	1.000	-1.1	1.000
Slope - measure of steepness (degrees)	-0.228	0.460	52.3	1.000	-103.8	0.999
Length of growing period (days)	0.005	0.988	-3.4	1.000	1.8	1.000
Year dummy (1=2011)	0.453	0.000	-270.0	0.000	169.4	0.002
ln(real exp price of maize (Jul-Sep)) (Mt/Kg)	-0.884	0.000	-2102.5	0.567	-1161.9	0.697
ln(real exp price of small g.nuts (Jul-Sep)) (Mt/Kg)	0.030	0.004	1647.8	0.000	559.4	0.000
ln(real exp price of cowpea (Jul-Sep)) (Mt/Kg)	-2.909	0.000	4233.3	0.000	-145.9	0.136
ln(real exp price of pigeon pea) (Mt/kg)	-1.271	0.000	1632.7	0.000	-135.3	0.000
ln(real exp price of cassava) (Mt/kg)	-0.144	0.341	-525.1	0.940	-249.5	0.954
ln(real exp price of cotton) (Mt/kg)	-0.138	0.000	498.5	0.000	91.0	0.000
ln(real exp price of sesame) (Mt/kg)	0.694	0.572	-1470.0	0.993	-116.8	0.999
Distance to nearest fertilizer retailer (km)	-0.002	0.048	6.4	0.751	1.0	0.938
Distance to nearest formal market (km)	-0.015	0.719	-12.4	0.998	-11.9	0.994
Distance to nearest seed retailer (km)	0.001	0.865	0.9	0.990	0.8	0.985
Travel time to nearest town, 30k+ people (hrs)	-0.001	0.432	-0.8	0.997	-0.1	0.999
1=Village/nearby had depot this/last yr for alt. cro	0.249	0.246	127.0	0.999	202.7	0.996
1=HH received price info through a radio	-0.040	0.861	-14.1	0.993	-26.1	0.982
Total landholding size (Ha)	0.029	0.957	31.9	0.999	22.1	0.999
# of HH members age 15-64	0.066	0.958	59.2	1.000	41.8	0.999
Tropical livestock units	0.007	0.985	-4.1	1.000	2.2	1.000
1=HH used animal traction	0.021	0.653	208.1	0.412	83.7	0.690
Head's age (years)	0.024	0.876	56.8	0.999	32.2	0.999
Head's education (years)	0.030	0.960	-37.0	1.000	3.7	1.000
1=HH headed by a single female	-0.023	0.570	-132.4	0.494	-54.1	0.641
Number of HH members age 0-4	0.030	0.946	224.9	0.995	90.2	0.995
Number of HH members age 5-14	0.031	0.191	159.7	0.088	68.9	0.709
Number of HH members age 65 or above	0.058	0.252	-129.5	0.706	-12.0	0.964
Number of observations	430		126		424	
Pseudo R-squared / R-squared						

8.2.11. Tobacco

While the real expected price of tobacco doubled between our two panel years, the percentage of growers only increased slightly (from 4.3 to 5.2%). Most of these growers are in Tete, where participation in tobacco production increased from 18% in 2007/08 to 21.5% in 2010/11. The main reason why participation may not have increased more dramatically in response to the doubling of the expected tobacco price is because nearly all tobacco in Mozambique is grown for export, the companies that contract growers to produce tobacco generally contract these farmers before the planting, and inputs for tobacco production (seeds, fertilizer, technical knowledge) are only provided to contracted farmers. That is, smallholder participation in producing a crop whose marketing is controlled by a single company is not simply determined by price but primarily by the decisions made by the tobacco company regarding how much tobacco area (and how many growers) they intend to support.

Turning to our econometric analysis, we find that a 1% increase in the expected price of tobacco results in a 4% increase in the probability of growing tobacco. Tobacco is almost exclusively grown as a cash crop and receives (together with sugar cane) more than 95% of all fertilizer used in Mozambique. As a result, an increase of ten kilometers in the distance to the nearest fertilizer retailer decreases the probability of growing tobacco by 1% (Table 53).

It appears that the increase in tobacco prices has elicited a positive intensification effect, as a 1% increase in the expected price of tobacco results in a 2.1% increase in smallholder tobacco yield (Table 54). Because tobacco is known to be a highly labor-intensive crop, part of this intensification would likely come from increased family labor applied per hectare. The large increase in price perhaps explains why we see such large positive effects of available adult labor on tobacco yields, as an additional member age 15-64 increases yield by 234% while an additional member age 65 or over increases yield by 380%. That said, we would have expected to find a negative effect of village average wages on tobacco yield, but instead we find a positive and significant effect. One explanation for this positive association between village wages and tobacco yields could be as follows. Tete is the one of the two main provinces where most tobacco is grown (the other areas are not in our partial panel sample), and although population densities in that province are relatively higher than in other zones, village wages in Tete are considerably higher than those in our other provinces. There are two likely explanation for this: first, Tete has the has the highest agroecological potential within our sample, with an average elevation of 1,197 meters and 89% of our sample farmers located within a high potential agroecological zone. Secondly, Tete has excellent sources of market demand, as they have the highest percentage of tobacco growers in Mozambique (a high-value cash crop), and excellent export market demand for maize and beans given their proximity to Malawi and Zambia as well as demand for beans from southern Mozambique. In addition, only a minority of tobacco growers used hired temporary labor in 2008 (25%) and 2011 (44%), thus while wages in Tete are considerably higher, these households may not be deterred from hiring labor given that most appear to have adequate family labor and given that demand for their crop output is quite high.

We also find that access and use of improved inputs have significant and positive effects on tobacco yields. For example, the use of inorganic fertilizers increases tobacco yields by 161% (Table 54). In addition, households that used animal traction had 186% higher tobacco yields relative to those that did not. This implies that animal traction use provides a large yield advantage, perhaps due to more timely planting, better soil aeration, and better weed management that animal traction tends to provide, relative to manually-prepared fields. Note that because this OLS yield regression includes household fixed effects, this means that any unobserved factors that may well be positively associated with animal traction use (such as farmer management ability, experience with tobacco production, field quality, etc.) are controlled for by the household fixed effect and do not bias the partial effect that we observe on the animal traction binary variable.[53] Tobacco is mostly grown in Tete Province where the use of animal traction is high, relative to the other four provinces covered in the survey.

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[53] That said, it is possible that the animal traction dummy might be picking up a positive bias via a time-varying factor (such as better extension from the tobacco company received in some areas in 2010/11). We ran a separate OLS-FE of log of tobacco yield that included a Control Function approach that both tests for potential bias from unobserved time-varying factors and corrects for them if found (see Appendix B-5 for details on this). Our conclusion from implementing the CF approach was that use of animal traction is not endogenous within the OLS-FE of tobacco yield, *ceteris paribus*.

We also find that an additional year of head's education improves yield by 83% (Table 54), a finding consistent with earlier work on the determinants of tobacco sales (Boughton et al. 2007). This finding is as we would expect given that tobacco is both labor-intensive and management intensive, in that this crop has relatively demanding crop input and management needs (compared with food crops that rural Mozambicans are accustomed to growing), and it is a crop with which few Mozambicans have experience growing. Thus, while we have not yet found evidence of positive returns to education in agricultural output in general (measured by household net crop income per hectare) in rural Mozambique (Walker et al. 2004; Mather 2009), the returns to education are indeed high for a labor and management-intensive crop like tobacco.

Table 53. DH Regression of Household Area Planted to Tobacco (ha), 2007/08-10/11

	Probit		Truncated normal		Probit + Trunc. N.	
	DV = 1 if HH plants tobacco		DV = HH area in tobacco (ha)			
			Growers (cond).		All HHs (uncond.)	
Explanatory variables	APE	Pvalue	APE	Pvalue	APE	Pvalue
1=zone 10 (wet SAT, high altitude north-central)	0.221	0.000	0.706	0.000	0.379	0.071
1=zone 5 (wet SAT, central coast)	-0.220	0.000	-0.506	0.035	-0.185	0.701
1=zone 7 (wet SAT, mid-elevation north-central)	0.244	0.000	2.213	0.000	1.229	0.000
1=zone 8 (SAT, coastal north-central)	0.000	1.000	0.000	1.000	0.000	1.000
Elevation - meters above sea level	0.000	1.000	-0.001	1.000	0.000	1.000
Expected main season rainfall - coeff. variation	0.002	0.989	-0.006	1.000	0.000	1.000
Main season rainfall (mm)	-0.002	0.995	0.030	1.000	0.006	1.000
Slope - measure of steepness (degrees)	-0.064	0.691	0.087	0.997	-0.032	0.999
Year dummy (1=2011)	0.036	0.155	-6.305	0.000	-1.284	0.000
ln(real exp price of maize (Jul-Sep)) (Mt/Kg)	0.028	0.249	0.205	0.218	0.070	0.884
ln(real exp price of small g.nuts (Jul-Sep)) (Mt/Kg)	0.451	0.000	0.564	0.000	0.496	0.000
ln(real exp price of cowpea (Jul-Sep)) (Mt/Kg)	-1.041	0.000	47.111	0.000	10.066	0.000
ln(real exp price of pigeon pea) (Mt/kg)	0.283	0.000	-0.420	0.000	0.132	0.000
ln(real exp price of cassava) (Mt/kg)	-0.040	0.757	1.035	0.947	0.207	0.942
ln(real exp price of tobacco) (Mt/kg)	0.041	0.000	-0.609	0.000	-0.107	0.000
ln(real exp price of sesame) (Mt/kg)	0.194	0.801	-4.740	0.962	-0.941	0.970
Distance to nearest fertilizer retailer (km)	-0.001	0.001	-0.004	0.034	-0.002	0.318
Distance to nearest formal market (km)	-0.008	0.501	-0.032	0.979	-0.014	0.965
Distance to nearest seed retailer (km)	0.001	0.788	0.007	0.915	0.003	0.962
Travel time to nearest town, 30k+ people (hrs)	0.008	0.000	0.002	0.888	0.004	0.658
1=Village/nearby had depot this/last yr for alt. cro	0.110	0.000	-0.063	0.729	0.072	0.773
1=Village has maize mill	-0.203	0.000	-0.075	0.671	-0.201	0.395
1=Nearby village has maize mill	-0.173	0.349	0.032	0.963	-0.140	0.937
1=HH received price info through a radio	0.007	0.881	0.031	0.883	0.013	0.968
Total landholding size (Ha)	0.037	0.934	0.079	0.999	0.048	0.997
# of HH members age 15-64	0.070	0.596	-0.258	0.993	-0.002	1.000
Tropical livestock units	-0.003	0.979	-0.008	1.000	-0.004	1.000
1=HH used animal traction	-0.095	0.000	-0.073	0.819	-0.088	0.566
Head's age (years)	-0.027	0.747	0.134	0.880	0.008	0.992
Head's education (years)	-0.009	0.996	0.002	1.000	-0.007	1.000
1=HH headed by a single female	-0.017	0.906	-0.285	0.992	-0.076	0.901
Number of HH members age 0-4	-0.010	0.977	0.007	1.000	-0.007	1.000
Number of HH members age 5-14	0.004	0.950	0.082	0.934	0.022	0.957
Number of HH members age 65 or above	0.375	0.454	-0.151	0.999	0.269	0.994
Number of observations	571		142		570	
Pseudo R-squared / R-squared						

Table 54. OLS-FE Regression of the Log of Household Tobacco Yield (kg/ha), 2007/08-10/11

	OLS-FE	
	DV = ln(HH tobacco yield (kg/ha))	
Explanatory variables	PE	Pvalue
Year dummy (1=2011)	1.457	0.357
Main season rainfall (mm)	-0.057	0.000
Expected main season rainfall - coeff. variation	0.962	0.000
ln(real exp price of tobacco) (Mt/kg)	2.164	0.000
ln(real exp price of maize (Oct-Dec)) (Mt/Kg)	1.211	0.579
ln(village ag wage, MTN/day)	0.573	0.079
Total landholding size (Ha)	-0.426	0.020
# of HH members age 15-64	2.393	0.000
Tropical livestock units	-0.020	0.700
1=HH used animal traction	1.778	0.000
1=HH applied fertilizer to tobacco	1.576	0.001
Head's education (years)	0.848	0.003
Head's age (years)	-0.634	0.379
Number of HH members age 65 or above	3.887	0.006
Number of observations	142	
F(18, 102) p-value / R2-within	.(.)/0.824	

Notes: Model includes household fixed effects and squared terms for landholding, number of members age 15-64, and head's age.

Table 55. DH Regression of Household Production of Tobacco (kg), 2007/08-10/11

	Probit		Truncated normal		Probit + Trunc. N.	
	DV = 1 if HH plants tobacco		DV = HH tobacco production (kg)			
			Growers (cond).		All HHs (uncond.)	
Explanatory variables	APE	Pvalue	APE	Pvalue	APE	Pvalue
1=zone 10 (wet SAT, high altitude north-central)	0.238	0.000	166.2	0.590	379.1	0.000
1=zone 7 (wet SAT, mid-elevation north-central)	0.212	0.000	-726.5	0.056	-37.8	0.730
Elevation - meters above sea level	0.000	0.999	0.3	1.000	-0.1	1.000
Expected main season rainfall - coeff. variation	0.002	0.987	-36.1	0.995	-7.4	0.997
Main season rainfall (mm)	-0.001	0.993	-1.7	1.000	-1.8	1.000
Slope - measure of steepness (degrees)	-0.056	0.000	144.8	0.734	-29.0	0.789
Length of growing period (days)	-0.004	0.000	6.3	0.690	-3.0	0.478
Year dummy (1=2011)	-0.061	0.000	-20740.8	0.000	-6557.3	0.000
ln(real exp price of maize (Jul-Sep)) (Mt/Kg)	-0.557	0.000	-3039.0	0.000	-1461.7	0.000
ln(real exp price of small g.nuts (Jul-Sep)) (Mt/Kg)	0.778	0.000	-562.3	0.900	780.0	0.342
ln(real exp price of cowpea (Jul-Sep)) (Mt/Kg)	-0.023	0.000	-333.4	0.000	-114.6	0.000
ln(real exp price of pigeon pea) (Mt/kg)	0.402	0.269	3818.5	0.651	1481.0	0.529
ln(real exp price of cassava) (Mt/kg)	-0.108	0.000	-513.5	0.000	-263.1	0.000
ln(real exp price of tobacco) (Mt/kg)	0.045	0.871	-43.4	0.995	41.9	0.984
ln(real exp price of sesame) (Mt/kg)	0.058	0.672	16766.3	0.000	4469.1	0.000
Distance to nearest fertilizer retailer (km)	0.000	0.982	12.2	0.958	3.8	0.953
Distance to nearest formal market (km)	-0.002	0.502	-3.9	0.958	-4.0	0.844
Distance to nearest seed retailer (km)	0.000	0.966	-10.0	0.821	-2.3	0.868
Travel time to nearest town, 30k+ people (hrs)	0.004	0.000	1.9	0.434	5.6	0.000
1=Village/nearby had depot this/last yr for alt. cro	0.048	0.000	-1187.1	0.000	-341.9	0.000
1=Village has maize mill	-0.087	0.000	3918.3	0.000	750.9	0.000
1=Nearby village has maize mill	-0.104	0.171	13137.4	0.000	1937.3	0.000
1=HH received price info through a radio	0.053	0.019	-132.9	0.348	28.5	0.565
Total landholding size (Ha)	0.059	0.604	24.1	0.995	72.5	0.952
# of HH members age 15-64	0.020	0.963	-241.3	0.986	-27.2	0.994
Tropical livestock units	0.003	0.970	17.8	0.986	7.8	0.979
1=HH used animal traction	-0.103	0.000	127.4	0.000	-94.5	0.000
Head's age (years)	-0.001	0.972	24.9	0.947	2.8	0.978
Head's education (years)	0.005	0.977	0.9	1.000	5.8	0.997
1=HH headed by a single female	-0.115	0.079	-179.3	0.845	-164.9	0.271
Number of HH members age 0-4	0.016	0.903	115.1	0.991	49.3	0.985
Number of HH members age 5-14	-0.024	0.108	137.8	0.133	7.4	0.851
Number of HH members age 65 or above	0.132	0.000	211.1	0.302	212.6	0.001
Number of observations	571		148		564	
Pseudo R-squared / R-squared						

9. SUMMARY OF DESCRIPTIVE AND ECONOMETRIC ANALYSIS

9.1. Introduction

This paper has three primary objectives, the first of which is to assess the extent to which the input and cropping decisions of small- and medium-holder households in the central and northern provinces included in the partial panel sample responded to increases in domestic food prices between 2007/08 and 2010/11, and how they responded – via extensification of crop production, intensification, and/or a combination of both. The second goal of the paper is to assess the role that changes in expected crop prices and market access had on smallholder cropping and input behavior, and the third is to assess what conditions or factors may constrain a more robust response and what implications (if any) there are for public policies that might alleviate those constraints. In Section 9.2. immediately below, we summarize the results of the descriptive analysis of smallholder changes in factor demand (input use) from 2008 to 2011, and what the results of econometric analysis of demand for each factor tell us about the role of prices and market access via other factors in driving any observed changes. Then in the following Section (9.3.), we summarize the results of the descriptive analysis of smallholder changes in crop-specific participation, area planted, yield, production and input use on those crops, as well as what the results of econometric analysis of each of those crop-specific household decisions tell us about the role of prices and market access via other factors in driving any observed changes.

9.2. Summary of Descriptive and Econometric Analysis of Smallholder Factor Demand in 2008 and 2011

9.2.1. Total Household Landholding and Total Household Area Cultivated

Because the sample we use for our analysis is longitudinal (i.e., the same households observed in 2008 and again in 2011), it is not surprising that we find that our sample households increased their household size in terms of adult equivalents by 8.8% from 2008 to 2011. Thus, our sample households' consumption needs increased by 8.8%, most of which are met by retention of crops that they produce.

Given that our sample households increased their total landholding by an average of 25% and total area cultivated to annual crops by 18% from 2008 to 2011, it is clear that these households have pursued extensification (in general) of annual crop production that is well above their increased consumption demands, on average. In addition, these households also increased the number of crops grown from 6.8 in 2007/08 to 8.1 in 2010/11 (with the exception of Tete, where we observe neither an increase in area cultivated (on average) nor an increase in number of crops grown). Thus, our sample farmers increased their average area cultivated per AE in 2010/11 by both planting more area to crops they grew previously (in 2007/08) and also increasing their area planted to new crops.

The large average increase in total household area cultivated appears to be driven primarily by increases in the expected prices of maize, rice, small groundnuts, and cowpeas. Some measures of market access also appear to have played a role, as the presence of a maize mill in the village (nearby village) increased total area cultivated by 14% (7.8%). Surprisingly, we find that an increase in the percentage of village neighbors using animal traction has a slightly negative (though significant) effect on total area cultivated, which is contrary to what we would expect, given that animal traction use increased quite a bit in the central provinces and that it is reasonable to assume that the labor demands of preparing a field are considerably lower for households that use animal traction.[54] In addition, we find that plough ownership does not have a significant effect on total area cultivated. Given this result, it would appear that increases in cultivated area are either due to increases to total landholding (via animal traction) that occurred before 2010/11 but after 2007/08 and/or an increase in the hours of family and/or hired labor applied per hectare in land preparation. While we do not observe family labor hours, we do find an increase in the percentage of households hiring labor for land preparation from 14.1% in 2008 to 22.6% in 2011, and a 46% increase in the average cost per hectare of labor for land preparation and planting (a proxy for hours of hired labor hired).

9.2.2. Hired Temporary Agricultural Wage Labor

The percentage of households in our sample that hired ag wage labor for any given crop-related task increased dramatically from 21.5% in 2007/08 to 31% in 2010/11. In fact, the percentages of households hiring labor for land preparation, planting, weeding, or harvest all increased significantly from 2008 to 2011, in several cases doubling. This increase in hired labor appears to be driven primarily by increases in the expected price of maize, though there are some other prices that have a positive effect on the probability of hiring ag labor (though these effects are either insignificant and/or of small magnitude). In addition, ownership of a plough increases the probability of hiring farm labor by 23%), while households headed by a single female are 9% more likely to hire farm labor.

We also find that the average cost of temporary ag wage labor per hectare increased by 52% from 2008 to 2011 (computed among all households), and that this increase also appears to be driven in large part by increases in the maize price, as a 10% increase in the expected price of maize leads to a nearly significant (p=0.12) 2.6% increase in the cost of hired labor per hectare. Other prices that have a significant and positive effect on the cost of hired labor per hectare include that of cowpea (which is typically cultivated in intercrop with maize) and tobacco, a highly labor-intensive crop, whose price increased dramatically from 2008 to 2010. We see additional evidence that the increase in the cost of hired labor per hectare is related to market forces in that the reduction of the distance to the nearest formal market increases the cost of hired labor per hectare by 0.8% among those already hiring labor and by 1% among any given household. That is, households closer to formal markets – who we would expect would receive higher prices than the average district-level SIMA or farm-gate expected prices we use in our regression models – tend to hire more labor. As with any input, the demand for hired labor is derived from the demand for the output being produced, thus it appears that households anticipating higher output prices responded by increasing their demand for hired labor.

9.2.3. Animal Traction

Household use of animal traction increased dramatically in Tete (from 26% of households in 2008 to 43% in 2011) and modestly in Manica (from 2.7% to 17.5%) and in Sofala (from 6.7% to 10.5%). Household ownership or use of either large livestock or animal traction is almost non-existent north of the Zambezi river, which conventional wisdom holds is due to trypanosomosis carried by the tsetse fly, a pest which is endemic in northern provinces (and parts of central provinces). Thus, since the TIA/IAI survey series began in 2001/02, each TIA survey has found between 0 and 0.5% of small and medium-holders using animal traction in

[54] Please see Section 7.1. for a potential explanation of this unconventional result.

northern provinces. In our sample, which includes some districts of Zambezia and Nampula, we observed only three households that report use of animal traction.

As we would expect, access to a plough and/or draught animal has a large and positive effect on the probability of using animal traction, as ownership of a plough (draught animal) has a strong positive effect on the probability of using animal traction as it increases this by 24% (9%). Likewise, a 10% increase in the percentage of village households that use animal traction (a proxy for access to traction rental) increases the probability of animal traction use by 1.7%. However, because household ownership of animal traction (a plough and/or a draught animal) increased only slightly from 2008 to 2011 in our sample, this suggests that the dramatic increase in animal traction use in our sample has come from an increase in animal traction rental over time, within villages where at least one household owns a plough (and that household or another owns a draught animal). Thus, it appears that the large increase in animal traction use has been driven by factors other than simply access to the animal/equipment (which is a pre-condition), rather, they appear to be largely driven by increases in expected crop market prices and proximity to specific crop markets. For example, a 1% effect in the expected price of maize leads to a 2.2% effect on the probability of animal traction use. Likewise, a 1% effect in the expected price of rice (small groundnuts, cowpeas, sesame) leads to a 6.1% (4.9%, 3.8% and 0.5%) effect on the probability of using animal traction.

We also find that the presence of buying depots or mills has a significant positive effect on animal traction use, as presence of a rice depot in or near the village (in the year prior and the current year) increased the probability of animal traction use by 3.5% (nearly significant at p=0.12), while the presence of a rice mill increased the probability of animal traction use by 10%. Similarly, we find that a one hour decrease in the travel time to the nearest town of 30,000 or more residents increases the probability of animal traction use by 0.6%. Additional determinants include an additional household member age 15-64 (which increases this probability by 2.3%) or a visit by an extension agent (related to crop production or marketing) that increases this probability by 5%.

9.2.4. Application of Organic Fertilizer (Manure) to Annual Crops

The percentage of households that applied organic fertilizer (manure) to annual food and cash crops increased dramatically in Tete (from 11% in 2008 to 23% in 2010), Manica (2.4% to 12.7%) and Sofala (0.9% to 6.2%). Although the districts in the northern part of our sample have some medium and small livestock, it appears that manure is only applied in areas with large livestock (as explained in Section 6.5.3.). This increased application of manure to annual crops appears to be driven largely by increases in expected crop prices. For example, a 10% increase in the expected price of maize leads to a 5.6% increase in the probability of manure application on an annual crop, while a 10% increase in the expected price of pigeon pea (cotton, sesame) leads to a 4.1% (0.6%, 0.9%) increase in the probability. Household access to manure (as measured by tropical livestock units per AE) also has a positive and significant effect on manure application to crops, as a 0.5 unit in household's TLU/AE leads to a 0.95% increase in the probability of applying manure to any crop. Finally, households that receive a visit from an extension agent are 3.7% more likely to apply manure to an annual crop.

9.2.5. Improved Seed Purchased That Year

As with manure application, we also find a large increase in the percentage of sample smallholders that purchased improved food crop seed, from 11.9% in 2008 to 20.3% in 2011. The majority of these purchases (and the increase over time) are due to purchase of improved maize or common bean varieties, though we also see sizeable increases in the purchase of improved seed of rice, large/small groundnuts, and cowpeas. The only crop for which improved seed use stayed constant was sorghum. However, even after a doubling in household use of purchased improved food crop seed, the percentage of households using, say, improved maize seed in 2011 (19%) is still quite low by regional standards given that the partial panel sample includes primarily the areas of medium and high potential from TIA08.

One of the key constraints to smallholder use of improved food crop varieties in these areas of rural Mozambique is physical access to seed retailers, as the average smallholder in our sample is 30 km from the nearest seed retailer. Thus it is perhaps not surprising that our econometric analysis of household purchase of improved seed finds that a decrease of 10 kilometers in the distance between the village and the nearest seed retailer improves the probability of using purchased improved food crop seed by 2.0%. However, a second key constraint would appear to be the lack of affordable credit for ag inputs, given that farmers in villages that had a seed fair that year were not significantly more likely to have purchased improved seed. Additional evidence that lack of credit is a key constraint to purchase of improved seed is that typical indicators of household wealth such as household landholding[55], head's age, and TLU all have significant (or nearly significant) positive effects on seed use. Head's age typically has a negative effect of adoption of new technology in the technology adoption literature from Africa and other developing regions, which suggests that in this case, head's age is proxying for lifecycle wealth effects (i.e., olderhouseholds tend to be wealthier per AE).

The typical third constraint to use of improved seed variety is farmer knowledge of and/or experience regarding the net benefits of their use. However, while we find that household receipt of an extension has a positive effect on this probability, this effect is insignificant. The lack of a signicant effect of extension on purchase of improved seed is especially disappointing in the context of rural Mozambique, where a visit by an extension agent could be measuring both knowledge transfer and improved access to seed, as several NGOs have promoted improved food crop varieties in various areas of Mozambique.[56] We also do not find a positive effect of yet insignificant (p=0.23) effect on use of improved seed, nor a significant effect from head's education level. We only find one crop whose expected price has a positive and significant effect on the probability of purchase of improved seed, as a 10% increase in the expected price of cowpea increases the probability of improved seed purchase by 4.5%.

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[55] Total household landholding has been shown to be highly correlated with total household income per AE in not only the context of rural Mozambique (Walker et al. 2004; Mather, Cunguara, and Boughton 2008) but also in many other east and southern African countries (Jayne et al. 2003). In rural Mozambique, even non-farm income/AE tends to increase in landholding (Mather, Cunguara, and Bougton 2008).

[56] Because the TIA survey instrument does not ask the household respondent to distinguish between different types of extension agent visits (i.e., government, NGO, firm leading an outgrower scheme, etc), it is possible that oen or more of these extension types might have a significant positive effect on household purchase of improved seed, yet by aggregating these separate types of extension types together, the hypothetically positive effect of one type is muted.

9.2.6. Inorganic Fertilizer

Although the real prices of nearly all food and cash crops increased dramatically from 2008 to 2011, there was no change over time in the percentage of households using inorganic fertilizer on annual crops in our sample (when looking at the full sample). This is perhaps not surprising given that every TIA since 2001/02 has found that 95% or more of fertilizer applied to annual crops is tied to either tobacco or sugarcane production. Within our partial panel sample, only in Tete are there smallholders who applied inorganic fertilizer to a food crop, and 87% of these households are also tobacco growers. Thus, it is not surprising that smallholder access to tobacco production (and thus fertilizer on credit that is inter-linked to the sale of that farmer's tobacco to the local tobacco company) is one of the key factors explaining fertilizer use on annual crops. For example, households from a village with a tobacco buying depot are 22% more likely to have used fertilizer (on any crop).

However, while proximity to a tobacco depot increases the probability that a household has access to not only fertilizer but also credit to obtain it, physical access to a retailer is also clearly an important determinant of fertilizer use. For example, 8% of households in our sample lived in a village that was visited by a fertilizer fair, and we find that such households are 4.2% more likely to have used fertilizer. In addition, a decrease of 10 km in distance to the nearest retailer of fertilizer increases the probability of fertilizer use by 9% (this effect is not far from significant at p=0.18). That said, it must be noted that physical access to fertilizer is a serious constraint for smallholders given that the average distance between our sample households and the nearest fertilizer retailer is 52 km – and that even in Tete, this average distance is 55 km.

While the near absence of fertilizer application to food crops in Mozambique has unfortunately not changed in aggregate terms since the first TIA in 2001/02, there were small increases in the application of fertilizer to maize, groundnuts, cowpea and several other legumes in Tete. For example, among those farmers in Tete with access to fertilizer via tobacco production (and the few who purchased fertilizer for use on a food crop although they do not participate in tobacco out-growing schemes), we find that a 10% increase in the expected price of small groundnuts (cowpeas) increases the probability of fertilizer use on any crop by 3.0% (11.7%). While the tobacco price itself rose 110% from 2008 to 2011, we find that a 10% increase in the tobacco price only increased the probability of fertilizer use (on any crop) by 0.2%. While this result may seem counter-intuitive, it is actually not surprising, given that our dependent variable is only measuring whether or not the household applied fertilizer to a food crop, and 85% or more of tobacco growers in Tete already applied fertilizer to their tobacco in 2007/08. That is, where we would most likely expect to see a larger response of fertilizer use to the tobacco price would be for the quantity of fertilizer applied per hectare of tobacco (which TIA does not observe).

9.3. Summary of Descriptive and Econometric Analysis of Smallholder Crop Participation, Area Planted, Yield and Production from 2008 To 2011

9.3.1. Introduction

In this section, we summarize the results of descriptive analysis of smallholder changes in crop-specific participation, area planted, yield, production and input use on those crops, as well as what the results of econometric analysis of each of those crop-specific household decisions tells us about the role of prices and market access via other factors in driving any observed changes. Our econometric results are summarized in Table 56, though readers interested in more crop-specific details should refer to Appendix Tables A-3 to A-8.

Table 56. Summary of Key Explanatory Factors from Econometric Analysis of Smallholder Crop Participation, Area Planted, and Yields in 2008 and 2011, and Sign of the Effects

Crop		Participation (HH grows the crop)	Area planted (ha)	Yield (kg/ha)
Maize	+	maize price	prices of maize, cowpea, c.bean pigeon pea; maize mill in village	price of maize; use of manure
	-		price of rice	
Rice	+			availability of family labor
	-		village farm wage	
Cassava	+	prices of rice, c.bean & s.groundnuts; HH headed by single female	prices of maize, rice	price of c.bean; availabile family labor; use of animal traction; manure; TLU (wealth); unobserved factors
	-			price of pigeon pea
Large ground-nut	+	prices of large & small groundnuts		price of s. groundnut; available family labor; manure; improved seed
	-	prices of maize, pigeon pea & cotton	oilseed press in/near village	prices of pigeon pea, sesame
Small ground-nut	+	oilseed press in/near village, HH receipt of ag market price info		price of large groundnuts; available family labor; use of improved seed
	-	price of s.gnut, rice	rice depot in/near village	
Cowpea	+	price of maize	price of maize	price of rice; maize mill; available family labor; improved seed combined with manure
	-	prices of cowpea, s.gnut		
Common bean	+	price of maize	prices of c.bean, maize, cassava	maize depot in/near village, maize mill; animal traction
	-	price of cowpea	price of cowpea	
Pigeon pea	+	price of p.pea	prices of maize, cassava	prices of pigeon pea, maize, cassava
	-		prices of rice, s.gnuts, c.bean	prices of rice, s.groundnuts
Sesame	+	prices of maize, rice	prices of maize, sesame; HH receipt of ag market price info	oilseed press in/near village; prices of sesame, cowpea, cassava, p.pea
	-	price of cowpea		price of c.bean
Cotton	+		price of cowpea	availabile family labor; pesticide use
	-	prices of maize, cowpea		village drought, vill. disease shock
Tobacco	+	price of tobacco		price of tobacco; available family labor; use of animal traction; use of inorganic fertilizer
	-			

Note: All prices noted above are expected real prices of that crop.

There was a large increase in the percentage of households growing cassava and pigeon pea, and small but notable increases in the percentages of household growing maize, small/large groundnuts, cowpea and common bean. The percentage of households growing rice and the three main cash crops (sesame, cotton, tobacco) stayed constant over time, while there was a decline in the percentage of households growing sorghum. However, increased crop participation by itself does not tell us whether households pursued extensification of a given crop on average, as this is would be indicated by an increase in average HH area planted to the crop beyond the 8.8% average increase in household consumption requirements between 2008 and 2011. We find this to have been achieved in the case of each crop except for cowpea (which saw no change in average area planted) and for sorghum and cotton, which experienced average declines in area planted of 10% and 15% respectively (Table 16b).

We next compared the change in household crop yield and household production per AE (both computed using all households), and found that in the case of crops such as maize, cassava, small and large groundnuts, common bean and pigeon pea, households have achieved both extensification (higher average area planted to the crop) as well as higher yields and production per AE. Yet, in the case of these crops, the growth in average yield and production per AE is larger than the growth in average area planted to those crops (Table 16b). In the case of rice, households have increased area planted and also achieved higher yields and production per AE, yet the percentage increase in area planted is double that of the yield and production gain (Table 16b). For sorghum and cowpea, we see no evidence of extensification but growth in yields and production per AE. In the case of cotton, we see no increase in participation or average area planted, and we also see an average 25% reduction in cotton yield. In the case of tobacco, participation did not change over time, yet average area and yields increased dramatically.

Given that we noted above that weather conditions for crop production during the main season were clearly better in 2010/11 relative to 2007/08, we cannot make any claims based on the average increase in crop yields alone as to the determinants of each increase in average crop yield. That is, while we can conclude that average yield growth greater than 8.8% exceeded household consumption demand growth over the same time period, without multivariate regression analysis, we cannot determine the extent to which this yield growth was due to better weather conditions, an increase in household crop inputs per hectare (i.e., intensification of crop production – perhaps by higher expected crop prices), and/or a combination of the two. However, the evidence in Section 4 above on input use over time suggests that at least some households did intensify production of some crops, given that we see average increases in use of hired temporary labor and the cost of temporary labor per hectare. In addition, in some provinces, we see significant increases in the average use of improved inputs such as animal traction, manure application on crops, and use of purchased improved seed varieties.

In the following tables, we summarize the results of both descriptive and econometric analysis of each crop addressed by this paper. The econometric results tell us the role that changes in expected crop prices and market access had on smallholder crop participation, and area planted, yield and production of that crop, relative to other factors that theory and experience suggest to be determinants of those household cropping decisions and outcomes. Evidence that changes in expected prices and/or market access have a significant effect on *extensification* of a particular crop is found in the econometric results of the effects of these variables on the probability that the household grows the crop (from the probit regression of whether the household plants the crop or not) and on area planted (from a double-hurdle regression of household area planted to the crop). Evidence that changes in expected prices and/or market access have a significant effect on *intensification* of a particular crop is found in the econometric results of the effects of these variables on the household yield of that crop (from an OLS regression of crop yield, including household fixed effects).

As noted at the beginning of Section 8, there are two important caveats to note about the results from the sample average household crop yields per year and our regressions of household crop yield. The first is that the increase in average yields over time is very likely due in part to the fact that agro-ecological conditions were clearly better in 2010/11 than in 2007/08. Thus, although our yield regressions include several village-level time-varying measures of actual rainfall conditions that season (and a year dummy), these measures are not ideal (as explained in more detail in Section 4.2. above), thus it is possible that other time-varying explanatory variables in our regressions that all tend to increase over time (such as prices) might pick up unobserved time-varying agro-ecological conditions. Likewise, our measure of family labor (number of adults in the household) is only a proxy for days of family labor applied (per hectare) to crop production. Thus, either of these unobserved time-varying factors – which both would tend to increase crop yields, might be correlated with our time-varying expected price variables. The implication is that the magnitude of the effect of expected prices on crop yields should be treated with caution.

9.3.2. Key Explanatory Variables Driving Extensification

The primary drivers of extensification appear to be increases in expected crop prices. There are four categories of price effects to note. The first is that of *own price* (the price of a given crop) on the probability of growing that crop (participation) and area planted to the crop, which production theory predicts to be positive. We find four crops for which own price has a positive and significant effect on participation (maize, large groundnut, pigeon pea, and tobacco) and three crops for which own price has a significant and positive effect on area planted (maize, common bean, and sesame) (Table 56). Production theory also predicts that the prices of competing commodities will have a negative effect on production of a given crop. We find evidence of a negative effect of competing crops in the case of rice (which has a negative effect on maize area), cowpea (small groundnuts), common bean (cowpea), and pigeon pea (small groundnuts, common bean). Each of the effects above are as expected, as rice and maize are both staple grains (that provide starch and carbohydrates), and each of the other competing crop combinations are different kinds of beans or groundnuts (legumes and oilseeds that are high in vegetable protein). Third, production theory also predicts that the price of a joint product (a commodity that is produced together with another one) will tend to have a positive effect on a commodity produced together with it. In this case, we see that the large increase in the dominant cereal staple crop rice, which is grown by most rural Mozambican smallholders in an intercrop with legumes, has a significant and positive effect on area planted to (or participation in) cowpea, common bean, and pigeon pea.

The fourth price effect category regards cassava, a crop for which we observed a dramatic increase in participation (from 48% of households in 2008 to 63.7% in 2011), in production per AE (an average household increase of 31% from 2008 to 2011) and also in yields (an average household increase of 35%). Yet this incredible increase in cassava production via both extensification and intensification was not driven by the price of cassava, but rather by rising maize and rice prices, which both had strong positive effects on cassava area planted. We discuss cassava as a separate category for two reasons – first because unlike maize and rice, it takes considerably longer to produce cassava (from planting to harvesting); second because unlike cereal or legume crops, the tubers can be harvested at any time. In fact, TIA data observes that smallholder cassava growers harvest this crop most extensively in September and October – that is, several months after maize and rice harvests have been completed. In addition to considerable drought tolerance, this is why cassava has been promoted by IITA and others as an ideal crop to promote household food security given both its hearty resistance to drought shocks and its inherent free storage properties (i.e., the household can harvest cassava when they need it, after first observing the outcome of their main season harvest of other key caloric staples such as maize and rice, and at that time determine how much to harvest and how much to leave in the ground for later).

We also find some significant effects of better market access (such as proximity to a formal market, to a buying depot or to agro-processing equipment for that crop) on crop participation and area planted. For example, the presence of a maize mill in the village has a positive effect on maize area, while the presence of an oilseed press has a positive effect on small groundnut participation.[57] These effects are as we would expect, given that demand for maize (groundnuts) may be higher given that the mill (oilseed press) owner may be willing to pay a premium for maize grain (groundnuts) in order to have sufficient volume to cover the fixed and variable expenses of this kind of capital-intensive processing equipment. Another way that it could provide an incentive for maize (groundnut) production is that household access to a mill (oilseed press) would enable the household to rather easily convert his/her maize grain (groundnuts) into maize flour (groundnut oil), which has considerably higher re-sale value in that state (net of the milling/pressing fee they would have to pay). We also see a positive effect of household receipt of agricultural market price information via radio on area planted to sesame and small groundnut participation, likely because cooking oil and small groundnuts are among the food commodity prices reportedly weekly by SIMA via radio.

9.3.3. Key Explanatory Variables Driving Intensification

In addition to playing a key role in driving extensification of many crops between 2008 and 2011, expected prices also were important factors that help to explain the average increases in yield of most of these crops between 2008 and 2011. We see own-price effects in the case of maize, pigeon pea, sesame, and tobacco; intercropping price effects in the case of pigeon pea (maize price); and competing price effects in the case of large groundnut (prices of pigeon pea and sesame), pigeon pea (prices of rice and small groundnuts), and sesame (price of common bean). Interestingly, an increase in the price of large groundnuts seems to have increased small groundnut yields, and vice versa – suggesting perhaps that in areas where one of the two were scarce (i.e., their prices were relatively higher), this in effect incentivized intensification of the closest substitute to large groundnuts, which is small groundnuts (and vice versa).

We also see a significant effect of market access in the intensification of sesame, as the presence of an oilseed press in or near the village had a positive and significant effect on sesame yields. Unfortunately, we were unable to assess the true effect of most of our market access variables given that they did not vary over time, and our yield regressions use household fixed effects (which controls for any time-constant factors, whether observed or unobserved). That said, while these price and market access effects tell us that smallholders are intensifying the production of specific crops – which implies that they are increasing the levels of one or more inputs per hectare applied to that crop – the partial effects of price and market access on crop yield does not tell us *how* smallholders are intensifying their

[57] Many oilseed presses in rural Mozambique are due to sesame promotion efforts, thus unless these presses can also process groundnuts, this correlation is likely spurious.

production. To try to address that question, we looked at other yield determinants in each crop yield regression.

In the descriptive analysis in Section 4, we noted the dramatic increases in the number of households hiring temporary labor (from 21.5% of households in 2008 to 31% in 2011) and in the average cost of hired labor per hectare. There were also rather large increases in the percentages of households using animal traction (in central provinces only, from 25.9% in 2008 to 43.1% to 2011 in Tete, and from 9.8 to 14.4% in Manica/Sofala combined). As both of those variable are only observed at the farm-level, we cannot conclude for certain that significant effects of, say, animal traction on a given crop are causal given that it is possible that the farmer did not prepare all his/her fields using animal traction. Given that caveat, our econometric analysis of crop yields finds large positive and significant effects of animal traction use, increasing yields of cassava by 270%, of common bean by 179%, and of tobacco by 186%.

We also found that percentage of households applying manure to any crop (within the central provinces) increased from 4.6% in 2008 to 13.1% in 2011, and this percentage increased for every crop with the exception of rice and sorghum. Our econometric analysis of yields shows that application of manure to a specific crop had large positive and significant effects in several cases – increasing yields of maize by 44%, of cassava by 179%, and of large groundnut by 192%. We note that use of inorganic fertilizer did not change over time, very few smallholders acquire it, and most of it continues to be used on tobacco or sugarcane. That said, application of fertilizer to tobacco raised tobacco yield by 161%. Likewise, use of pesticides on cotton raised cotton yields by 123%.

Finally, we found that the percentage of households using purchased improved food crop seed varieties increased from 11.9% in 2008 to 20.3% in 2011, with percentage increases for each food crop except sorghum (and pigeon pea and cassava, for which this was not observed). Our econometric analysis of crop yields found that use of purchased improved seed increased yields of small groundnut by 66%, and large groundnut by 69% (not significant at p=0.27). In the case of cowpea, we find that the combination of manure applied to cowpea and purchase of an improved cowpea variety increased cowpea yield by 207%.

10. DISCUSSION AND POLICY IMPLICATIONS

10.1. The Continuing Challenge of the Food Price Dilemma and a High Price Food Environment

Evidence from this paper shows that rural smallholders in Mozambique *do* respond to higher expected food prices by increasing their household food crop production per AE, as microeconomic theory of producer behavior would predict. It is, therefore, encouraging that smallholders in the partial panel sample responded to the increased food price environment of 2008 to 2011 by extensification and intensification of crop production to the extent that their crop production per AE and yields increased so dramatically (though part of this increase is clearly attributable to better weather conditions). That said, the extent to which these sample farm households' increased food crop production has resulted in larger volumes of food staples sold into domestic markets remains an important empirical question for further research. However, we do not need the results of a study of smallholder food crop sales behavior during 2008-2011 to observe that whatever increase in volumes of food crops that smallholders produced, consumed at home (retained) and marketed in southern, central and northern regions between 2008 and 2011, this has apparently not been great enough to prevent rather large increases in both urban and rural inflation-adjusted (real) prices of key food staples such as maize, rice, beans and groundnuts (as shown in Table 1 for our rural smallholder villages and as found in the major urban centers of Maputo, Beira and Nampula by Mather et al. 2013).[58]

The implication of this fact is that while it is encouraging to see evidence that the smallholders in our sample did manage to achieve rather large percentage increases in average household production per AE from 2008 to 2011, an even larger and continuous smallholder supply response will be required if the agricultural sector will be capable of:

a) generating and sustaining broad-based rural economic growth;
b) making new gains in rural poverty reduction; and
c) producing an *aggregate* volume of surplus and marketed cereals, grains, and root crops such that the additional domestic food crop produced and marketed is large enough to have a dampening effect on domestic prices, as neighboring Zambia has been able to achieve in recent years (at least for maize).

Another implication of our descriptive and econometric analysis of smallholder factor demand (input use) and output supply (household area planted and crop yields) as well as basic agricultural marketing theory suggests that the GoM can most effectively and efficiently facilitate a larger and continued smallholder supply response by focusing increased investment and policy attention on two main types of public goods: improved rural road density, and improved smallholder access to improved crop input technologies, particularly improved food crop varieties and access to large livestock. These results also provides a clear indication of something that the GoM would not be recommended to pursue. For example, given that farmers in many of the most productive areas of the country have not yet been able to respond with sufficient marketed surplus to constrain the rise in domestic prices of many key staple food crops since 2008, this clearly implies that the GoM does not need to consider policies to help support prices for farmers, so as to incentivize staple crop production – such as through large-scale purchases of grain by a parastatal grain board or via the application of tariffs on imported grain.

[58] That said, we acknowledge that a significant portion of maize sold by smallholders in northern and central Mozambique is informally exported to neighboring countries (Malawi, Zambia, and Tanzania).

10.2. Rural Road Infrastructure

Mozambique has one of the lowest road densities in southern and eastern Africa. For example, neighboring Zambia had 91,440 kilometers (km) of roads (primary, secondary, tertiary) in 2001, while Mozambique had just 30,331 km of roads in 2009.[59] This means that Zambia had 16.1 km of roads per 100 square km (in 2001), while Mozambique had just 3.9 km of roads per 100 square km (in 2009). Within the context of rural Mozambique, one of the largest components of marketing margins between farm-gate and retail levels in the supply chain of a given food crop (i.e., the difference between the price received by farmers and that paid by consumers at the retail level) is the cost of transporting food commodities from rural to urban areas (and from surplus to deficit areas). Mozambique's lack of sufficient primary, secondary and tertiary roads imposes large transportation costs on rural producers (who receive lower prices than they would if road density were higher) and consumers (who pay higher retail prices than they would). Thus, one likely reason why retail food prices remain high in rural and urban Mozambique is because road densities are so low. This may also help explain why maize meal prices in Mozambique have been considerably higher on average over the last decade than those in neighboring countries (Mason et al. 2009), and why maize meal-grain margins have fallen over the last ten years in Zambia and Kenya, yet not in Mozambique.[60]

Thanks to over a decade of investment by the GoM in SIMA and the rapid growth of first radio and then cell coverage across rural Mozambique, it is quite likely that transaction costs of food crop marketing[61] have fallen considerably in recent years, due to this combination of routine and widespread provision of publicly-generated crop price information plus private sector investments in ICT. Yet the actualized and yet-to-be-realized benefits for both producers and consumers (in the form of lower food commodity prices due to reduced marketing margins) from these two important technological developments cannot be fully achieved without dramatic investments in rural roads that would lower transportation costs. For example, access to SIMA price data likely improves the prices that farmers receive for their surplus food production for a variety of reasons:

1) Timely receipt of SIMA price data regarding the nearest market monitored by SIMA is likely to enable a farmer to negotiate a more fair price for his/her surplus grain/legumes/etc., with traders that visit his/her village in the post-harvest period;
2) The existence of publicly available (free) price data via radio likely reduces the barrier to entry for grain/bean/etc., assembly and trading, thus improving competition at that stage of the supply chain and thereby driving up the prices paid to farmers in a given village to something close to the difference between the SIMA market price and transport and handling costs between that market and the village;

[59] Authors' computations from World Bank Development Indicator database.The most recent year for which road information is available for Zambia is 2001.

[60] In addition, the margin between maize meal and maize grain has fallen dramatically over the last ten years in Zambia and Kenya yet not in Mozambique (Authors' computations using SIMA data; Mason et al. 2009). Part of the explanation for the decline in Zambia has to do with liberalization within the maize milling sector that allowed small hammer mills better access to grain in the lean season, yet the explanation in Kenya (whose processing sector was already liberalized) is more likely linked to massive investments made by the GoK in rural roads over that time period, as found in dramatic reduction in the distance from survey villages to the nearest motorable road (authors' computations from Tegemeo household survey data from 1997 to 2010).

[61] These transaction costs include search costs borne by traders regarding which villages have surplus food for sale and when – which amount to actual costs incurred by traders and passed on to producers and consumers)

3) Access to cell phones and cell service for both villages and would-be-buyers (traders, assemblers) of surplus food from a village should reduce the real and possibly significant search costs for a buyer/seller (i.e., a type of transaction cost).

That said, even though the combination of improved SIMA price information and cell coverage likely enable farmer to negotiate higher prices for their surplus crop production, the largest component of marketing margins between a village and a rural or urban market at any given point in time is transportation costs. Thus, in spite of the fact that SIMA and cell phones have likely lowered marketing costs of food staples somewhat, the extremely low rural road density in the central and northern Mozambique implies that transport costs from surplus to deficit areas (and from remote to populated areas) are still quite large, and that although villages receive visits by many traders in the post-harvest period[62] (i.e., they have market access), farmers still face relatively high input prices and relatively low output prices (for their surplus grain – they face high costs of purchasing grain in their village in the lean season because of high transport costs). For example, investments in rural roads that lower transportation costs between surplus and deficit areas would enable farmers to receive even *higher* expected prices for their output and pay *lower* prices for improved inputs such as improved seed and inorganic fertilizer. The higher the ratio between expected output and input prices, the greater the economic incentive for farmers to adopt improved crop inputs which can improve their crop productivity beyond that which can be achieved solely through increased seeding rates and increased labor per hectare applied for land preparation, weeding, and harvesting. In fact, our econometric results clearly show that expected output prices of several food and cash crops had a strong positive effect on total area cultivated and use of animal traction. While we found fewer food crops with a significant positive effect on use of an improved food crop variety, this may well be due to the fact that the average village distance to the nearest seed dealer was 30 km (thus many farmers literally did not have the option of buying seed), and because there were simply not that many cases of improved seed use with which to estimate partial effects.

In addition, improved rural road infrastructure would also improve the profitability of both urban and rural non-farm enterprises that respond to demand from both the agricultural and non-agricultural sectors, by lowering the cost of any external inputs required (such as farm equipment for farm service providers/retailers, construction materials for builders, etc.) via lower transportation costs. We thus recommend that secondary and tertiary road investments/maintenance need to continue and increase dramatically in order to improve trade flows between major regions and reduce transportation costs of agricultural and other commodities. However, it is critical that decisions regarding the targeting of rural road investments are coordinated between the roads sector and economic sectors including agriculture/CAADP. For example, such decisions must be coordinated with spatially defined growth prospects in agriculture (such as Comprehensive Africa Agriculture Development Programme [CAADP-defined Development Corridors) and coordinated with local governments.[63] Projects implemented for the construction and maintenance of secondary and tertiary roads should primarily be done through Labor Intensive Public Works programs that involve local communities and help increase rural employment (incomes) while improving access conditions for smallholders (Benfica and Mather 2013).

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[62] As per focus group interviews in 2009/10 during a maize supply chain study conducted by MSU in various areas of central and northern Mozambique (Personal communication with Duncan Boughton 2013.).
[63] Where concessions are awarded to contract farming companies, secondary and tertiary road construction, rehabilitation and maintenance could be part of the Firms' Corporate Social Responsibility mandate (Benfica and Mather 2013).

10.3. Large Livestock, Animal Traction, and Manure

Our econometric analysis of smallholder crop yield found that animal traction has positive and significant effect on yields of cassava (increasing yield by 270%), common bean (86% increase) and tobacco (132% increase). We also found that application of manure to a given crop also resulted in significant positive effects, as it increase smallholder yield of maize by 44%, cassava by 179%, and large groundnut yield by 192%, while the combination of improved seed and manure increased cowpea yield by 207%. Yet, the dramatic productivity increases from animal traction use are only available to smallholders who either own large livestock (a draught animal such as an ox or donkey) and a plow, own either a draught animal or plow and can borrow/rent the other, or those who live in a village where animal traction rental is possible. Likewise, the incredible productivity increases for smallholders who apply manure to a crop are only observed among smallholders who either own large livestock or else live in a village in which they are raised.[64]

Since the initial years since the 1992 peace accords, conventional wisdom on large livestock in rural Mozambique has held that the reason that we observe almost no large livestock in northern provinces (as per every TIA since 2001/02) – nor animal traction use – is due to a combination of depletion of herds during the 16-year civil war and the continued presence of tsetse fly populations carrying trypanosomosis, which present a serious constraint to raising large livestock (Walker et al. 2004)[65]. The authors of the National Agriculture Investment Plan 2014–2018 (PSA) (PNISA 2014) share this view, as they state the following:

> "About 75% of the country is infested by one or more species of tsetse fly (*Glossina morsitans morsitans , G. pallidipes , G. brevipalpis and G. austeni*). In addition to limiting the growth of the livestock holdings, this situation also limits the realization of the country's agro-ecological potential by constraining more widespread use of animal traction (PNISA 2014, p.39)."

However, the authors of this paper have heard some MINAG officials speculate that tsetse populations have diminished in recent years,[66] implying that disease pressure is, therefore, no longer a serious constraint to large livestock holding north of the Zambezi river, and that the main constraint at present is simply a lack of knowledge of large livestock husbandry and/or smallholder financial or credit constraints to purchasing such livestock.

This speculation begs three questions. First, given that we know that insect populations (vectors for some animal and crop diseases) can vary over time given changes in land use and/or weather (and of course, man-made efforts at eradication and/or vaccination), what exactly is the nature and date of the evidence that has informed the conventional wisdom

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[64] Please see Section 6.5.3. for an explanation of why smallholders with medium (pigs, goats, sheep) or small livestock (poultry) very rarely apply animal manure to crops.

[65] In addition to tsetse flies, other cattle diseases may also be more frequent in the north due to higher rainfall. One example of such cattle diseases is the lumpy skin disease. Southern provinces also tend to have better pastures than the central and northern provinces.

[66] The speculation that tsetse fly populations in the north may have diminished significantly in the last decade or so is based on several explanations: a) With rural people returning to their home villages after the war, many more fields are now open, the timber business has expanded, both of which may reduce tsetse populations by reducing the amount of trees and shade available to them; b) increased average temperatures above a certain threshold reduces the tsetse fly's ability to fly, and its mating and thus population decline rapidly as it becomes less mobile; c) new parks (coutadas) have been defined, and tsetse flies may have moved there as these areas provide more shade and humidity; d) higher use of trypanocides in recent years; etc.

regarding the tsetse fly and trypanosomosis incidence in rural Mozambique, especially north of the Zambezi river? To that question, we would note Specht (2008) cites sources from both pre-independence (Pires 1952) and post-civil war periods (RTTCP 2000) to note that infections with trypanosomes represent one of the major constraints for cattle production in Mozambique because approximately two thirds of the country is infested by its vector, *Glossina spp*. In addition, Pires (1952) recorded that cattle husbandry during the colonial period was absent in large areas in central and northern Mozambique, and Specht (2008) notes that many of these areas are part of the "common fly belt", which extends over some 320 000 km^2 in Malawi, Mozambique, Zambia and Zimbabwe. There is also more recent evidence (from 2002 to 2005) from blood smear testing of large livestock in four central provinces (and part of Zambezia) that found that these provinces in the center – where large livestock are currently raised and vaccination is used by some livestock holders – still face serious constraints to raising large livestock due to bovine trypanosomosis carried by the tsetse fly (Specht 2008).[67]

The fact that Specht's (2008) blood tests from 2002-05 were taken approximately ten years since the end of the civil war (and thus ten years after households began returning to their native villages, opening up new areas of cultivation, clearing forest, etc.) begs a second question which is:. why does one expect tsetse fly populations and disease pressure to have fallen in the center and/or north since 2005 (or why disease pressure in the north would be different from the center in 2005), unless something such as weather or other factors have changed dramatically enough since 2005 to have adversely affected the tsetse fly in both the center and the north? Third, do livestock and/or insect experts knowledgeable with northern Mozambique consider such speculation to be credible (that tsetse fly populations and thus, disease pressure have fallen dramatically in the north since the end of the civil war)? Fourth, what would these livestock and insect experts recommend with regard to how the Ministry and/or researchers would ideally go about testing tsetse fly populations and disease pressure in northern provinces, given that currently there appear to be no livestock to test (at least not on smallholder farms)?

It is clear from the history of agricultural development in both developed and developing countries (that achieved significant reductions in rural poverty), that the integration of large livestock into smallholder cropping systems generates significant positive benefits for smallholder agricultural productivity, crop and livestock incomes, and resilience of household consumption to adverse village or household-level health, weather or other shocks. Given the benefits of the integration of large livestock into smallholder farming systems, we recommend for future (and immediate) research that livestock/insect experts be consulted about question three above, and that the public sector (MINAG, donors) invest as soon as possible in geographically-representative empirical testing of tsetse fly populations and disease incidence in northern provinces.[68] In fact, the PNISA (2014) document specifically recommends this kind of empirical assessment (PNISA 2014, p.38).

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[67] Specht (2008) found that infections with trypanosomes were highest in smallholder cattle from Sofala Province with 36.8 % of the 872 blood smears examined positive for trypanosomes, and lowest in cattle of commercial farmers in Manica Province with only 6.2%.

[68] The nearly complete absence of large livestock in northern provinces suggests that perhaps MINAG/researchers would need to transfer large livestock to trusted farmers and/or extension stations in northern provinces and to then proceed with a series of blood tests over a certain period of time so as to test for disease incidence, in addition to whatever tests might be implemented to estimate tsetse fly presence and/or populations from one province to the next.

The reason that empirical testing is critical is that it is clear that regardless of whether or not disease pressure is still a serious constrain in the north, significant livestock extension efforts and perhaps subsidized livestock transfer programs (perhaps involving farmer organizations that would share in the costs of purchasing an animal and a plough) would be required to facilitate rapid adoption of large livestock purchases, and public and private investment in provision of livestock veterinary services would also be needed. The substantial costs that such extension and subsidized transfer programs would entail mean that GoM cannot proceed with a public-private large livestock promotion program in the north without first understanding the true nature of the constraints that explain the current absence of large livestock there. For example, assuming that disease pressure is still a problem, this would require investments (in tsetse eradication, vaccination programs/services, livestock transfer programs and livestock extension) to reduce this disease pressure.

What *is* abundantly clear is that this is not a new problem: since TIA/IAI survey series began in 2001/02, each TIA survey has found between 0 and 0.5% of small and medium-holders owning large livestock or using animal traction in northern provinces. Thus, the complete absence of large livestock in northern provinces represents an enormous loss of economic opportunity for rural households, which is all the more tragic considering that rural Nampula and Zambezia represent approximately half of the nation's rural population, and these provinces (and Niassa) also contain areas with medium and even high agro-ecological potential, for which the returns to animal traction use could be quite high. Yet, it would appear that while the GOM has known since 2001/02 that there is no animal traction north of the Zambezi river, to our knowledge, there has been no serious attempt by the GoM to address or even acknowledge the problem, until the PNISA (2014) document proposed a study of tsetse populations and disease constraints in the center and north. For example, animal traction is not even mentioned in key poverty-reduction strategy documents as PARPA/PARP, and the Agricultural Census 2009/10 did not include a question on whether the household used animal traction! The Mozambique agricultural sector research community is equally at fault with the GoM for not making a greater effort to get the absence of large livestock in the north on the policy agenda, as apart from references to the potentially large positive benefit of animal traction in one Directorate of Economics (DE) working paper (Mather 2009) there has been to our knowledge no concerted effort by DE, *Instituto de Investigacao Agraria de Mocambique* (IIAM), or UEM to produce research outlining the potential benefits of animal traction use in the north and the potential means by which to control the problem.

There are several successful cases of tsetse fly eradication in Africa. A wide range of applicable techniques of chemical control, from low-tech (traps, targets, treated cattle, and ground spraying) to high-tech (pour-ons[69], aerial spraying and sterilized male tsetse technique to reduce the likelihood of naturally fertilized female flies). In Zanzibar low-tech approaches were used over large areas, followed by a sterile insect technique to eliminate residual fly populations (Schofield and Maudlin 2001). Control of tsetse populations with insecticides was shown to be feasible and successes were achieved in Botswana, Uganda, and Zimbabwe (Jordan 1986 cited in Schofield and Maudlin 2001).

This inaction by public sector policymakers and researchers regarding the nature and extent of constraints to large livestock holding in central and northern provinces must be addressed as soon as possible because the actions required to first establish the current constraints to

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[69] Pour-ons are applications of insecticides to animals on which tsetse feed.

raising large livestock there (i.e., measure current tsetse fly populations and/or disease pressure in central and northern provinces, among other factors)[70] and then proceed with appropriate investments that address those constraints are clearly public goods. This includes: a) research to assess the true nature and extent of constraints to large livestock holdings; b) if tsetse populations and disease pressure remain serious constraints, this implies a need for public expenditure on tsetse eradication and/or vaccination campaigns in addition to improved community access to vaccination services in the long-term; c) livestock extension programs specifically designed to facilitate smallholder knowledge of proper large livestock husbandry; d) public/private coordination to facilitate the transfer of large livestock to new areas, once the disease constraint is deemed to be manageable, perhaps by subsidizing large livestock purchases by farmer organizations. The public good nature of activities a) to c) noted above imply that unless the public sector (MINAG and donor community) provides this research and any necessary investments to alleviate those constraints to large livestock in the north, no one will.

10.4. Smallholder Access to Improved Food Crop Varieties

Our econometric analysis demonstrates that smallholder use of purchased improved seed varieties has significant and positive effects on yield in several cases, increasing yield of small groundnut by 66%, while the combination of manure applied to cowpea and purchase of an improved cowpea variety increased cowpea yield by 207%. However, even though the percentage of our sample households that purchased improved food crop seed doubled from 2008 to 2011, the percentage of households using improved maize seed in 2011 (19%) is still quite low by regional standards given that the partial panel sample includes primarily the areas of medium and high potential from TIA08.[71]

Literature on seed systems and technology adoption in developing countries offers various explanations for non-adoption of improved crop varieties by farmers (Feder, Just, and Zilberman 1985; Tripp 1997). The primary constraints to adoption typically include: limited physical access to improved seed, lack of affordable credit to purchase the seed at planting time, lack of sufficient knowledge and/or experience regarding the potential benefits of improved seed relative to the costs and risks involved; and inappropriate or unprofitable technology.[72] Our sample data show that limited physical access to seed retailers is clearly a key constraint to smallholder use of improved food crop varieties in these areas of rural Mozambique, as the average smallholder in our sample is 30 km from the nearest seed retailer. Thus, it is not surprising that our econometric analysis finds that a decrease of 10 kilometers in the distance between the village and the nearest seed retailer improves the probability of using purchased improved food crop seed by 2.0% — a large partial effect. Our results also suggest that a second key constraint in the Mozambican context is lack of

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[70] Research needed to understand the current situation with tsetse fly populations and tryp disease pressure might include a) geographically-representative sampling of tsetse fly populations at key times of the year and/or b) MINAG coordinates delivery of large livestock from central provinces to northern MINAG research stations, where the livestock would simply be raised under 'normal conditions' at various locations in each province, and routine blood tests before and after their transfer to the north would help assess the probability of tryp infection and the extent of disease pressure.

[71] In neighboring Zambia, 41% of small- and medium-holders used purchased hybrid or improved maize seed in 2007/08 (authors' computations using nationally-representative rural household data from small and medium holders in the Supplemental Survey of 2008 (CSO 2008)).

[72] For example, assessments of the profitability of new agricultural technology made from on-station experimental trials may imply that new improved varieties released by local breeders are profitable, yet that technology may be unprofitable for the average smallholder because the on-station trial did not appropriately represent farmer' agronomic and/or economic conditions.

affordable credit for ag inputs, given our finding that farmers in villages that had a seed fair that year were not significantly more likely to have purchased improved seed. In addition, we find that typical indicators of household wealth such as household landholding, head's age, and TLU all have significant (or nearly significant) positive effects on smallholder use of improved seed. With respect to farmer knowledge of improved seed, while we find that household receipt of an extension has a positive effect on this probability, it is insignificant, and head's education has no significant effect on improved seed use.

Our survey data do not enable us to empirically assess the profitability of improved seed use under smallholder conditions,[73] thus it is possible that some households have perhaps tried improved seed (or witnessed a neighbor's experience with it) and found it that it simply does not perform as well as traditional varieties (in terms of the farmer's production needs and consumption preferences), given that farmer's specific agro-ecological conditions and the input and output prices he/she faces. That said, given our empirical findings of significant yield gains from smallholder improved seed use and the nature of improved seed (especially OPVs), it would appear that efforts to improve smallholder access to improved seeds (especially OPVs) could have significant benefits for smallholder food production and food security. There are three reasons why the nature of improved seed represent a relatively accessible technology for farmer experimentation: first, the cost of seed required per hectare is considerably less expensive than, say, inorganic fertilizer or traction ownership; second, unlike large livestock or plough ownership, this technology is divisible (i.e., a farmer can experiment with and buy relatively small or large quantities of seed, depending on their financial constraints and/or desire); and third, improved seed is typically a scale-neutral technology.

Our econometric evidence suggests that physical access and credit constraints are two key constraints to increased use of improved varieties, and it is clear that farmers require improved extension efforts by extension agents and/or whatever promotional efforts may be made to improve smallholder access to seed, so that farmers understand proper seed spacing, fertilization timing (etc.) if available, etc. A voucher subsidy scheme might be an ideal way to facilitate private sector investment in developing seed supply chains and improve relationships between private sector retailers, village community leaders, and government and/or NGO extension efforts. However, we have several recommendations related to public-sector-led seed promotion efforts. First, we would strongly caution the GoM and donor community from offering 100% subsidies for seed, as lessons learned from many other SSA countries finds that offering seed for free (or virtually free) can have unintended long-term consequences that are detrimental to the development of a private-sector-led input distribution system. For example, it can generate an expectation among smallholders that seed is either expected to be given to them free and/or that it is not worth it for them to pay the full commercial price for seed (need citation).

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[73] To empirically assess the profitability of improved seed use under smallholder conditions (using smallholder survey data), we would need plot-level data on the quantity of improved seed applied per hectare, plot-level data on crop output per hectare, and information from the farmer regarding the unit price he/she paid for the seed. None of those three types of data were collected in the TIA08 or PP2011 household or village-level surveys, nor have they ever been collected in previous TIA surveys, which appear to have been designed primarily to help provide nationally-representative statistics on agricultural crop and livestock production and access to services, not to assess smallholder crop productivity or analyze the factors that explain variation in smallholder crop production or productivity.

Second, seed promotion efforts should be spatially coordinated with the key crop production constraints faced by farmers in targeted communities. For example, communities in some areas may well have agro-ecological conditions that are ideal for hybrid maize varieties, while other communities may have conditions more appropriate for varieties bred specifically for drought and/or heat tolerance. Third, seed promotion efforts should be spatially coordinated with investments in secondary and tertiary rural road investments. The reason for this is that while subsidizing the seed itself can play an important role in the short-run by helping reduce the financial risk for participating farmers to experiment with improved varieties under their own conditions, seed subsidies are unlikely to be financially sustainable in the long-run, and village that face high transport costs to and from markets will have lower incentives to develop sustained demand for commercially provided improved food crop seed unless transport costs to their village are reduced (which would both lower the unit costs of seed and raise the prices at which farmers can sell surplus food production). Fourth, another constraint to seed use would appear to be limited access to affordable credit for crop inputs, which implies that households need to self-finance inputs if they are to obtain them.

There are many reasons why credit for crop inputs is either unaffordable or inaccessible to rural smallholders in Mozambique, as noted by (Poulton, Kydd, and Dorward 2006), as explained in detail in Appendix B-6. This appendix also explains why attempts to try to subsidize credit for crop inputs (and achieve reasonable repayment rates) have only been successful in SSA for non-edible cash crops. However, there are other ways in which the coordination of public/private investments could improve smallholders' access to cash during the planting season with a much higher probability of success. For example, investment in the development and dissemination of affordable on-farm storage technologies is one way in which to enable farmers to both improve their output to input price ratios while also enabling smallholders to store grain long enough to sell it during the planting period (when other sources of cash income may be scarce, depending on the household's access to non-farm income). Secondly, for areas known to produce surplus grain on a consistent basis, investment in cooperative-owned warehouse receipt systems is an alternative means by which to enable farmers (in this case, farmer coop groups) to sell their surplus grain, legumes, etc., later in the year when prices are considerably higher, which can not only provide higher returns per hectare but also provide cash for the household both at harvest (when they sell their produce to a warehouse) and during the lean season (when the warehouse sells their produce and sends the revenue minus storage/marketing costs to the farmer).

10.5. Smallholder Access to Inorganic Fertilizer

Our econometric analysis demonstrates that smallholder use of inorganic fertilizer increases maize yield by 44% and tobacco yield by 161%. While there was an increase in the percentage of smallholders who applied fertilizer to maize in our sample, this was only found in Tete and appears to be largely tied to either contracted tobacco production (or proximity to growers with such contracts) given that the overall percentage of households obtaining fertilizer did not change, and given that proximity to a tobacco buying depot is the primary determinant of household fertilizer use.

Given the magnitude of increases in the expected prices of crops that especially benefit from inorganic fertilizer (such as maize), one might have expected some increase in the percentage of growers accessing fertilizer. That said, this result is not surprising for three reasons. First, the vast majority of smallholders in the partial panel sample – which happen to reside in many of the highest potential districts within rural Mozambique, at least for maize production (with the exception of some areas in Niassa that are not included in the partial panel) – do not have reasonable physical access to inorganic fertilizer. For example, in the partial panel sample, the sample average distance to the nearest fertilizer retailer is 52 km. Even in Tete, where fertilizer use is highest (33% of our sample in Tete used inorganic fertilizer), the distance to the nearest fertilizer retailer is 55 km. By contrast, rural households in the Eastern Province of Zambia – lived 13 km (on average) from the nearest fertilizer retailer in 1999/2000, which was several years prior to the initiation and scaling-up of Zambia's large-scale fertilizer subsidy program.[74] This province borders Tete and is classified as having medium agro-ecological (800-1000mm of rainfall per year, on average)[75] A comparison of the fertilizer supply chains of Zambia and Mozambique is beyond the scope of this paper, and we recognize that part of this vast difference in access to fertilizer and use on maize between rural smallholders from similar agro-ecological areas of Zambia and Malawi has its roots in significant differences between the economic and political colonial and post-colonial histories of these two neighboring countries. Nevertheless, the comparison suggests that rural Mozambican smallholders face constraints to fertilizer access (perhaps related to much lower road density in Mozambique, noted above) that are considerably larger than those of their Zambian neighbors.

A second reason why the lack of an increase in the sample average of smallholders using fertilizer is not surprising is because TIA surveys since 2001/02 have found that approximately 95% of the fertilizer used by Mozambican smallholders is applied to either tobacco or sugarcane, and the percentage of smallholders acquiring fertilizer has remained relatively constant since 2001/02.[76] While we note that Tete farmers are more likely to use other improved inputs such as animal traction, fertilizer and manure on food crops, the number of tobacco growers appears to not be large enough to have attracted fertilizer retailers that service smallholder demand for fertilizer from crops apart from tobacco. This is confirmed by the fact that households in Tete (where 33% of households use fertilizer, at least within our partial panel sample) are on average 55 km from the nearest fertilizer retailer. In addition, only 8% of households in Tete live in a village that received a fertilizer fair in 2011. Thus, the fact that even households within Tete do not live within a reasonable distance from fertilizer retailers strongly suggests first that tobacco companies that provide fertilizer on credit to contracted tobacco growers (called inter-linked credit) apparently deliver fertilizer directly to contracted growers during the planting period, and second that fertilizer access in Tete (and Mozambique) is still almost entirely connected to inter-linked credit available via household participation in tobacco out-grower schemes.

Improving smallholder access to fertilizer for use on food staples such as maize has become a key goal for many African governments since the Abuja Declaration (2006) and especially since the 2007/08 International Food Price Crisis.

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[74] Authors' computations based on the nationally-representative rural household data from the Post-Harvest Survey of 1999/2000 and the Supplementary Survey 2000/01 by CSO, Zambia.

[75] This Zambian province is not an outlier, as the average distance to the nearest fertilizer retailer across all medium (high) potential zones in Zambia was 14 km (20 km) in 1999/2000. Zambia has similar cash crops to Mozambique (cotton, tobacco, sugarcane) that account for much of their fertilizer use, and like most areas of Mozambique, Zambia's cropping systems are heavily dominated by maize production, yet 40% of maize growers across all of Zambia's medium-potential areas applied fertilizer to maize in 1999/2000!

[76] It is well-known that one of the reasons that tobacco growers have access to fertilizer is because the companies that contract them to grow tobacco provide fertilizer (and other inputs) on credit (termed inter-linked credit); these companies are typically able to recover the value of the input loans they advance to contracted growers given that tobacco growers have no other marketing outlet for their high-value tobacco production.

However, while the use of fertilizer on maize within Tete suggests that it is likely to be profitable within some of those districts,[77] we would caution the GoM from investing in anything other than small pilot targeted fertilizer subsidy programs without first having IIAM coordinate on-farm trials to establish both that fertilizer use is indeed profitable for use on maize within a specific district[78] and establish the ideal type and dosages of fertilizes for use in that zone. This assessment needs to also consider the typical soil, rainfall, and weather risk characteristics of that zone as well as the expected relative prices of both fertilizer and maize within that district (and their potential variation).

10.6. Implications of the High Price Environment for Staple Crop Marketing and Price Policy

It is clear that the combination of increased international grain prices (due in large part to increased international demand for grains, which is likely going to continue to grow) and increased domestic demand for grains and other food crops due to increasing average incomes, urbanization, and increased demand from agro-processors suggests that the higher average food price environment seen in Mozambique since 2008 will likely continue for the foreseeable future. Given that farmers in many of the most productive areas of the country have not yet been able to respond with sufficient marketed surplus to constrain the rise in domestic prices of many key staple food crops since 2008, this clearly implies that the GoM *does not* need to consider policies to help support prices for farmers, so as to incentivize production – such as through large-scale purchases of grain by a parastatal grain board or via the application of tariffs on imported grain. Rather, the GoM needs to consider policy options by which it can eventually solve the *food price dilemma* by maintaining favorable prices for farmers, yet reduce retail food prices for both urban consumers and the majority of rural households who are net buyers of staples such as maize.

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[77] We base this assumption on T.W. Schultz's (1964) claim that smallholder farmers across the world are often poor not because they are irrational or lack ambition or ingenuity but because they face constraints that either prevent them from making investments that would enable them to improve the returns to their land and labor and/or face risks that make their rational welfare-maximizing decision one which compels them to remain within a semi-subsistence orientation.

[78] On-farm trials can help establish what maize-nitrogen response rates – under typical farmer management practices – appear to be in a given district. In addition, rapid appraisal or other data gathering during the on-farm trials is needed to collect approximate fertilizer and improved seed prices, as well as typical maize sale and purchase prices in the areas where trials are conducted. The combination of estimates of maize-nitrogen response rates (under typical farmer management practices) and input and output prices can provide an approximate marginal value cost ratio and thus an assessment of how profitable fertilizer use might be on a crop like maize.

10.7. Implications of the High Price Environment for Levels and Composition of Public Expenditure

For the GoM, successfully resolving the *food price dilemma* is intertwined with the challenge of achieving further reductions in urban and rural poverty. Given that poverty rates in Mozambique remained relatively stagnant from 2002/03 to 2008/09, one would expect that poverty rates in urban and rural areas likely increased somewhat since 2008 given higher food prices and the fact that all urban consumers and the vast majority of rural households are net buyers of food staples like maize and rice. Crop income (including the value of both retained and sold crops) is the predominant source of income for most rural Mozambican households, accounting for 73% of rural household income on average in 2002 (Table 1), and greater than 80% of the total income of the poorest 40% of rural households. Crop income was also responsible for much of the increase in total rural household income from 1996-2002 for the poorest 60% of Mozambicans (Boughton et al. 2006). However, much of the growth in agricultural production and crop income in rural Mozambique from 1994 until 2006 or so (when rural incomes began to stagnate) primarily came from agricultural extensification (increasing area cultivated) and very little from intensification (increased productivity via higher levels of inputs and/or shifting area into higher-return cash crops) (World Bank 2008). Given that levels of improved technology use (improved seed, manure applied to crops, inorganic fertilizer, animal traction) remain low in rural Mozambique – even in our sample areas which represent a good portion of Mozambique's zones with medium and high agro-ecological potential – it seems doubtful if continued area expansion by manual cultivation and/or intensification via increased family or hired labor applied per hectare will continue to generate growth in crop income per AE over time, without widespread improvements in the adoption of improved seed, increased smallholder access in the center and north to large livestock (which can provide both animal traction and manure for use on crops), and/or increased production of higher-value crops.

The importance of achieving wide-spread crop *productivity* increases in rural Mozambique cannot be overstated, as history shows the necessity of productivity increases in agriculture: except in the cases of a handful of city-states, there are virtually no examples of mass poverty reduction since 1700 that did not start with sharp rises in employment and self-employment income due to higher productivity on small family farms (Lipton 2005). The historical experience to date of both developed and developing countries that have managed to resolve both the food price dilemma and to achieve widespread poverty reduction suggests that the GoM focus investments in the agricultural sector on the provision of a few critical public goods: rural road and market-related infrastructure, agricultural research and development (R&D), and extension. For example, two recent empirical studies using long-term data from Asia provide evidence of the mix of public investments and policies that helped many Asian countries achieve their smallholder-led green revolutions.[79]

The first study estimated the contribution of various types of public investments and public policies to both agricultural growth and poverty reduction in six Asian countries: China, India, Indonesia, South Korea, Taiwan, and Vietnam (EIU 2008). The study found that a sound policy and enabling environment yielded the highest returns to agricultural growth and

[79] While there are important differences between Southeast Asia and Sub-Saharan Africa in agro-ecological potential and historical political economy factors that must be considered when looking to the Asian Green Revolution for potential policy lessons for African countries, these studies nevertheless have important potential lessons for African agricultural development.

poverty reduction.[80] Investments with the next highest rates of returns in terms of agricultural growth and poverty reduction included: agricultural R&D, investments in rural roads, electricity, health, and education.

The second study used data from India from the 1960s to 2000 to estimate the returns (over the whole period, and by decade) to various types of government expenditures in terms of agricultural growth and poverty reduction (Fan, Gulati, and Thorat 2008). They found that across this time period, spending on roads, agricultural R&D, and education provided the greatest poverty reduction impacts. However, by the last decade (the 1990s), the only government expenditures still achieving returns greater than 300% were roads and agricultural R&D. They summarize their results as follows: "These results have significant policy implications: most importantly, they show that spending government money on investments is surely better than spending on input subsidies. And within different types of investments, spending on agricultural R&D and roads is much more effective at reducing poverty than putting money in, say, irrigation" (pp. 18–19)." These findings are consistent with evidence from Africa showing returns to investment in agricultural R&D over 20% per year (Masters, Bedingar, and Oehmke 1998; Oehmke and Crawford 1996).

The link between investment in agricultural R&D and high economic returns from these Asian success stories is clearly shown to be relevant to the context of rural Mozambique by a recent study that simulated the effect of public agricultural expenditure (by type of expenditure) on Mozambique's agricultural growth rate (Mogues, Benin, and Woldeyohanne 2012).[81] This study finds that in order for Mozambique to achieve its agricultural growth rate targets as per its CAADP commitment in a sustainable manner requires the following (ibid 2012):

1) Investments that can bring about technical change (e.g., agricultural R&D) should receive 28-46% of the share of total public agricultural expenditure (PAE)
2) Provision of services and support to farmers that contribute to factor expansion and greater input use (e.g., farm subsidies) should take up 21–31% of PAE.
3) Expenditure to improve efficiency of input use (e.g., irrigation, information on best practices) should take up 6–8% of PAE.
4) The amount spent on general expenditures (e.g., salaries, institutional support) should decline from the current 75% to 24–36%.

We note that the recommendations from the analysis of Mogues, Benin, and Woldeyohanne (2012) implies several changes from public spending priorities within the agricultural sector as compared with PAE patterns from 2005-07 (Zavale et al. 2011). First, from 2005-07, irrigation made up 43% of all spending, though much of that was for renovation of a dam and the Chowke irrigation scheme, which may now be completed. Second, expenditure on agricultural R&D was only 10% while that for extension was 5%. Third, the majority of expenditure was on institutional support, which we assume to be salaries of government officials. Thus, the findings from Mogues, Benin, and Woldeyohanne (2012)–and the lessons learned from the two long-run studies of successful widespread rural poverty reduction in Asia cited above– both suggest that MINAG needs to dramatically increase the share of PAE on Agricultural R&D, minimize expenditures on irrigation (especially large-scale irrigation),

[80] The study highlighted the importance of the following types of policies: increased individual farmers' rights over their land and output, when combined with agricultural market liberalization, led to substantially improved incentives for farmers and stimulated rapid growth in farm output and private investment (p. 7–8).
[81] This study used as many parameters as possible from Mozambican data sources, but where data was missing, parameters were supplied from similar SSA countries (Mogues, Benin, and Woldeyohanne 2012).

and reduce expenditures on institutional support. Given that institutional support is largely salaries, this implies that to raise the share of Ag R&D, MINAG needs to allocate most of any future increases in total PAE to Ag R&D while also shifting funding currently spent on irrigation schemes to Ag R&D. We also note that the GoM needs to increase spending levels allocated to the agricultural sector, as between 2001 and 2011, the share of PAE in total public expenditure was about 5.3% per year, which is below the GoM's targeted levels of PAE under CAADP (Mogues, Benin, and Woldeyohanne 2012).

10.8. The Composition of Spending within Agricultural R&D

A final recommendation is simply that the GoM and MINAG in particular base the composition of their spending within agricultural R&D on the recommendations from IIAM's agricultural research prioritization study (Walker et al. 2006). This study notes:

> "The productivity of IIAM in the next 15 to 20 years is tied to the success of the cassava and maize programs. These two staple food crops represent about 50% of the value of production and 55% of the potential to alleviate income poverty in the smallholder sector. A 20% increase in productivity of either maize or cassava translates into a reduction in the severity of income poverty by as much as 19%, and leads to a poverty reduction that exceeds 5% in 34 of the 80 survey districts (Walker et al. 2006)."

Yet, the resource allocation for the implementation of the Action Plan for Food Production (PAPA) in response to the 2007/08 world food crisis did not appear to have even considered the objective criteria and analysis by IIAM, which was empirically-informed by TIA survey data and IIAM crop development research trials. For example, while cassava has the highest potential for poverty reduction, funding for cassava varietal improvement research was only budgeted to receive 0.1% of the PAPA budget for the ten products. The lion's share (80%) of the crop research budget went to rice (the third-most prevalent cereal crop grown by Mozambican smallholders, behind maize and sorghum) and Irish potatoes (the third-most prevalent root crop, behind cassava and sweet potatoes).[82] Fortunately, it appears that beginning in 2008, spending on crop science research began to shift closer to the recommendations of IIAM's priority setting report, as cassava, maize, and groundnuts were the most heavily researched, with shares of 9 to 12% of total FTE (full-time equivalent) for crop and livestock researchers across agencies, while rice, soybeans, and cotton followed, with shares of 5 to 7% (Flaherty, Mazuze, and Mahanzule 2010).

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[82] Even more inappropriate was the fact that wheat, an insignificant crop whose competitiveness is still highly debatable, was allocated 8.9% of the budget – ahead of cassava, maize, groundnuts, beans, etc.

11. CONCLUSIONS AND POLICY RECOMMENDATIONS

Recent analysis of domestic prices of key staple crops in several major retail markets in Mozambique finds that due to increased demand from both international and domestic sources, since 2008, the country's consumers and producers of staple crops appear to have entered a new higher-price environment for domestic food staples (Mather et al. 2013). This situation creates both a challenge and an opportunity for Mozambique, which is commonly referred to as the *food price dilemma*. In short, the dilemma for GoM policymakers is that urban consumers (and the majority of rural households who are net buyers of key staple foods like maize) prefer lower food prices (relative to other prices in the economy) as this improves their welfare. On the other hand, the minority of rural smallholder households that are net sellers of key food staples prefer higher prices for their marketed surplus as this improves their welfare. For example, considering the case of maize, the predominant cereal staple crop produced and consumed in most areas of the country, the vast majority of rural smallholder farmers are still semi-subsistence producers, and higher maize prices actually reduce the welfare of the 78% (71%, 50%) of rural households in the south, (center and north) respectively who were net buyers of maize in 2008[83]. Thus, higher maize prices only directly benefit the small minority of rural households (4%) in southern, central (12%), and northern (18%) Mozambique who are net sellers of maize (i.e., they sold more maize than they bought in 2007/08).

Thus, higher food staple prices create a serious challenge for Mozambican policy-makers as it reduces the welfare of all urban households and the majority of rural households. That said, higher prices also represent an opportunity in they may help to initiate an increase in smallholder factor demand (i.e., input use in crop production) and output supply (crop production and yields). If an increase in smallholder factor demand iscombined with private sector investment in provision of improved crop inputs (such as improved seed varieties, inorganic fertilizer, animal traction rental services, large livestock veterinary services, etc.), this could initiate a virtuous cycle of both farm and private sector investment that could lead to higher smallholder food crop productivity.

Given the serious challenge that Mozambican households face from a higher food price environment, there are three empirical and vital questions related to the extent and nature of smallholder response to this environment for which GoM policymakers require answers. First, to what extent have the input and cropping decisions of our sample small- and medium-holder households in the center and north responded to increases in domestic food prices between 2007/08 and 2010/11. If so, how they responded – via extensification of crop production (increasing area planted to food crops), intensification (increasing labor and/or other inputs applied per hectare), and/or a combination of both? In addition, is household supply response greater than the growth over time in household consumption needs? That is, are households not only producing additional food for their own consumption, but theoretically generating a surplus to increase the aggregate volume of marketed food staple crops produced domestically?

[83] The term net buyer of maize means that the household purchased maize and either did not sell any maize or sold less than they purchased. The net buyer/seller figures are authors' computations using TIA08 nationally-representative rural household survey data on household production, indications as to whether the household bought maize that year, and average maize consumption per capita by IOF zone in 2007/08. See footnote 1 for more details.

Second, what role have changes in expected crop prices and market access played in affecting smallholder cropping and input behavior, relative to other household- and village-level factors? Third, are there conditions or factors that appear to be constraining a more robust smallholder supply response to this higher food price environment, and what implications (if any) there are for public policies that might alleviate those constraints? In this paper, we address each of those three empirical questions using descriptive and econometric analysis of panel rural household data from selected central and northern Mozambique districts, which cover smallholder input and cropping choices and outcomes during the main seasons of 2007/08 and 2010/11. We have eleven key findings from our empirical analysis of smallholder factor (input) demand and output supply.

First, our descriptive analysis finds that smallholders are responding to higher food staple prices through a combination of both extensification (planting more area to annual crops) and intensification (applying more inputs per hectare, be it family labor, hired labor and/or improved inputs that generate higher yields, such as use of animal traction, inorganic fertilizer, organic fertilizer, and/or improved seed varieties). The descriptive evidence of extensification is simple to assess and the results are quite clear: between 2007/08 and 2010/11, smallholders in the areas of our sample in center and north increased their household total area cultivated (ha) by 18.6% on average while they increased their total landholding by 25%, on average. Given that household AE (which is a measure of household caloric consumption needs) increased by 8.8% on average between 2008 and 2011, the increase in cultivated area of 18.6% is clearly far beyond what one would expect if these households were simply expanding their total landholding and area cultivated in response to their increasing household consumption needs as their household size grew over time (due to the birth of children and/or arrival of children or adults new to the household). In addition, it is important to note that total landholding is increasing even faster than area cultivated. Thus, the large increases in area cultivated (on average) do not appear to be coming at the expense of fallows or permanent crops; in fact, the ratio of total area cultivated to annual crops to total landholding remained relatively constant (on average) over the two years of our panel, across all areas of our sample.

Second, in addition to expanding their total area cultivated, households increased the number of crops grown from 6.8 to 8 crops, on average. However, in Tete we see an exception to the extensification and diversification trend, as we do not find a statistically significant increase in total area cultivated in that province, and the average number of crops actually fell somewhat there in 2010/11. This suggests that farmers in Tete responded to higher prices of food and cash crops by specializing, while farmers elsewhere in the center and north of our sample responded via both extensification of total crop area and diversification of the crops they grew.

Third, there was a large increase from 2008 to 2011 in the percentage of households growing cassava and pigeon pea, and small but notable increases in the percentages of household growing maize, small/large groundnuts, cowpea and common bean. The percentage of households growing rice and the three main cash crops (sesame, cotton, tobacco) stayed constant over time, while there was a decline in the percentage of households growing sorghum. However, increased crop participation by itself does not tell us whether households pursued extensification of a given crop on average, as this is indicated by an increase in average HH area planted to the crop beyond the 8.8% average increase in household consumption requirements between 2008 and 2011. We find this to have been achieved in the case of each crop except for cowpea (which saw no change in average area planted) and for sorghum and cotton, which experienced average declines in area planted of 10% and 15% respectively.

Fourth, we find that the average yields of all crops increased more than the 10% between 2008 and 2011, with the exception of rice and cotton, whose average yields fell by 5% and 25%, respectively. Given that weather conditions for crop production during the main season were clearly better in 2010/11 relative to 2007/08, we use multivariate regression analysis (econometrics) to differentiate between the roles of different time-constant and time-varying village- and household-level factors – other than improved weather conditions – that may explain variation in yields both across households and over time.

Fifth, our econometric analysis of household crop participation and area planted to each crop show that the primary drivers of extensification appear to be increases in expected crop prices. These price effects can be categorized into four groups:

a) We find four crops for which the own price (expected price of the crop) has a positive and significant effect on participation in growing that crop (maize, large groundnut, pigeon pea, and tobacco) and three crops for which own price has a significant and positive effect on area planted (maize, common bean, and sesame).
b) We find evidence of a negative effect of competing crops in the case of rice (which has a negative effect on maize area), cowpea (small groundnuts), common bean (cowpea), and pigeon pea (small groundnuts, common bean). Each of those effect above are as expected, as rice and maize are both staple grains (that provide starch and carbohydrates), and each of the other competing crop combinations are different kinds of beans or groundnuts (legumes and oilseeds that are high in vegetable protein).
c) We see that the large increase from 2008 to 2011 in the expected price of the price of the dominant cereal staple crop maize, has a significant and positive effect on area planted to (or participation in) cowpea, common bean, and pigeon pea. The reason for this is that maize is grown by most rural Mozambican smallholders, and is most often grown in an intercrop with legumes.
d) We find that the dramatic increase in cassava production from 2008 to 2011 via both extensification and intensification was not driven by the changes in the price of cassava, but rather by rising maize and rice prices, which both had strong positive effects on cassava area planted.

Sixth, we also find some significant effects of better market access (such as proximity to a formal market, to a buying depot or to agro-processing equipment for that crop) on crop participation and area planted. For example, the presence of a maize mill in the village has a positive effect on maize area, while the presence of an oilseed press appears to have a positive effect on small groundnut participation.[84] In addition, we find a positive effect of household receipt of agricultural market price information via radio on area planted to sesame and small groundnut participation, perhaps because cooking oil and small groundnuts are among the food commodity prices reportedly weekly by SIMA via radio.

Seventh, our econometric analysis of the determinants of smallholder crop yield finds that expected prices also were important factors that help to explain the average increases in yield of most of these crops between 2008 and 2011, controlling for changes in weather conditions

[84] Many oilseed presses in rural Mozambique were the result of sesame promotion efforts, thus unless these presses also can process groundnuts, the correlation between 'village has oilseed press' and groundnut production is likely spurious (i.e., not causal).

over time. For example, we see positive own-price effects on yield in the case of maize, pigeon pea, sesame, and tobacco; intercropping price effects in the case of pigeon pea (i.e., an increase in the maize price increased pigeon pea yields); and competing price effects (negative effects on yield) in the case of large groundnut (prices of pigeon pea and sesame), pigeon pea (prices of rice and small groundnuts), and sesame (price of common bean).

Eighth, we also see a significant effect of market access in the intensification of sesame, as the presence of an oilseed press in or near the village had a positive and significant effect on sesame yields. Unfortunately, we were unable to assess the true effect of most of our market access variables given that they did not vary over time, thus they drop out of our yield regressions, which use household fixed effects.[85] That said, while these price and market access effects tell us that smallholders are intensifying the production of specific crops – which implies that they are increasing the levels of one or more inputs per hectare applied to that crop – the partial effects of price and market access on crop yield does not tell us *how* smallholders are intensifying their production. To try to address that question, we looked at a combination of descriptive analysis of household input use and other determinants of smallholder crop yields (especially agroecological factors and/or factors of production), as noted in the next three findings.

Ninth, there was a dramatic increase in the percentage of households hiring temporary labor across all provinces, with a sample average increase from 21.5% of households in 2008 to 31% in 2011). There was also a significant increase in the percentage of households using animal traction (in central provinces only), from 25.9% in 2008 to 43.1% to 2011 in Tete, and from 9.8 to 14.4% in Manica/Sofala combined. As both of those variables are only observed at the farm-level, we cannot conclude for certain that significant effects of, say, animal traction on a given crop are causal given that it is possible that the farmer did not prepare all his/her fields using animal traction. Given that caveat, our econometric analysis of crop yields finds large positive and significant effects of animal traction use, increasing yields of cassava by 270%, of common bean by 179%, and of tobacco by 186%. We note that this positive effect of animal traction on crop output is consistent with that of Mather (2009), who found that animal traction use improved smallholder net crop income by 33% in central provinces, using panel household data from TIA02-05.

Tenth, the percentage of households applying manure to any crop (within the central provinces) increased from 4.6% in 2008 to 13.1% in 2011, and this percentage increased for every crop with the exception of rice and sorghum. Our econometric analysis of yields shows that application of manure to a specific crop had large positive and significant effects in several cases – increasing yields of maize by 44%, of cassava by 179%, and of large groundnut by 192%. We note that use of inorganic fertilizer did not change over time, very few smallholders acquire it, and most of it continues to be used on tobacco or sugarcane. That said, application of fertilizer to tobacco raised tobacco yields by 161%, on average. Likewise, use of pesticides on cotton raised cotton yields by 123%.

Eleventh, the percentage of households using purchased improved food crop seed varieties increased from 11.9% in 2008 to 20.3% in 2011, with percentage increases for each food crop except sorghum (nor for pigeon pea and cassava, for which information on seed type was not

[85] Use of household fixed effects within OLS enables the analyst to control for any and all time-constant factors (observed and unobserved), which has distinct advantages (see Section 5.3. of this paper) but it also means that while we control for time-constant factors (observed or unobserved) we cannot estimate the partial effects of any of these factors specifically.

observed). Our econometric analysis of crop yields found that use of purchased improved seed increased yields of small groundnut by 66%. In the case of cowpea, we find that the combination of manure applied to cowpea and purchase of an improved cowpea variety increased cowpea yield by 207%.

In summary, we find that while there has been a robust smallholder response to higher food prices, by both extensification and intensification of crop production, there remain serious constraints to sustained and even larger supply response that will be required if the GoM is to help smallholder farmers, private sector input and output market actors, and CSOs to collectively solve the *food price dilemma* – that is, to maintain favorable prices for farmers while reducing retail food prices for both urban consumers and rural net buyers. Solving this dilemma will require achieving a number of goals simultaneously.

1) Maintain favorable output to input price ratios for farmers, which will require both;
    a. A reduction in transportation costs (for both inputs and crop outputs), and
    b. A mix of public and private investments and an policy enabling environment that will help improve smallholder access to improved inputs such as seeds of improved varieties, large livestock, animal traction rental services, inorganic fertilizer, and quality extension services.
2) Reduce retail food prices for both urban consumers and the majority of rural households who are net buyers of staples such as maize, which will require;
    a. Increased smallholder food production and volumes of marketed surplus, and
    b. Lower transportation costs.

Achieving those two goals will require significant GoM investment and policy attention on several key constraints that are listed below. These policy prescriptions come from a combination of the empirical findings noted above, lessons learned from several long-term studies of success stories from Asia in widespread poverty reduction and improvements in smallholder food staple productivity (EIU 2008; Fan, Gulati, and Thorat 2008), a recent study that simulated the effect of public agricultural expenditure (by type of expenditure) on Mozambique’s agricultural growth rate (Mogues, Benin, and Woldeyohanne 2012), and others studies as noted directly below.

a) Increase investment in secondary and tertiary rural roads so as to reduce transportation costs that raise prices for consumers and lower the crop output/input price ratios facing smallholders;
b) Implement research needed to assess the exact nature and extent of the constraints to large livestock keeping in northern provinces, which is preventing small- and medium-holders north of the Zambezi river from accessing not only the income, asset growth, and resilience opportunities that come from raising large livestock, but also improving their crop productivity via animal traction and manure application;
c) Provide the public goods required to alleviate the constraints to large livestock holding that are found in northern provinces (tsetse eradication efforts, vaccination campaigns, large livestock extension promotion, etc.);
d) Increase the proportion of agricultural R&D within total ag sector spending (Mogues, Benin, and Woldeyohanne 2012), and focus an increasing share of that budget on crops with the greatest potential for poverty reduction, namely maize and cassava (Walker et al. 2006); and
e) Carefully engage in efforts to facilitate dissemination of improved seed varieties in a way that helps to facilitate private sector investment in developing seed supply chains and improve relationships between private sector retailers, village community leaders, and government and/or NGO extension efforts; these efforts must be spatially

coordinated with the key crop production constraints faced by farmers in targeted communities as well as with investments in secondary and tertiary rural road investments.

APPENDICES

Appendix Table 1. Mean Smallholder Quantity Produced Per AE by Crop (Kg/AE) and Province, Computed Including All HHs (Growers and Non-Growers), 2008 And 2011

Province	Maize		Rice		Sorghum		Cassava		L.groundnuts	
	2008	2011	2008	2011	2008	2011	2008	2011	2008	2011
Nampula	79	126	1.2	6.4	8.6	16.1	305	536	1.7	4.5
Zambezia	128	167	5.9	7.5	11.3	17.6	537	480	1.4	6.4
Tete	202	262	0.0	0.0	1.0	0.5	27	84	7.7	9.1
Manica	200	339	0.2	0.2	22.7	15.0	114	166	0.3	0.3
Sofala	106	170	24.2	24.8	25.2	24.7	88	286	0.9	1.2
Total	135	198	6.5	8.2	13.2	15.5	267	350	2.2	4.6

Province	S.groundnuts		Cowpea		Comm. bean		Pigeon pea		Sesame	
	2008	2011	2008	2011	2008	2011	2008	2011	2008	2011
Nampula	5.7	7.3	7.4	10.9	0.4	0.0	1.5	8.7	9.0	3.0
Zambezia	1.0	1.4	3.8	4.8	3.0	5.5	26.3	54.2	0.8	0.7
Tete	4.4	5.1	5.1	7.0	19.4	19.5	1.2	1.6	3.0	0.0
Manica	1.5	2.2	1.7	1.6	1.8	3.5	0.3	11.0	4.9	6.5
Sofala	2.3	2.8	1.5	4.3	0.3	0.4	0.5	8.4	12.6	12.8
Total	2.8	3.6	4.0	5.9	4.4	5.4	8.8	22.0	5.6	4.1

APPENDIX A-1. Regression Diagnostics

Table A-1. Regression Diagnostics for Models on Cropped Area

LR test of restricted versus unrestricted	Pvalue on the constant of OLS of the difference in log-likelihoods	Coeff. on the constant of OLS of the difference in log-likelihoods	Coeff on the attrition variable	Pvalue on the attrition variable	Equation	First stage	Second stage	Attrition results
32.913	0.000	1,149,902	0.36	0.504	Maize area	DH is the preferred model	Truncated normal is the preferred model	Use regular weights
13.823	0.000	225,643	-1.24	0.010	Rice area	DH is the preferred model	Truncated normal is the preferred model	Need attrition-adjusted weights
13.743	0.000	262,018	-0.22	0.139	Beans area	DH is the preferred model	Truncated normal is the preferred model	Use regular weights
8.986	0.000	255,984	0.07	0.624	Cowpeas area	DH is the preferred model	Truncated normal is the preferred model	Use regular weights
18.908	0.000	228,210	-0.28	0.574	Pigeon peas - area	DH is the preferred model	Truncated normal is the preferred model	Use regular weights
12.111	0.000	91,756	2.32	0.002	Cotton area	DH is the preferred model	Truncated normal is the preferred model	Need attrition-adjusted weights
10.657	0.000	96,488	-0.33	0.010	Tobacco area	DH is the preferred model	Truncated normal is the preferred model	Need attrition-adjusted weights
6.611	0.000	122,168	0.18	0.391	Sesame area	DH is the preferred model	Truncated normal is the preferred model	Use regular weights

Table A-2. Regression Diagnostics for Models on Total Production

LR test of restricted versus unrestricted	*Pvalue on the constant of OLS of the difference in log-likelihoods*	*Coeff. on the constant of OLS of the difference in log-likelihoods*	*Coeff on the attrition variable*	*Pvalue on the attrition variable*	*Equation*	First stage	Second stage	Attrition results
22.962	*0.000*	*421,538*	*0.00*	-	*Maize production*	DH is the preferred model	Truncated normal is the preferred model	Use regular weights
13.944	*0.000*	*216,118*	*-589.15*	*0.314*	*Rice production*	DH is the preferred model	Truncated normal is the preferred model	Use regular weights
13.052	*0.000*	*163,357*	*-11.00*	*0.955*	*Beans production*	DH is the preferred model	Truncated normal is the preferred model	Use regular weights
16.570	*0.000*	*302,157*	*258.53*	*0.389*	*Cowpeas production*	DH is the preferred model	Truncated normal is the preferred model	Use regular weights
15.306	*0.000*	*359,153*	*356.45*	*0.422*	*Pigeon peas production*	DH is the preferred model	Truncated normal is the preferred model	Use regular weights
12.111	*0.000*	*76,788*	*1792.66*	*0.028*	*Cotton production*	DH is the preferred model	Truncated normal is the preferred model	Need attrition-adjusted weights
10.611	*0.000*	*1,572,887*	*165.07*	*0.689*	*Tobacco production*	DH is the preferred model	Truncated normal is the preferred model	Use regular weights
6.611	*0.000*	*238,722*	*144.86*	*0.865*	*Sesame production*	DH is the preferred model	Truncated normal is the preferred model	Use regular weights

Table A-3. Summary of Analysis of Smallholder (HH) Maize and Rice Production, 2008 and 2011

Crop	% of HHs	2008	2011	HH mean value	2008	2011	% ch.
	Planting the crop	90.4	93.7	HH area planted (ha)	0.83	0.93	12.1
Maize	Applying fertilizer to crop	3.9	5.0	HH yield (kg/ha)	879	1,258	43.1
	Applying manure to crop[1]	3.1	11.3	HH production (ka)	539	890	65.0
	Using improved seed	10.9	18.9	HH prod/AE (kg/AE)	135	198	46.2

Results from econometric analysis of determinants of HH area planted (extensification)

Participation: There was a sizeable increase in % of HHs growing maize in Nampula and Zambezia, though not apparently driven by maize prices

Area planted: 1) Increase in prices of maize and crops intercropped with maize (cowpea, common bean, pigeon pea) have large positive effect; 2) increase in price of rice has large negative effect; 3) presence of maize mill in village increase maize area by 0.1ha

Results from econometric analysis of determinants of HH yield (intensification)

Yield: 1) 1% rise in maize price increases yield by 1.6% ; 2) use of manure increases yield by 44%

Crop	% of HHs	2008	2011	HH mean value	2008	2011	% ch.
	Planting the crop	16.7	16.4	HH area planted (ha)	0.07	0.11	54.2
Rice	Applying fertilizer to crop	0.0	0.0	HH yield (kg/ha)	498	472	(5.2)
	Applying manure to crop[1]	0.0	0.0	HH production (ka)	21	35	64.0
	Using improved seed	0.7	4.3	HH prod/AE (kg/AE)	6.5	8.2	24.8

Results from econometric analysis of determinants of HH area planted (extensification)

Participation: Even though the expected price of rice rose dramatically over time, there was virtually no change in overall percentage of rice growers in our sample

Area planted: Appear to be largely driven by the availability and price of hired labor, as 1% increase in the village agricultural wage reduced area planted to rice by 0.2 hectares – a large marginal effect, while available family labor did not have significant effect on area planted.

Results from econometric analysis of determinants of HH yield (intensification)

Yield: Average rice yields actually declined, but the key factor explaining yield differences appears to be available family labor, as an additional adult age 15-64 increased yield by 62%. Yield stagnation may in part be due to fact that there is no use of inorganic fertilizer or manure on rice and very limited use of improved rice varieties.

Table A-4. Summary of Analysis of HH Sorghum and Cassava Production, 2008 and 2011

Crop	% of HHs	2008	2011	HH mean value	2008	2011	% ch.
	Planting the crop	37.8	33.8	HH area planted (ha)	0.15	0.14	(10.0)
Sorghum	Applying fertilizer to crop	0.0	0.0	HH yield (kg/ha)	544	942	73.3
	Applying manure to crop[1]	0.0	0.0	HH production (ka)	56	73	31.8
	Using improved seed	3.0	2.6	HH prod/AE (kg/AE)	13.2	15.5	17.4

Crop	% of HHs	2008	2011	HH mean value	2008	2011	% ch.
	Planting the crop	48.2	63.7	HH area planted (ha)	0.23	0.25	10.4
Cassava	Applying fertilizer to crop	0.6	0.3	HH yield (kg/ha)	6,694	9,046	35.1
	Applying manure to crop[1]	0.6	5.3	HH production (ka)	1,041	1,407	35.2
	Using improved seed	na	na	HH prod/AE (kg/AE)	267	350	31.2

Results from econometric analysis of determinants of HH area planted (extensification)

Participation: 1) Driven primarily by price increases in rice, common beans, and groundnuts; 2) HHs headed by single female were 15% more likely to have planted cassava

Area planted: We find that increases in both expected maize and rice prices led to increased area, as a 1% increase in price of maize (rice) led to a 0.28ha (0.21) increase in area planted to cassava (the rice effect is not far from significant at a p-value of 0.15).

Results from econometric analysis of determinants of HH yield (intensification)

Yield: 1) increase in common bean price had a large positive effect; 2) increases in maize and rice prices had relatively large positive effects (though not significant); 3) increase in the pigeon pea price reduces yield; 4) additional family laborer age 65+ increases yield by 114%; 5) use of animal traction increases yield by 270%; use of manure increases yield by 179%; 6) increase in TLU by one unit increases yield by 26%, suggesting that wealthier households have better access to hired, shared, or borrowed labor; 7) the average effect of unoberved factors in 2011 (the year dummy) has a large 133% effect on yield, demonstrating that various unobserved factors have also helped greatly improve cassava yield

Table A-5. Summary Analysis of HH Large and Small Groundnut Production, 2008 and 2011

Crop	% of HHs	2008	2011	HH mean value	2008	2011	% ch.
	Planting the crop	14.2	17.4	HH area planted (ha)	0.05	0.07	54.2
Large	Applying fertilizer to crop	3.8	0.0	HH yield (kg/ha)	319	421	32.0
groundnut	Applying manure to crop[1]	1.5	5.6	HH production (ka)	10	15	51.6
	Using improved seed	1.7	5.8	HH prod/AE (kg/AE)	2.2	4.6	107.4

Results from econometric analysis of determinants of HH area planted (extensification)

Participation: The small increase in participation comes mainly from large increases in Nampula and Sofala, and seem to be driven mainly by price changes, as: 1) a 10% increase in the price of large (small) groundnuts increased the probability of planting the crop by 4.2% (4.0%); 2) Increases in competing crops have the opposite effect, as a 10% increase in the price of maize (pigeon pea, cotton) led to a 5.2% (1.4%, 0.7%) decrease in the probability of planting large groundnuts.

Area Planted: There is only one variable with a signficiant effect on area planted, perhaps because it changed so little across the sample. The presence of an oilseed press in the village (or nearby village) actually reduces area planted to large groundnut by 0.24 ha, which is counter to what we would expect to find.

Results from econometric analysis of determinants of HH yield (intensification)

Yield: Yields among current growers increased greatly on average, and the drivers of this change appear to be prices, labor availability, and use of improved technology. 1) a 1% in price of small groundnut (whose price is positively correlated with that of large groundnut) increased yields by 10%, while that of large groundnut had a large positive but insignificant effect on L.groundnut yield; 2) a 1% increase in the price of pigeon pea (sesame) led to an 8% (2.7%) decrease in L.groundnut yield (competing crops); 3) an extra adult age 15-64 had large positive but insignificant effect on yield, though an extra adult age 65+ increased yield by 104%; 4) manure use increases yield by 192%; 5) use of purchased improved seed increases yield by 69% (p=0.27).

Crop	% of HHs	2008	2011	HH mean value	2008	2011	% ch.
	Planting the crop	19.7	23.7	HH area planted (ha)	0.06	0.07	18.5
Small	Applying fertilizer to crop	2.7	2.4	HH yield (kg/ha)	293	387	32.3
groundnut	Applying manure to crop[1]	7.1	11.7	HH production (ka)	11	17	51.9
	Using improved seed	5.3	7.7	HH prod/AE (kg/AE)	2.8	3.6	27.6

Results from econometric analysis of determinants of HH area planted (extensification)

Participation: 1) 1% increase in price of s.groundnut and rice reduces probability of planting s.groundnut by 0.21% and 0.36%; 2) oilseed press in or near the villageincreases probability of planting the crop by 18%) and receipt of market price information via radio increases it by 5%.

Area Planted: 1) Presence of a rice buying depot reduces area planted by 0.11 ha. The lack of other significant effects of prices or market access is perhaps due to the fact that the price of this crop did not vary much over time (on average it increased only 11%), neither did participation and average area planted to the crop.

Results from econometric analysis of determinants of HH yield (intensification)

Yield: The 33% average increase in S.groundnut yield appears to be driven by prices, available family labor, and access to improved seed. 1) S.groundnut price has a positive yet insignificant effect on yield, yet a 1% increase in the expected price of L.groundnuts increases S.groundnut yield by 3.2%; this suggests that as L.groundnuts became more expensive over time (its price rose 22% over time as compared with 11% for s.groundnut), this drove up the incentive to produce the closest substitute to this food crop (S.groundnuts). 2) An additional adult age 15-64(65+) increases s.groundnut yield by 39% (219%); 3) Improved seed increases S.groundnut yield by 66% (nearly significant at p=0.14); 4) Animal traction reduces S.groundnut yield 105%, likely a spurious effect.

Table A-6. Summary Analysis of HH Cowpea and Pigeon Pea Production, 2008 and 2011

Crop	% of HHs	2008	2011	HH mean value	2008	2011	% ch.
	Planting the crop	35.3	39.9	HH area planted (ha)	0.09	0.09	(0.9)
Cowpea	Applying fertilizer to crop	3.2	1.3	HH yield (kg/ha)	313	379	21.3
	Applying manure to crop[1]	6.3	14.0	HH production (ka)	16	25	53.6
	Using improved seed	2.2	6.6	HH prod/AE (kg/AE)	4.0	5.9	46.4

Results from econometric analysis of determinants of HH area planted (extensification)

Participation: 1) Cowpea price has negative/significant effect on probability HH grows cowpea, while a 10% increase in maize price increases probability of growing cowpea by 2%. This suggests that increases in cowpea participation (and area) are driven not by cowpea prices but by maize prices, because cowpea is often intercropped with maize 2) 10% increase in s.groundnut price leads to2.8% decrease in probability that HH grows cowpeas

Area planted:1% increase in maize price increases area planted to cowpea by 0.17 ha ..

Results from econometric analysis of determinants of HH yield (intensification)

Yield: 1) positive but insignificant effect of cowpea price; 2) nearly significant and large positive effect of rice price; 3) maize mill in the village results in 1.6% increase in cowpea yield; 4) yield increases appear to come from additional family labor, as additional adult increases yield by 114% and an extra adult 65+ increases yield 161%; 5) combination of improved seed with manure increases yield by 207%

Crop	% of HHs	2008	2011	HH mean value	2008	2011	% ch.
	Planting the crop	26.4	43.5	HH area planted (ha)	0.09	0.16	87.6
Pigeon	Applying fertilizer to crop	0.3	0.1	HH yield (kg/ha)	531	611	15.1
Pea	Applying manure to crop[1]	0.0	4.5	HH production (ka)	28	83	197.3
	Using improved seed	na	na	HH prod/AE (kg/AE)	8.8	22.0	148.9

Results from econometric analysis of determinants of HH area planted (extensification)

Participation: Given the large increase in % of households growing the crop, it is surprising that the effect of a 10% increase in the expected price of pigeon peas is quite small, as it only increases the probability of growing pigeon peas by 1.1%.

Area: There is a positive but insignificant effect of the pigeon pea price on area planted. 1) Pigeon pea appears to be driven by increases in the prices of the crops grown in intercrop with it (maize and cassava). For example, a 1% increase in the expected price of maize leads to an increase of 1 ha of pigeon pea among current growers and a 0.22 ha increase in pigeon pea area among any given household, while an increase in the price of rice (not intercropped with pigeon pea) decreases rice area. 2) Prices of groundnuts and common bean – crops that compete with pigeon pea as the companion to maize within a maize intercrop, as well as competitors in terms of cash sales value and household source of vegetable protein – have a large and significant negative effect on pigeon pea area.

Results from econometric analysis of determinants of HH yield (intensification)

Yield: Pigeon pea yields increased somewhat over time, thus much of the increase in production was due to extensification (not intensification). Nevertheless, a 1% increase in this price had a 1.2% increase in pigeon pea yield. As we saw with area planted to pigeon pea, the price of crops intercropped with pigeon pea (maize/cassava) have a positive/significant effect on pigeon pea yield, while that of competitor crops (small groundnuts) or a staple that is not intercropped with pigeon pea (rice) has a negative effect on pigeon pea yield. It is not clear not clear how intensification is implemented as the proxy for adult labor is insignificant, though given the minimal use of manure and zero use of improved seed, increased labor per hectare and/or higher seeding rates are likely the way that some HHs achieved higher yields in response to higher prices.

Table A-7. Summary Analysis of HH Common Beans and Sesame Production, 2008 and 2011

Crop	% of HHs	2008	2011	HH mean value	2008	2011	% ch.
	Planting the crop	16.6	18.9	HH area planted (ha)	0.06	0.07	6.1
Common	Applying fertilizer to crop	8.8	6.2	HH yield (kg/ha)	493	556	12.7
beans	Applying manure to crop[1]	2.8	10.5	HH production (ka)	21	24	14.7
	Using improved seed	5.5	14.6	HH prod/AE (kg/AE)	4.4	5.4	21.9

Results from econometric analysis of determinants of HH area planted (extensification)

Participation: Largely driven by changes in price of maize with which it is often intercropped, as a 10% increase in maize price increases the probability of growing common beans by 2.1% 2) Also influenced by prices of competing crops, as a 1% increase in cowpea price reduces probability of growing c.bean by 1.2%.

Area: Largely driven by changes in the common bean price, price of maize and then competing crops like cowpea: 1) 1% increase in common bean price increases area by 0.1ha; 2) 1% inc maize (cassava) price increases area by 0.2ha (0.03ha); 3) 1% inc cowpea prices decreases area by 0.4ha

Results from econometric analysis of determinants of HH yield (intensification)

Yields: 1) There is only one significant price effect (1% increase in pigeonpea price increases common bean yield by 12.8%) but this does not make sense; 2) presence of maize depot (mill) increases yield by 175% (117%), again showing how strong the link between maize demand and common bean production is; 3) use of animal traction increases common bean yield by 86%.

Crop	% of HHs	2008	2011	HH mean value	2008	2011	% ch.
	Planting the crop	13.9	13.4	HH area planted (ha)	0.07	0.06	(14.8)
Sesame	Applying fertilizer to crop	0.0	0.0	HH yield (kg/ha)	456	689	51.0
	Applying manure to crop[1]	0.1	6.7	HH production (ka)	21	27	28.7
	Using improved seed	na	na	HH prod/AE (kg/AE)	5.6	4.1	(27.0)

Results from econometric analysis of determinants of HH area planted (extensification)

Participation: Overall participation did not change, but there was an increase in Nampula and a decrease in Sofala. A 10% increase in price of maize (rice) leads to 1.2% (2%) increase in sesame participation; 10% increase in cowpea price leads to 3% decrease in sesame participation.

Area Planted: a 1% increase in maize price increase sesame area by 1.1ha (growers) and 0.2 (all hhs); a 10% increase in the expected sesame price has a positive and nearly significant effect (p=0.13) effect on area planted (increase of 2.9 ha) among current growers (Table 50). However, among all HHs, a 10% increase in the sesame price increases area planted by 0.6 ha. HH receipt of price information results in 0.04ha increase in area – perhaps because this enables households to better anticipate the rise in grain and legume prices in 2010/11 and respond by planting more area to a high-return cash crop with which sesame growers can access more cash with which to buy grain/beans in the lean season.

Results from econometric analysis of determinants of HH yield (intensification)

Yield: Average sesame yields increased by 51% from 2008 to 2011. 1) This yield increase seems to be driven in part by access to an oilseed press in or near the village, which increases yields by 460%; 2) In addition, the large increase in sesame price appears to also have increased yields, though this positive effect on the sesame price variable is not significant (p=0.226). Prices of other crops also influence sesame yield, with the price of maize having a large positive yet insignificant effect on sesame yield, while that of cowpea, cassava and pigeon pea have large positive & significant effects on sesame yield. Increases in the expected price of common beans have a large negative effect on sesame yield (perhaps as this is a rival edible cash crop).

Table A-8. Summary Analysis of HH Cotton and Tobacco Production, 2008 and 2011

Crop	% of HHs	2008	2011		HH mean value	2008	2011	% ch.
	Planting the crop	4.9	4.9		HH area planted (ha)	0.04	0.04	11.7
Cotton	Applying fertilizer to crop	5.2	2.9		HH yield (kg/ha)	862	643	(25.4)
	Applying manure to crop[1]	0.0	5.2		HH production (ka)	27	22	(18.3)

Results from econometric analysis of determinants of HH area planted (extensification)

Participation: Though overall participation remained constant across the sample, there was a slight increase in Nampula and decrease in Zambezia. This change in participation appears to be driven by the maize price, as a 1% increase in the price of maize (cowpea) led to a 1.2% (3.2%) decrease in the probability of planting cotton (cowpea is often intercropped with maize).

Area Planted: Among cotton growers, cowpea has a significant positive effect on cotton area. Surprisingly, a1% increase in cotton area reduces area planted to cotton by 0.95ha. We likely have a collinearity problem with the truncated normal of cotton area planted.

Results from econometric analysis of determinants of HH yield (intensification)

Yield: Average household cotton yields fell by 25% (by 19% among growers in both years). One explanation is found in our finding that village-level drought (incidence of crop disease) that season affecting a large number of villagers reduces cotton yield by 265% (138%). However, the incidence of those two shocks (measured only with a dummy variable by year) actually fell in cotton and other areas from 2008 to 2010. Thus, unless these variables are picking up a larger negative magnitude of drought/disease shock (although incidence has fallen), this suggests that there may be unobserved factors with a negative effect on cotton yields that our model does not include (perhaps a decline in cotton company extension visits or quality, late delivery of pesticide, etc). While average yields declined, there is still inter-household yield variation, and we find that an additional adult age 15-64 increases yield by 100% and use of pesticide increases yield by 123%.

Crop	% of HHs	2008	2011		HH mean value	2008	2011	% ch.
	Planting the crop	4.3	5.2		HH area planted (ha)	0.03	0.04	11.6
Tobacco	Applying fertilizer to crop	62.2	66.3		HH yield (kg/ha)	995	3,619	263.7
	Applying manure to crop[1]	2.3	7.5		HH production (ka)	27	382	1,297

Results from econometric analysis of determinants of HH area planted (extensification)

Participation: We find that a 1% increase in the expected price of tobacco results in a 4% an increase in the probability of growing tobacco.

Area: There appears to be a misspecification/collinearity problem with the truncated normal regression of tobacco area planted.

Results from econometric analysis of determinants of HH yield (intensification)

Yield: Average tobacco yields increased dramatically (263%), which appear to be driven largely by tobacco prices: a 1% increase in the expected price of tobacco increases yield by 2.1% (and the tobacco price increased 110% from 2008-11). Because tobacco is a highly labor-intensive crop, part of this intensification has likely come from increased family labor applied per hectare. In fact, we find that an additional member age 15-64 (65+) increases yield by 234% (380%). Access to and use of improved technology also explains large yield differences across households, as those who use animal traction increase tobacco yield by 186%, use of inorganic fertilizer increases tobacco yields by 161%.

APPENDIX B-1. Minag Definitions of Small- and Medium-Holder Households

The Ministry of Agriculture of Mozambique (MINAG) uses multiple criteria related to cultivated area and livestock holdings to define small- and medium-holder households. MINAG defines smallholders as rural households with less than 10 hectares of rainfed cultivated area, less than 10 large livestock (bulls, cows), less than 50 medium-size livestock (pigs, sheep, goats), and less than 5,000 chickens/turkeys/ducks, MINAG defines medium-holder rural households have between 10 and 50 hectares of rainfed cultivated area, between 10 and 100 large livestock, between 50 and 500 medium livestock, and between 5,000 and 20,000 birds. In the overall TIA08 national sample, less than 2% of the weighted number of households are medium-scale, and among those, less than 10% are classified as medium-scale due to their cultivated area. That is, there are very few medium-scale farm households in rural Mozambique, and those that exist at present are almost entirely classified as such due to their livestock holdings and not their cultivated area.

APPENDIX B-2. Procedures We Used to Generate Average Quarterly SIMA Retail Crop Prices for Each TIA08 District

For each commodity whose prices are tracked by SIMA, we identified SIMA markets (rural or urban) that in our estimation are likely to be the most relevant price for farmers in that district who might buy or sell that crop. We used the following selection criteria for each crop to assign a SIMA market (or the average of more than one) to each district representated in the TIA08-11 partial penal:

1) Spatial Proximity to the District and/or Information on Trade Flows

We used spatial proximity of the given district to each SIMA market as well as information on trade flows to estimate which SIMA market(s) most likely capture the derived demand for food crops at the village-level for maize in that district. In some cases this was only one market; in other cases it was the average of two or three (based on proximity and availability of SIMA markets.

2) Frequency of Price Data (Case of Maize) (Option #1)

a) Using the raw SIMA data for maize, we first computed the *weekly* average maize price (i.e., often two prices are reported per week from each market for a given crop, if data was collected from more than one trader).
b) We then computed a *monthly* average price of maize for each SIMA market (average of weekly prices), and generated the number of average weekly prices observed per month.
c) We then kept only those SIMA markets that had one or more weekly price observations in 10 or more months of the year.
d) We then computed a quarterly average maize price for each of the markets that had at least 10 months of one or more maize price observations.

The reason we did not use markets that did not have maize grain price observations in three or more months of the year is because of our intention to test the sensitivity of smallholder input use and output supply to prices at different quarters of the year. For example, for the majority of households that are net buyers of maize or rice, the decision price they use to make production decisions may well be the opportunity cost of maize or rice in the lean season – not in the immediate post-harvest period.

3) Comparability of the Price for a Given District over Time

Because a key aspect of our analysis is to measure the response in area or production or input use to a change in crop prices over time, we need to ensure that our measures of the output price are comparable from one TIA year to the next. For example, any given price that is observed contains important information with regards to space (where the sales transaction occurred) and time (month of sale) and product attributes (farmgate/wholesale/retail, state of processing, etc.). We have to assume that quality is homogenous and sales are made in the same state of processing (i.e., grain for maize) – and we obviously will use either farmgate prices in both years or SIMA (retail) prices in both years for a given crop. Therefore, it would not be appropriate to use one SIMA market for district A's maize price in 2007, and then use 3 SIMA markets to compute district A's maize price for 2010.

APPENDIX B-3. Deciding Which Source of Available Data on Crop Output Prices to Use for a Given Crop's Various Models

While we noted some of the advantages to using SIMA quarterly prices as the expected prices of certain crops that farmers use to make their input and cropping decisions, there are two main disadvantages of using SIMA prices to study smallholder output supply response to changes in crop prices:

1) SIMA prices are at the retail level; and
2) We do not have a measure of transport costs from each TIA village to the SIMA urban and/or rural markets we use to compute an average quarterly price for each TIA08 district (and thus village).[86]

That said, we use the same SIMA markets to compute the district price for each of the two partial panel years, thus at least we are using prices that are identical from one panel year to the next in terms of their temporal, spatial, and quality attributes.

By contrast, for the purposes of this paper, there are several disadvantages of using food crop prices from either TIA07 or CAP10 as expected prices including:

1) Variation in temporal nature of TIA and National Agricultural and Livestock Census (*Censo Agro-Pecuaria*-CAP) prices over time—while we suspect that most of the farm-gate sale prices observed in those surveys are from the 3-4 months following the main season harvest, we do not actually know that for certain in the case of storage food crops (this is not a problem for cash crops, as non-food cash crops such as tobacco, cotton, etc., are sold immediately after harvest);
2) Variation in spatial nature of TIA and CAP prices over time—sale prices from the household surveys come from different points in space (within the same district) over time given that TIA07 and CAP10 surveyed different villages; and
3) Variation in price observations over time between TIA and CAP—the number of sale price observations that produce price estimates for TIA07 is typically quite small if not zero for some districts, thus we may not even have a district-level price for each crop for each district of village if we rely on TIA07 alone (CAP10 is a considerably larger survey that does not suffer from this problem).

[86] Future research should consider computing the travel time from each TIA village to a given SIMA market, using an updated spatial map of rural roads (from 2007) and Jordan Chamberlain's (2013) travel time methodology.

APPENDIX B-4. Notes on Our Tests of Different Price Quarters to Use for the Expected Price of a Given Crop in Regressions of Food Crop Area, Production, and Yield

When we ran our maize regressions using the expected maize prices in quarter two (April-June) or three (July-September), we consistently found a negative effect (sometimes insignificant, sometimes significant) of maize price on maize area, production and/or yield. There are two reasons why a negative effect of the expected maize price on maize area, production or yield is unlikely. First, the theoretical results from either a producer only or an agricultural household model both predict that farmers will respond to an expected increase in the price of a staple crop by increasing production of it. Second, the specific context in this case makes it difficult to explain a negative relationship between the expected maize price and maize production. For example, the real price of maize increased dramatically in all areas of our sample between 2007/08 and 2010/11. At the same time, average maize area increased somewhat in every region (except Nampula), and that average maize production and yields increased dramatically in every region, maize production and yields increased during this time period as well (while household consumption demands only increased by an average of 8.8%). In addition, total area cultivated increased by 18%, and maize is the primary staple in most of these sample areas and grown by 98% of farmers in the central zones, by 90% in Zambezia and even 75-80% in Nampula.

By contrast, when we use the expected price of the fourth quarter (October-December) for maize, we find a positive effect of this price on maize area, production and yield. Likewise, we find negative effects of the expected rice price in the post-harvest period (April-June), as well as in July-September and even October-December. We find a positive response of rice production and yield only to expected prices in the end of the lean season, from January to March. This makes sense in that nearly all the rice producers in our sample also produce a fair amount of maize, and maize does not store as well as rice. Thus, it is reasonable to assume that these growers – very few of which sell either maize or rice in sizeable quantities – first consume their harvested maize, and only later in lean season do they consume their rice.

Appendix B-5. Controlling for Unobserved Shocks via the Control Function Approach

As we noted in Section 4.1. above, from the conceptual model given in (1) from that section, we estimate the effect of output prices and market access on output supply and input demand as follows:

(2) $$Q_{it} = \beta X_{it} + \varepsilon_{it}$$

(3) $$\varepsilon_{it} = c_i + \mu_{it}$$

As noted above, correlation between time-constant unobserved household heterogeneity (c_i) and regressors X_{it} can induce endogeneity bias in our estimates of the partial effects (β) of each regressor. We use two approaches to control for time-constant unobserved household heterogeneity (c_i): CRE in our probit and double-hurdle models, and OLS with household-fixed effects in our yield models. However, it is possible that a regressor such as use of animal traction might still be endogenous if it is correlated with an unobserved time-varying factor such as receipt of better extension advice from the tobacco company in some tobacco-growing areas in 2010/11 or sometime between 2007/08and 2010/11). In addition, input decisions are commonly considered to be potentially susceptible to simultaneity bias as the decision to, say, use animal traction, may be made simultaneously with the farmer's output decision.

Following Rivers and Vuong (1988), we test for correlation between unobserved time-varying shocks and household use of animal traction (in the tobacco yield regression) using a Control Function approach. The CF approach involves two steps. First, we estimate a reduced form probit regression of the potentially endogenous variable (use of animal traction) as a function of all the variables in our structural regression (the DH of tobacco production) plus one or more instrumental variables (IV). Second, we include the residual from the probit regression of fertilizer use as a regressor in the OLS-FE regression of log tobacco yield, along with the endogenous variable itself (1=HH use of animal traction), and the residual from the first-stage probit regression (termed the Control Function). The regressor use of animal traction is considered to be endogenous if the partial effect of the probit reduced form residual is significant in the OLS-FE regression of log tobacco yield.

As with the 2SLS approach to instrumenting for an endogenous variable, the CF approach requires an IV that satisfy two criteria. First, the IV must have a significant effect on the endogenous variable (use of animal traction) in the reduced form regression. Second, we must assume that our instruments are not correlated with the dependent variable of the structural equation (log of tobacco yield), conditional on the other observable factors—a maintained assumption that cannot be tested. We use the village percentage of the neighbors of household *i* using animal traction in year *t* (i.e., the availability of animal traction in the village, computed from each household's perspective) as an IV for use of animal traction.

This IV satisfies the first criteria, as it has a significant (positive) effect on household use of animal traction. While the second criteria cannot be tested, we are confident in arguing that this IV would not be expected to have a significant correlation on household tobacco yield – controlling for other factors. The reason is because the IV is actually the time-varying term for this village percentage, as any correlation between household tobacco yield and the time-average of village percentage (of animal traction use) is separately controlled for because we have included the time-average of the village percentage of the neighbors of household *i* using animal traction in year *t*. As we noted in 8.2.11 above, the residual from the probit CF is not significant in the OLS-FE regression of log yield, thus we conclude that use of animal traction is not endogenous.

Appendix B-6. Why Is Credit for Crop Inputs for Use on Crop Other Than Tobacco Or Cotton Either Non-existent Or Interest Rates Unaffordable for Rural Smallholders in Mozambique?[87]

There are a variety of reasons why interest rates for small businesses and farmers in rural Mozambique are so high. As noted by (Poulton et al, 2006):

1) The small scale of deposits and loans in rural areas lead to high administrative and management costs per transaction (i.e., per deposit/loan). These relatively high administrative costs per loan are exacerbated by the wide spatial dispersion of rural households and poor communications infrastructure, which lead to high costs of loan administration, monitoring and enforcement. *(That said, these costs associated with the wide spatial distribution of rural households can be dramatically minimized by*

[87] This section is primarily based on concepts outlined by Poulton et al (2006) though it draws heavily from Mather et al. 2015)

ICT and would be reduced further if mobile-phone access to banking systems are established in Mozambique).

2) The seasonality of agricultural production leads to patterns of lumpy demand for and repayment of loans by farmers. For example, a typical farmer will want to take out a loan at planting (September to December, depending on the zone) and will likely not be able to repay it until harvest (March to June, etc.).
3) Rural households within a given village or ward face covariant risks due to adverse weather or prices. Covariant simply means that the risk facing one household in a given agricultural season is highly correlated with the risk facing other households. In other words, when a drought hits a ward or district, all households in the ward/district are likely to be adversely affected, whether they are growing crops or working in the non-farm economy.
4) Rainfed crop production is inherently risky due to the unpredictable nature of adverse shocks such as drought, flooding, pest and disease pressure which can lead to large declines in crop yield. This is a key reason why banks and other financial institutions charge such a high interest rate to farmers, given the high risk that such loans will not be repaid due to the riskiness of rainfed agricultural production.
5) Banks or institutions that lend to a typical small- or medium-holder farmers face additional risk given that most farmers do not have sufficient collateral with which to guarantee repayment. For example, because most Tanzanian small and medium-holders do not have either formal land title or transferable land rights to officially surveyed plots, they cannot use their land rights as collateral. Other potential sources of collateral could include savings deposits, livestock holdings, and/or farm equipment, though these typically only belong to larger and/or wealthier farm households who often simply self-finance their agricultural inputs rather than face high interest rates.
6) Banks or institutions that lend to farmers who produce a commodity such as maize or rice face even more risk than those who lend to a producer of a cash crop such as cotton, tea, tobacco, coffee, etc.:
    a. Maize/rice are staple food commodities, thus producers may decide to store/save/consume their production rather than make the sales necessary to repay a loan. By contrast, cash crops such as coffee/tea/tobacco have little to no consumption value for rural households.
    b. Maize/rice are storable, thus producers do not have to make a sale immediately after harvest in order to gain income or utility from their production (as is the case with cash crops that must be processed soon after harvest in order to be of high value – such as sugarcane, tobacco, etc.)
    c. Maize/rice producers can sell their produce to a wide range of buyers. By contrast, producers of most cash crops (tobacco, sugarcane, cotton) only have a small number (or sometimes only one) potential buyer of their crop, thus they do not have an option of selling their output to someone other than the organization that provided the farmer with an input loan.
    d. In sum, for any crop which does not need specialized technology in processing or storage after harvest and which potentially has many buyers renders itself prone to side selling.

The reasons above all help to explain why rural areas are often not served by banks, and why, in the cases where such loans may be available to farmers, financial institutions that lend to rural households (and especially to farmers with rainfed production systems) charge such high interest rates. In summary, high rural interest rates are typically due not to either collusion or lack of competition among lenders, but rather are simply the result of real costs and risks that such lenders face: high per-loan transaction costs of administration, monitoring and enforcement, and a high risk that adverse weather or other events may leave loan recipients with poor harvests and thus unable to repay their input loans.

Appendix B-7. Recommendations for Improving the Ability of the IAI Household and Village-Level Surveys to Facilitate Analysis to Help Understand Household Adoption of Improved Technologies

Data on Input Use by Crop

- TIA/IAI instruments only collect plot-level information on land use; information on the quantity harvested is collected at the household-level and information on the prices or quantities of key improved technologies used (inorganic fertilizer, manure, improved seeds, type of plot preparation) is not recorded. Without plot-level data on inputs and outputs, it is not possible to reliably estimate the determinants of crop yields, marginal effects of input use on harvested quantity, and thus estimates of the approximate profitability of input use in a given area

Extension

- Neither TIA08 nor the PP2011 surveys ask respondents for the source of the extension (i.e., government, NGO, outgrower scheme for cotton, tobacco, sugarcane, etc.), thus any analysis we do using an indicator of household receipt of extension aggregates the extension services of very different organizations together into one indicator.
- If one were interested in testing links between extension access to crop productivity, in addition, it would be necessary to ask not simply whether the household received a visit on a general topic area (such as crop production), but to ask specific questions such as:
    - Has the household heard about specific crop/plot management techniques (i.e., crop rotation, planting in rows, plot land preparation techniques, etc.)
    - From whom did they hear about this?
    - Have they seen the technique demonstrated? (if yes, by whom)
    - Has the household used any of these techniques before?
    - If they used the technique this past season, on which plots were they used?
    - If not, why not?

Seed Source

- While TIA surveys ask whether households use an improved variety, there is not enough information collected to adequately assess the factors influencing their adoption. For example, one would want to know:
    - Did the household use improved seed that season?
    - What was the type (hybrid, OPV, brand name, etc.) used?
    - Was this seed purchased that year or recycled from the farmer's previous harvest or a neighbor's?
    - If purchased – what was the source; if recycled, what was the original source of that germplasm (neighbor, seed retailer, NGO, etc.).
- To further address constraints to adoption of improved seed varieties, additional questions are needed to understand why farmers have ever had access to a variety, if so did they plant it? If not, why not? If they have grown it before, why are they not growing it now?

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