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A Farm-Level Perspective of the Policy Challenges for Export Diversification in Malawi

Example of the Oilseeds and Maize Sectors

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ABSTRACT

The primary goal of the study is to investigate the potential to expand oilseeds, specifically soybeans, as an alternative commercial crop to tobacco among Malawian farmers. A principal motivation for undertaking the study at the microeconomic level is to determine, in a theoretically consistent fashion, the type of policy and economic environment under which farmers begin to shift more of their scarce resources to oilseed production.

The study aims to provide recommendations to a growing demand among policy makers and development partners for a greater diversification of exports and crop production systems of the majority smallholder farmers in Malawi. Using representative farm models, the study examines the potential for expanding production of soybeans among typical smallholder farming systems in Malawi. The results will help guide future policies and investments targeted at promoting greater crop diversification and incomes, in order to reduce poverty and malnutrition in Malawi. Given the amount of labor and land resources allocated to maize production for food security purposes, we also consider the policy challenges that emerge for crop diversification as a result.

Keywords: farm modeling, linear programming, export crop diversification, food security

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1. INTRODUCTION AND CONTEXT

Besides being a critical source of livelihoods and incomes for the majority of Malawians, the agricultural sector contributes more than any other sector to the country's export earnings and national income. Within agriculture, burley tobacco has continued to dominate, as it has since independence, as the single most important export crop in Malawi. Maize, on the other hand, serves as a key food staple. Other crops widely grown include groundnuts, beans, cassava, and pigeon pea. However, the dominance of tobacco in exports and that of maize for food security have far outweighed those other crops in their relevance for policy support and development over the years. The heavy reliance on these two major crops has translated into volatility in economic growth and food insecurity due to changing global marketing trends and periodic shocks, whether from ad hoc policy interventions or climate.

More recently, and for tobacco in particular, uncertainties surrounding future earnings have led the government of Malawi and development partners to seek alternatives for ensuring a healthy and diversified growth in export earnings. In fact, the National Export Strategy emphasizes the need to expand into other agricultural exports such as soybeans and groundnuts (Ministry of Industry and Trade, 2013). Aside from the need to diversify export earnings, crop diversification has also been promoted to improve soil health (through crop rotation with oilseeds, for example) and to improve nutrition (through the promotion of legumes).

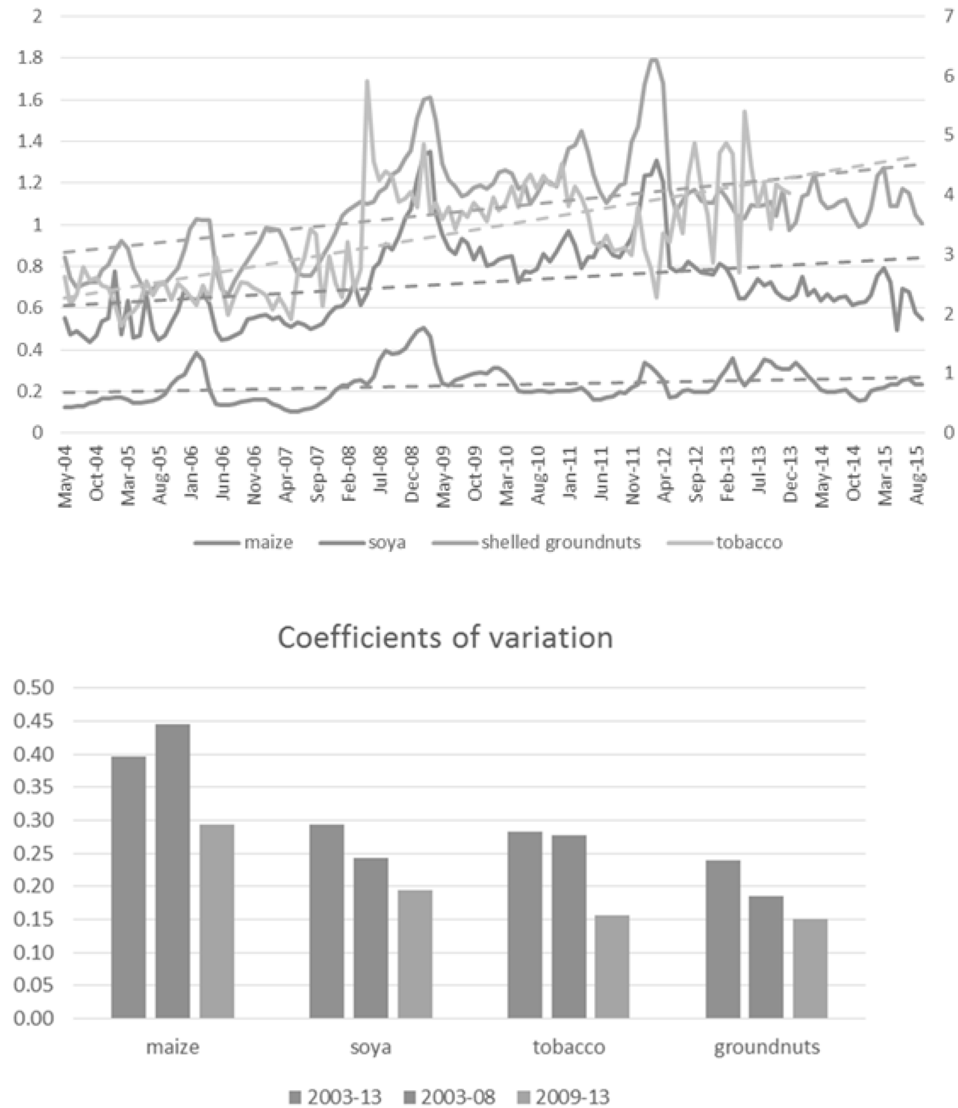
The potential for promoting crop diversification through expanded production of oilseeds and legumes is not new to Malawi. In 1984, for example, the World Bank released a report assessing the feasibility of export crop diversification in Malawi (World Bank 1984). The study attempted to identify crops and technologies that would help farmers use production resources more efficiently while increasing foreign exchange earnings and for input substitution. Results stressed the importance of promoting groundnuts and oilseeds as potential substitutes—while still emphasizing tobacco's important role given the existing infrastructure. The upgrading of existing oilseed-processing capacities was emphasized as part of any production growth strategy in the sector. Increasing maize productivity (and other food crops) grown for subsistence was also emphasized as a fundamental strategy to help release both land and labor for more commercially oriented crops, including maize.

One of the more important arguments in favor or crop diversification is that it offers a more balanced portfolio of income-earning sources to farmers instead of relying on a single crop like tobacco. Aside from the dangers of relying too much on a single crop, tobacco farmers have to rely on the price offered by a handful of major tobacco firms operating in Malawi today—Alliance One, Limbe Leaf, and JTI—especially as contract farming has become more important. Tobacco prices can be quite volatile depending on price movements in global markets and quality of leaf produced. Consequently, price uncertainty can be quite significant in tobacco farming. The appearance of contract farming may help to reduce some uncertainty during planting—however, because prices are still ultimately determined at auction, the risks associated with an uncertain price remain. Nevertheless, farmgate prices remain well below auction prices. A recent study by Mkwara and Marsh (2014) that looks into how contract farming has affected earnings finds farmgate prices to be much lower relative to auction prices, citing high transaction and logistics costs as an explanation.

Price Uncertainty, Government Policies, and Cropping Patterns

Price uncertainty in Malawi is prevalent for maize and some of the country's other high-value crops such as tobacco and soybeans. This can be seen in Figure 1.1, which shows maize prices as experiencing the most volatility, followed by soya and tobacco. How these prices have varied across the years can be attributed to many factors, among them natural domestic market forces, the presence of thin markets, climate variability, regional or global price trends for tradable crops, and government policies and interventions. Of those, thin markets and government interventions are especially relevant for two of the country's dominant crops: maize and tobacco.

Figure 1.1 Commodity prices, 2004–2015 (US$ per kilogram)



Sources: Authors' calculations based on MoAIWD (2015a) and Malawi, Tobacco Control Commission (2014).
Note: Tobacco price plotted on right-hand axis. Coefficients of variation calculated using monthly $US prices.

Market uncertainties do occur as a result of ad hoc government policy shifts or even reversals from previous policy positions. In fact, periods of discretionary government interventions in Malawi can be closely associated with more volatile prices. One example is the government's management of the National Food Reserve Agency (NFRA), which acquires maize stocks for the government's Strategic Grain Reserve and oversees releases from that reserve, serving as a buyer against food shortages. In recent years, the NFRA's price-setting processes have lacked transparency, and the timing of NFRA purchases have changed drastically from one year to the next, making it hard for private traders to anticipate when, how much, and at what price the government will procure and release maize stocks. The government also supports the Agricultural Development and Marketing Corporation (ADMARC), the principal parastatal agricultural marketing board that seeks to stabilize maize prices by procuring from smallholder farmers at above-market prices when prices are low and selling maize at a subsidized price when market prices are high. As there are no published or transparent rules governing ADMARC's procurement or marketing activities, the timing, magnitudes, and locations of purchases and sales are inconsistent across years. Finally, the government controls maize trade through export bans. In practice, the imposition of such bans lacks a transparent decision-making process, is timed inconsistently from year to year, and is susceptible to unilateral private-sector pressure (Edelman et al. 2015; Pauw and Edelman 2015).

The soybean market has also seen its share of discretionary government interventions. Those occurred in the form of export bans implemented between June and July 2010, June and October 2011, and March and September 2012. Although soybeans were removed from the list of commodities subject to export bans in September 2013, government has recently (as recent as 2016) explored other measures to deter soybean exports, including an export levy and a requirement that all exports be processed through a single trading company with close ties to the government. According to a qualitative analysis of the soybean export process and trade policy reforms, the process tends to be discretionary as well, adding more uncertainty to the soybean trade and markets (Aberman and Edelman 2015).

The tobacco sector, on the other hand, is a sector in which the private sector dominates, with limited government interventions aside from regulatory oversight. The tobacco industry in Malawi is regulated by the Tobacco Control Commission (TCC), a governmental body charged with regulating tobacco production, manufacturing, and marketing. According to an institutional analysis of the tobacco sector, the private sector exerts considerably more influence on the TCC and on the governance of the tobacco sector more generally than the government. So the government has little scope to intervene in the tobacco sector in ways that would appear to be discretionary from the perspective of the private sector (Otanez, Mamudu, and Glantz 2007).

Finally, the government intervenes very little in the groundnut market. Government involvement in the export process is limited to a few simple procedures, such as currency and customs declarations and certification of origin, and there is no record of government ever banning groundnut exports. In addition, the government does very little monitoring of the informal groundnut trade: in 2014, 33 percent of all groundnut exports left Malawi informally (Edelman and Aberman 2015). The government does support interventions designed to reduce aflatoxin levels, but such interventions do not significantly alter groundnut markets or marketing activities, either domestic or regional.

Clearly, market uncertainties appear more pronounced among commodities that periodically experience ad hoc government interventions, with serious consequences on how farmers and traders, and the private sector more generally, react to them over the short and long run. In the short run, market uncertainties can lead farmers and traders to temporarily disengage from the market (Abbink, Jayne, and Moller 2011; World Bank 2014). If the uncertainties persist, they can go as far as disinvesting from it altogether, and in the process hinder the development of the market and the institutions that support it in the long run (North 1987, 1994). Under such conditions, productive capacities shrink, markets become thinner, and prices become even more volatile as small shifts in supply and demand can lead to disproportionately larger shifts in price. In many respects, this has occurred for staple food markets and maize in particular.

Malawian maize markets are particularly volatile, with a coefficient of variation in maize prices typically higher than those of the other countries in the southern Africa region (about 45 percent versus a range of 20 to 35 percent, according to Jayne et al. 2010). The volatility in Malawi has been in large part influenced by both domestic policies and the existence of thin markets, according to a number of studies that have examined this issue directly. For example, the recent work by Sassi (2015) shows that maize price volatility in Malawi is more directly linked with domestic rather than international market factors—emphasizing the role of domestic policies in both contributing to and potentially mitigating any large price fluctuations. In another cross-country analysis covering eastern and southern Africa, Chapoto and Jayne (2009) find that staple food prices are more volatile and less predictable in countries such as Malawi where policy interventions are more ad hoc (or discretionary).

Market uncertainty for a major food staple such as maize can seriously hinder the sector's potential for commercialization and growth. Out of a concern for food security, a majority of poor smallholder farmers will simply devote more land to food staples as they typically have to spend a larger portion of their household budget on food expenditures (Fafchamps 1992). Additionally, given such farmers' low incomes and limited access to assets, they become entrapped in a vicious cycle of poverty, unable to purchase inputs to adopt productivity-enhancing technologies and therefore release more land to higher-value crops and incomes (Alwang and Siegel 1999).

It is not surprising, therefore, that most Malawian farmers choose to grow maize for subsistence first—with only a small proportion reaching the market. Meanwhile the small amounts of maize marketed only contribute to more price uncertainty, including lower prices received at the farmgate given high transaction and transportation costs and few buyers. In fact, much of the selling of maize occurs under duress, when households are cash-strapped to pay for food, school fees, and other basic necessities, including a family emergency. Low returns from sales of food staples at farmgate have been found to be quite common in southern and eastern Africa due to high commerce costs (Barrett 2008), a situation that ultimately limits household-level market access, price transmission, and trader competition, and results in the high volatility found in regional markets.

One should expect from this evidence, therefore, that farmers in Malawi, as elsewhere in the region, will avoid investing in productivity-enhancing technologies for food staples, especially without any government support (for example, through input subsidies). Similarly, they will also avoid other high-value crops so long as markets remain highly volatile, which has important implications for crop diversification. The importance of price risk in choosing which crops to cultivate has been found to be quite relevant in Malawi. Using a two-step multivariate crop selection and conditional acreage share model, Mukasa (2015) finds price risk to be among the most important factors discouraging farmers from allocating land to crops. Given the varying patterns of price movements across the four crops included here, it is no wonder Malawian farmers either become reluctant to produce surplus staple foods for the market (resorting to subsistence production instead) or are discouraged from investing in further productivity-enhancing technologies as well as from diversifying into new crops.

Patterns of area allocation to crops at the national level in Malawi, while grossly generalized, appear to support the expected behavior of farmers when faced with price risk, whether influenced by ad hoc government interventions or natural market forces. As Table 1.1 illustrates, groundnuts, for example, with a market that sees little government intervention and that demonstrates the most predictable prices among all four commodities, have witnessed the largest increase in their share of total arable land between 2004–2008 and 2009–2013, followed by soybeans and tobacco combined. Meanwhile, the share of land allocated to maize appears actually to have decreased across the same time periods.

Table 1.1 Area allocated to major crops in Malawi, 2004–2013

	Average (,000 hectares)		*Share of arable land (%)*		
Variable	**2004–2008**	**2009–2013**	**2004–2008**	**2009–2013**	**% change**
Beans	242	292	8%	8%	0%
Cassava	166	201	5%	6%	0%
Cowpeas	101	68	3%	2%	-1%
Groundnuts	247	317	8%	9%	1%
Maize	1,525	1,661	48%	46%	-2%
Millet	42	46	1%	1%	0%
Pigeon pea	155	197	5%	5%	1%
Sorghum	70	85	2%	2%	0%
Soybean	74	91	2%	2%	0%
Sunflower seed	7	12	0%	0%	0%
Tobacco	139	166	4%	5%	1%
Total	*2,768*	*3,136*	*87%*	*86%*	*-1%*

Source: Authors calculations based on MoAIWD (2015b).

While risks associated with price volatility are critically important in driving incentives for farmers to grow particular crops, production risks are also relevant. As most Malawian agriculture is rain fed, much of the production risk comes from rainfall variability, although periodic infestation of pests and disease also adds to it. Annual losses from production risk alone can be quite high in Malawi. According to a recent World Bank report by Giertz et al. (2015), they have averaged about US$149 million annually between 1980 and 2012, for example.

Research Objective and Hypothesis

The primary objective of this paper is to investigate the potential for oilseeds, specifically soybeans, to expand as an alternative commercial crop to tobacco among Malawian farmers. We hypothesize that the presence of high price volatility reduces farmers' willingness to expand into oilseed production from tobacco. We test that hypothesis using a mathematical programming farm-level risk model for a range of soybean and tobacco farmers in Malawi. By undertaking the study at the microeconomic level, we also seek to determine, in a theoretically consistent fashion, the type of policy and economic environment under which farmers may begin to shift more of their scarce resources to soybean production.

The overall motivation for the study is to assess policies to promote crop diversification through increased soybean production. Using representative farm risk models, the study examines the potential for expanding production of soybeans among typical smallholder farming systems in Malawi faced with both price and yield risk. Given the amount of labor and land resources allocated to maize subsistence production for food security purposes, we also consider the policy challenges that emerge as a result.

The report is organized as follows. We begin with a brief discussion of the model and data sources, a descriptive overview of the study sites selected for this work, and a presentation of the model simulation strategy. Based on a number of model simulation exercises intended to answer our research questions, we discuss the results in the third section, covering both the potential for oil seed expansion and potential for maize commercialization. We offer some key messages and policy implications arising from the results of the analysis in the conclusion.

2. METHODOLOGY AND DATA SOURCES

A simple mathematical programming model of the farm incorporating risk was developed specifically for this study, to test whether more volatile prices in soybean markets constrain the crop's expansion and growth among smallholder producers relative to tobacco, and, in turn, explore the extent to which a number of policy options being considered for promoting soybean production can be effective or not. The model is also used to examine the options for maize commercialization, especially given that crop's prominence in Malawi for food security, and therefore, the policy challenges that emerge as a result.

Model development relied on a number of field visits to three districts with high potential for soybean production to inform parameter estimates for the farm-level risk model. The results will in turn help guide future policies and investments targeted at promoting the production of soybeans for export or domestic markets and, in turn, greater crop diversification and incomes.

A Mathematical Programming Farm Model with Risk

The mathematical programming approach was chosen as an especially attractive approach for our purpose of analyzing the potential for smallholder soybean production in Malawi at the microeconomic level. As Hazell and Norton (1986) point out, the approach provides a natural framework for organizing quantitative information about the supply side and microeconomics of agriculture. It is also especially suitable for sensitivity analysis—such as in understanding the implications of changing resource endowments, market conditions, technologies, and policies. For our purposes, it permits us to empirically evaluate the extent to which farmers may be limiting their land allocation to soybeans because of the higher income risks associated with it, as well as resource constraints and other competing goals, such as the need to ensure food security first.

Often-cited critical constraints for smallholder agriculture in Malawi are those on land, cash, or credit—given the low-income status of many households and food security concerns. According to Alwang and Siegel (1999), land scarcity is a major constraint limiting the income-earning potential of many Malawian smallholders. Exacerbating this are the concerns for food security that lead farmers to allocate their limited land and labor resources to maize, for example. In the process, less land is available for higher-value crops, and with few assets, smallholders become trapped in a vicious cycle of subsistence agriculture—unable to expand or even intensify production of better-earning crops.

The importance of ensuring food security first at the farm level has meant that Malawian smallholder farmers place a higher value on maize than the sum of the resource inputs that go into its production. This is especially true when prices in maize markets are quite volatile. In other words, the payoff to own labor is perceived by a typical farm household concerned with food security as much higher (or less risky) for growing the household's own maize requirements than to purchase those requirements on the market. In this way, Malawian farmers are very rational and risk averse.

A number of researchers have applied mathematical programming to understand the microeconomics of Malawian smallholder agriculture. Alwang and Siegel (1999) also adopt a simple linear programming model of representative smallholder households to examine the issue of labor and land relative scarcity in Malawi, especially as it is affected by the concern for food security and limited assets. This ultimately leads to a suboptimal allocation of labor and land to higher-value crops—while the resulting low returns to both resources exacerbate food insecurity and poverty further.

Other authors have adopted mathematical programming techniques for the same reasons. Dorward et al. (2003), for example, used a set of farm-household models to examine market interactions between different households within a rural economy setting. The models captured issues of seasonality, heterogeneity of household types, partial engagement with imperfect markets, food security objectives, and integration of household, farm, and off-farm activities, resources, and constraints. More recently, Holden (2014) assessed the impact of agricultural input subsidies and maize technology choices in Malawi using linear programming at the farm level. Results of his modeling work not only illustrate the vulnerability of land-poor households in Malawi but also show how subsidies have helped facilitate intensification of maize and survival on smaller farms. Higher fertilizer prices (or lower tobacco prices) only worsen further the impoverishment of poorer households.

Data Sources and Descriptive Background

The sourcing of data involved field visits, expert interviews, and secondary data sources. We review these in more detail here and in the process provide a brief description and background of each location studied with respect to cropping and land-use patterns.

For the farm models to correctly reflect farm behavior among soya, tobacco, groundnut, and maize farmers in Malawi, model parameters need to be either estimated or collected from actual data wherever possible. This involves not only drawing information from any existing household surveys conducted in the last few years and the literature, but also fieldwork that involves focus group discussions and expert interviews of select representative farmers. To this end, we developed a field research plan to inform the farm-level risk model parameter estimates.

The fieldwork was organized into two parts. First, a scoping field trip was conducted to visit selected soya, groundnut, and tobacco farming areas. Study sites at the district level were selected according to their importance for soybean production—as well as whether they were widely reported to grow some of the dominant crops in the country: tobacco, maize, and groundnuts. It was therefore decided that the final selected locations would have to be in the top-three soybean-production agricultural development divisions in Malawi: namely Kasungu, Lilongwe, and Mzuzu (Table 2.1).

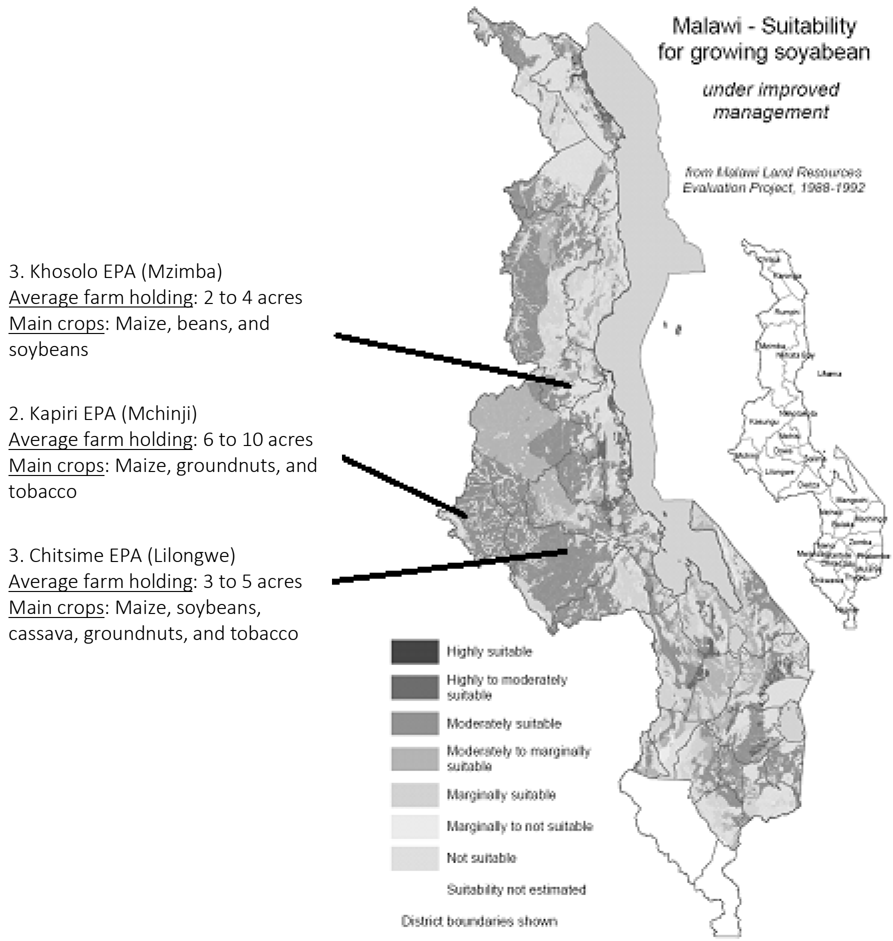
Table 2.1 Soybean production by agricultural development division, 2012

Agricultural development division	Area (ha)	Production (mT)	Yield (mT/ha)	% by ha	% by mT
Kasungu	43,614	49,559	1.14	45%	51%
Lilongwe	34,192	32,174	0.94	35%	33%
Mzuzu	11,409	10,237	0.90	12%	11%
Blantyre	3,401	1,979	0.58	3%	2%
Karonga	1,699	1,655	0.97	2%	2%
Machinga	1,943	896	0.46	2%	1%
Salima	732	542	0.74	1%	1%
Shire Valley	440	228	0.52	0%	0%
National	*97,430*	*97,270*	*1*	*100%*	*100%*

Source: MoAIWD's APES data (for area, production, and yields).
Note: ha = hectares; mT = metric ton.

Following consultations with the Farmers Union of Malawi (FUM), we selected the final districts and extension planning areas to target for the study. They are shown on the map in Figure 2.1. Fieldwork was conducted from October 27 to October 30, 2015, across the three districts in coordination with FUM. The objective of the fieldwork was to get an overall understanding of the types of constraints and issues facing tobacco and soybean farmers in each location more generally while eliciting more detailed information on key model parameters such as labor requirements and time spent for each production activity and technology, level and intensity of other inputs used, availability of resources more generally, and constraints related to the socioeconomic, natural, or policy environment. Narratives collected were used to further refine and validate model results.

Figure 2.1 Location of study sites based on suitability of soybean production



Source: Map adapted from Benson, Mabiso and Nankhuni (2016).
Note: EPA = extension planning area.

The fieldwork component employed multistage simple random sampling and purposive sampling to select the respondents and the study areas. In the first stage, three districts were selected based on their high suitability for soya, groundnut, and tobacco production. The next stage involved a purposive selection of villages in the districts; these villages were identified by FUM district officials as being representative of the district regarding soya, groundnut, and tobacco production practices. From the selected villages participants in the focus group discussions were randomly selected. Three farmers from each focus group were also purposively selected for the farmer expert interviews. In total, three focus group discussions (that included on average 25 farmers per discussion) and 12 in-depth expert interviews were carried out.

While most of the evidence resulting from this fieldwork contributed to validating key model parameter estimates, qualitative findings from the focus group discussions complement findings from existing literature as well. In particular, key challenges to marketing the examined commodities include the following: low prices dictated by vendors; uncertain prices due to the lack of structured markets, particularly for soya and groundnuts; and the need to sell immediately after harvest when prices are lowest due to cash flow and credit constraints. Appendix A contains a full field report.

Next, we examined existing qualitative data to better understand how households perceive the commodities in terms of how they choose to market them. In particular, we build on a study of household preferences and decision-making dynamics related to production, consumption, and sale of agricultural commodities (Aberman and Roopnaraine 2015). The fieldwork for this study involved 80 individual in-depth interviews conducted in the three selected locations and focus group discussions. Households were purposively sampled according to the following criteria: (1) many village members are producing one or more of the crops of interest; and (2) they are within 5 kilometers of a major daily market. We extracted findings from the transcribed interviews related to prices and marketing decisions using a range of code- and text-based search protocols.

For the three locations visited, respondents reported a range of typical farm sizes in the area as follows: Lilongwe, 3 to 5 acres; Mchinji, 6 to 10 acres; and Mzimba, 2 to 4 acres. In Lilongwe, the main crops grown (by importance) were found to be maize, soybeans, groundnuts, some cassava and sweet potato, and tobacco (although not as common). More land was allocated to soybeans and groundnuts. Respondents believe soybeans have been replacing tobacco in the area—especially given their proximity to oil processing. In Mchinji, the main crops grown (by importance) included maize, groundnuts, and tobacco. More land is allocated to maize, followed by groundnuts and lastly tobacco. In Mzimba, the main crops grown (by importance) included maize, beans, tobacco, and soybeans. Ninety percent of farmers allocate more land to maize for food security reasons, followed by beans and lastly tobacco and soybeans (last three are mostly for cash).

Based on this preliminary analysis of the qualitative data and narratives from the fieldwork, the following key findings emerged. First, households treated groundnuts and soya almost exclusively as a current account, selling these commodities for relatively routine needs:

> *I sold the groundnuts to raise money for the people molding bricks for my house and the rest for buying house groceries. Sold two 90 kg bags of groundnuts and used the money to buy window frames and wires. We sold soya to sort our family challenges. We needed to buy kitchen utensils and farm inputs.*

Households treated maize more like a savings account or insurance policy for emergencies, selling it only when absolutely necessary:

> *Sold 3 bags of maize out of the 17 harvested to pay for mother's hospital bills.*
>
> *Sold maize to buy mother's coffin and hired a car for the funeral.*

When searching for relationships between marketing decisions and prices of particular commodities, we found less evidence. For maize, households mentioned that low prices and ADMARC marketing activities were deterrents to selling maize. For soya, it appears that both low prices and the lack of a reliable market potentially deter sales:

> *We hardly find good markets for soya. Many of us in my village grow a lot of soya but we end up selling it at low prices or just keeping it at home. We no longer value it because we feel we waste much of our time and energy hoping for high prices which never came to be. Sometimes there are even no places where to sell.*

Further analysis could be undertaken on these data, especially regarding the role of gender and the extent to which commodities are bartered as opposed to sold outright. But based on the above extractions, it appears that the availability and predictability of markets can influence marketing decisions and, in the case of soya, planting decisions as well.

The findings from the field visits generally supported district-level statistics on cropping patterns. Using our information on typical farm sizes and district-level data with respect to the distribution of acreage under each crop, we calculated initial acreage allocation for each representative farm as shown in Table 2.2.

Table 2.2 Initial area allocations assumed for each location (hectares)

Variable	Mzimba	Mchinji	Lilongwe
Beans	0.21	0.29	0.17
Groundnuts	0.19	0.53	0.38
Maize	0.45	0.64	0.57
Maize-groundnuts	0.57	0.68	0.64
Soybeans	0.09	0.17	0.12
Tobacco	0.12	0.12	0.14
Total	*1.62*	*2.43*	*2.02*

Source: Based on field interviews and adjusted with district-level data from MoAIWD (2015b).

Finally, drawing on a wealth of district-level data available from the Ministry of Agriculture, Irrigation and Water Development (MoAIWD) on crop yields and prices between 2006 and 2014, we calculated the mean expected gross margins and their variability as a key input into weighing the risky nature of each crop's potential future returns. As Figure 2.2 shows, for example, maize, tobacco, and soybeans show much higher volatilities in gross margins, captured here by the variability in both prices and yields. Additionally, for maize, from Figure 2.2, the price volatility appears much greater during periods when the government imposed an export ban. What is unexpected are the higher prices on average during an export ban, which may be explained by the fact that the bans tend to be imposed whenever there are expectations of supply shortages from domestic production.

Figure 2.2 Variation of gross margins for maize and other crops in study locations, 2006–2014 (calculated with real prices, 2014 Malawian kwacha)

a) Maize

(Note: during periods with and without export bans, shaded is with ban)

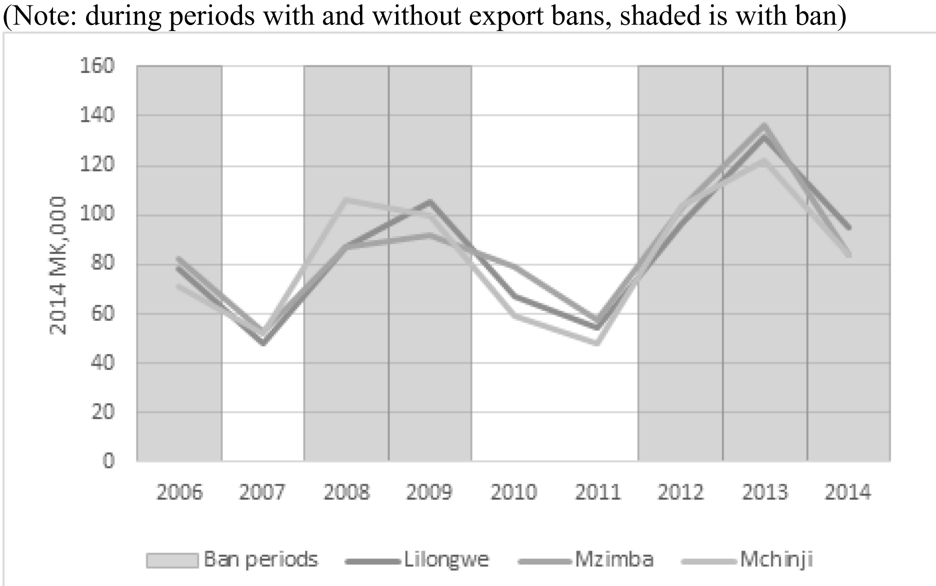
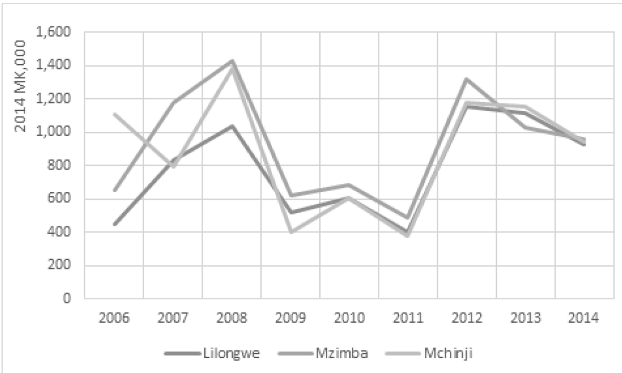
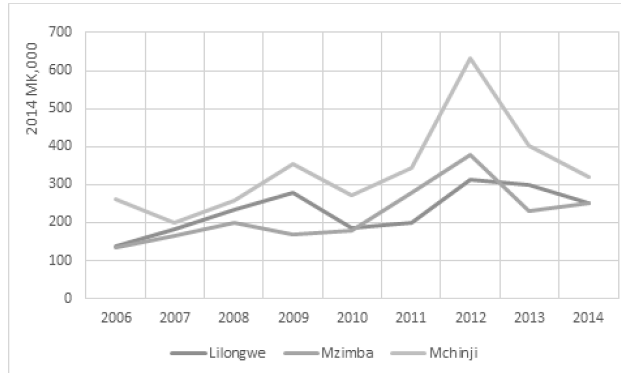


Figure 2.2 Continued

b) Tobacco

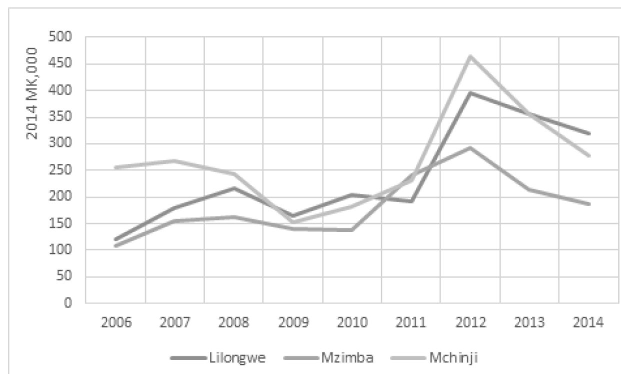


c) Soybeans



d) Beans

e) Groundnuts



Source: District-level data from MoAIWD (2015a; 2015b).

Model Structure and Assumptions

Our modeling work focuses on representing a typical smallholder farmer in three locations that have high potential for soybean production. Additionally, given our interest in examining the effect of volatile markets on crop choices, we have explicitly incorporated risk in the model. The model is derived from the mean standard deviation analysis approach as described in Hazell and Norton (1986). Using known values of gross margins and their variability and covariability from the recent past, the objective function is modeled in such a way as to maximize whole farm returns while minimizing their variability. A risk premium parameter is included to weigh in the level of risk aversion a farmer may have toward market volatility—based on the variability of returns he or she has experienced in the recent past. We provide a mathematical derivation of the model in Appendix B.

Movements in the expected mean and variance of farm gross margins over time should affect the decisions farmers make when allocating their scarce labor and land resources across different crops, especially if their principal motive is to maximize profits. The higher the price of one crop over another, the greater the incentive should be to allocate more resources to it. However, this rarely occurs for at least two reasons. In the short run, for example, any sunk investments in a particular activity can prevent farmers from moving away from it entirely. In addition, the presence of any uncertainties about the stability of price changes or expected yields based on what is typically observed can lead risk-averse farmers not to respond. For the mathematical programming risk model, therefore, the main objective of a farmer is to select cropping activities that maximize expected farm returns while also minimizing their variability based on the known information about the expected mean and standard deviation of gross margins across the activities. The mean and standard deviation of gross margins are based on the most recent past—2006 to 2014.

The model incorporates a risk parameter to allow us to vary the level of risk farmers are willing to consider in making their decision—which basically adjusts the standard deviation of gross margins by a multiple to create a range of risk levels between the neutral (no risk) and a maximum (with risk). For our purposes, we chose to use a median risk level to reflect risk-averse farmers in Malawi. Annex B provides more detail on the risk parameter values used in the model.

As noted earlier, a primary concern about the household's food security can drive farmers to allocate resources to the cultivation of a food staple such as maize before considering which other crops to allocate the remaining resources to. This is quite common in Malawi. To account for this, the objective in the model is subjected to a food-security-first requirement of producing sufficient quantities of maize for home consumption. This is set at one 50-kilogram bag of milled maize for a household of four per month (two adults with two children) plus about 2 kilograms of groundnuts for the same-size household. For our model, we assumed a household of six in total (two adults, two youth, and two children), which translates into an annual requirement of 1,063 kilograms of harvested (unmilled) maize and about 35 kilograms of groundnuts (see Table C.1 in Appendix C for more details).

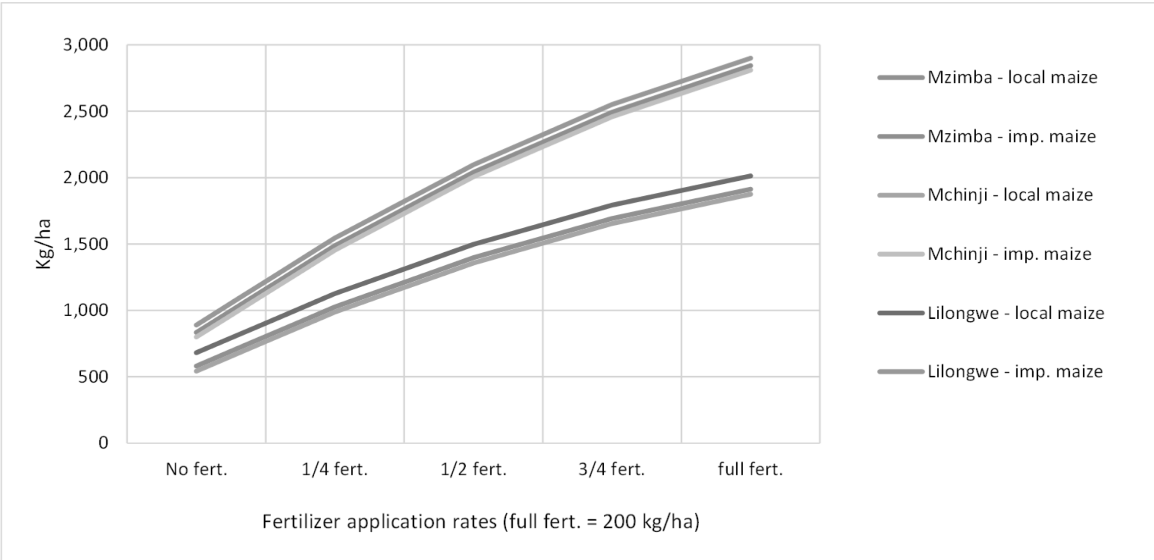
The model includes a number of resource constraints. Own family labor is restricted to the household size but converted to an adult labor equivalent of 2.75 persons.[1] However, the hiring of labor from outside the family is not restricted but simply comes at a cost of a seasonally adjusted wage rate. Land is fixed at current farm sizes. Farmers are assumed to have a very small amount of fixed cash reserves for seeds and fertilizer (fertilizer is used only on maize and tobacco). Finally, fertilizer subsidies for maize are assumed to be 65 percent.

Altogether, for each district, the model has six possible crop activities: beans, groundnuts, maize, soybeans, tobacco, and a maize-groundnut intercrop. It has three seed types: (a) a local variety (as recycled seed); (b) an improved variety that requires seed purchases; and (c) improved varieties provided under a loan package (a caveat for tobacco is that it includes only improved seeds). For soybeans, improved seeds require an inoculant. Four fertilizer application rates are modeled based on their share of a maximum or full recommended dosage of 200 kilograms per hectare such that 1/4 = 50 kilograms; 1/2 = 100 kilograms; 3/4 = 150 kilograms; and full = 200 kilograms. Fertilizer is applied only on maize and tobacco (for maize, this can be with local or improved seeds). Labor use coefficients for land preparation, ridging, planting, and weeding are modeled seasonally (monthly) as person hours per hectare while harvesting and postharvest labor are modeled as a function of yields. Crop yields vary by type of seed and a simple fertilizer response function for maize and tobacco, as discussed further below. Yield increments due to different technologies are adapted to these data and compared with other sources in the literature (for example, Benson 1997). And finally, annual average crop prices (in real terms) and yields over the past eight years (2006 to 2014) are used to calculate the mean and covariances of gross margins over the past eight years.

For all the crops, we introduced a number of technologies that involved the adoption of either improved seeds, fertilizer, or a combination of the two. Fertilizer is required only on maize and tobacco fields. Fertilizer response functions for the four application rates were estimated using sources in the literature where possible. For maize, for example, the work by Benson (1997) was especially useful—resulting in the response functions illustrated in Figure 2.3 for each location.

[1] Labor equivalence scales are defined as 0 percent for children, 50 percent for youth, 75 percent for an adult female, and 100 percent for an adult male. For our household makeup with two adult parents (one male and one female), this translates to 2.75 adult labor equivalents in the household.

Figure 2.3 Assumed fertilizer response function by location for maize



Source: Fertilizer response parameters borrowed from the past work of Benson (1997, 1999) and, more recently, Snapp et al. (2014), adjusted with district-level data.
Note: Initial yields with no fertilizer are based on actual observed patterns from district-level data, MoAIWD (2015b)

Model Simulation Strategy

A key research question the farm model explores is what it will take for the typical Malawian smallholder farmer to diversify into soybeans from tobacco. We also ask what it will take for maize to evolve into a commercial crop—given its dominance as a food staple. We answer those questions by analyzing the economic conditions that a typical smallholder farmer faces in making decisions about what to grow based on two objectives—food security followed by income generation. To achieve those two objectives, the farmer not only considers his or her own limited land and labor resources, but his or her expectations about future returns (based on performance of the market and policy environment in the most recent period).

An underlying hypothesis is that a rational Malawian farmer is risk averse and therefore will only allocate his or her scarce resources to an activity that at least offers food security or a secure return, or both, as opposed to an activity that offers the highest potential return but bears greater risk. A number of simulations representing a change in the economic or policy environment are introduced to the models to determine the extent to which farmers will grow more soybeans or maize, or both, for market.

In considering the potential for soybeans, there are five simulations altogether with some testing for any potential interactions with tobacco incentives:

- *Base* — To reflect current conditions (but with no tobacco contracting).
- *SB1* — Introduce a more structured soybean market (here captured by reducing the volatility of farmgate soybean prices by 25 percent).
- SB2 — Alternative to SB1, introduce a loan package for soybean inputs, in particular seeds and a seed inoculant.
- SB3 — Introduce a loan package for tobacco inputs as currently practiced by a number of tobacco firms contracting directly with farmers. Because the package typically includes seeds and fertilizer for half an acre of maize, based on respondents in the field, we include this as well.

- *SB4* — Combine SB1 (more structured soybean markets) and SB3 (tobacco loan package) to test for any potential competition (crop area displacement) between the two as a result.
- *SB5* — This time combine SB2 and SB3, as two loan packages (soybean and tobacco), to test for any potential competition.
- It should be noted at the outset that while we initially planned on introducing an export parity price for soybeans to assess its potential as an export crop, this proved irrelevant after several attempts to calculate the price over the period between 2006 and 2014. For all the years, the export parity price fell below the domestic price in all three regions, although less so in Lilongwe.

In exploring the potential for expanding maize commercialization, that is, beyond its requirement for satisfying the food security objective, we introduce three simulations that consider both policy shifts and price changes, as follows:

- *MZ1* — Remove fertilizer subsidy in the base model.
- *MZ2* — Drawing on the MZ1 simulation, determine a price at which maize can come into the solution as a marketed crop and with no fertilizer subsidy
- *MZ3* — With the higher price determined in the MZ2 simulation, remove the consumption constraint to check for the extent to which maize may still stay in the solution. While it is illogical to remove the consumption constraint given its importance for most Malawian smallholder households, it allows us in this case to calculate a residual farm income after subtracting the cost of purchasing the maize on the market for home consumption as farmers opt to market their own maize.

3. MODEL RESULTS

The first part of our modeling exercise is to ensure that we have a base model that closely resembles how farmers have allocated their scarce resources to different crops under current conditions. This is intended to provide a model that best represents the crops and technologies chosen by typical smallholder farmers in the three locations—based on both the fieldwork conducted and secondary data sources representing the three districts in which the three villages visited were located. Every effort was made to not only reflect the focus group discussions on most common crops grown in the area, but also rely heavily on district-level data for past trends in yields and market prices.

Table 3.1 presents the results of our final base model. Using actual district-level yields and market prices (with farmgate prices at 75 percent of the reported retail market prices) as gross margins, we also report the resulting mean and standard deviations of overall farm returns (incomes) based on the cropping choices farmers make under each level of risk consideration. If farmers view risky returns as unimportant, they can potentially seek higher incomes through the choices they make at planting by simply ignoring any associated market or production risks (this is under the "no-risk" scenario in Table 3.1). If risk is considered important (the "with-risk" scenario), farm incomes will be lower as farmers seek to minimize income variability overall (typically, the higher the expected mean income, the higher the variability of income). It turns out that incomes appear more volatile in the Lilongwe District, followed by the districts of Mchinji and Mzimba as evident in their coefficients of variation (c.v.) in Table 3.1. On the other hand, incomes are lower in absolute terms in Mzimba—close to the poverty threshold of US$1 per day, given an average exchange rate of 417 Malawian kwacha (MK) per US$ in 2014. Only the typical farmer in Mchinji earns more than $2 per day (or MK 834).

With regard to crop area allocations, results for the with-risk scenario in Table 3.1 closely resemble typical crop area allocations among the major crops based on the focus group discussions and secondary data sources. For example, soybeans come into the solution more prominently in Lilongwe compared with Mchinji and Mzimba—which appears to be supported by the data and field observations. Beans, on the other hand, turn out to be more important in Mchinji and Mzimba. For Mzimba, that crop's importance was especially highlighted among the female farmers we interviewed. Tobacco was also quite important in the two districts relative to Lilongwe. As expected, groundnuts also appear more prominent in Mchinji, although that crop is also important in the other two areas.

By design, the area allocated to maize is about half a hectare (or an acre) to satisfy the food-security-first goal of producing 1,063 kilograms of maize at a minimum for a household of six as discussed earlier (Table 3.1). Any variations in the acreage to maize are mostly due to the rate of intensification of maize cultivation in each area, which can vary depending on how farmers allocate their limited cash reserves for purchasing inputs. For example, it turns out that farmers in Lilongwe apply only one-half of the recommended fertilizer dosage on about 0.56 hectare of their maize fields with improved seeds (hence the higher acreage to meet the 1,063 kilograms consumption target). Cash constrained, they choose to allocate some of their cash to purchasing inputs for the more profitable soybean crop. Farmers in Mchinji and Mzimba apply fertilizer on their maize fields at about three-fourths of the recommended rates. Interestingly, all three locations choose to use the local maize seed variety with a full recommended fertilizer dosage for the maize-groundnuts intercrop targeted for home consumption. This later activity comes into the solution to satisfy the food security constraint for both maize and groundnuts.

Table 3.1 Base model results, mean and variance of returns

	No risk			With risk		
Variable	**Lilongwe**	**Mchinji**	**Mzimba**	**Lilongwe**	**Mchinji**	**Mzimba**
Farm income and variability						
Annual earnings (MK,000)	280.1	377.0	198.1	258.8	357.2	196.6
Standard deviation (MK,000)	123.2	144.6	73.2	98.0	119.9	56.8
C.V. (%)	44.0%	38.4%	36.9%	37.9%	33.6%	28.9%
Daily earnings (MK/day)*	767.5	1,032.8	542.9	709.1	978.6	538.6
Area allocations (ha)						
Beans	-	-	-	-	1.11	0.54
Groundnuts	1.35	1.57	0.64	0.56	0.69	0.37
Maize	0.46	0.43	0.49	0.56	0.43	0.49
Maize-groundnuts	0.06	0.06	0.07	0.06	0.06	0.07
Soybeans	-	0.37	0.42	0.85	-	-
Tobacco	0.16	-	-	-	0.14	0.16
Total	2.02	2.43	1.62	2.02	2.43	1.62
Production (kg)						
Beans	0	0	0	0	419	184
Groundnuts	1,179	1,396	505	510	637	303
Maize	1,063	1,063	1,063	1,063	1,063	1,063
Soybeans	0	401	326	676	0	0
Tobacco	108	0	0	0	102	112
Fertilizer used (kg)						
Maize	12	12	14	12	12	14
Tobacco	8	0	0	0	7	8
Total	20	12	14	12	19	22
Fertilizer application rates						
¼ req.	24%	0%	0%	0%	22%	22%
½ req.	0%	0%	0%	90%	0%	0%
¾ req.	67%	88%	88%	0%	69%	69%
Full req.	9%	12%	12%	10%	9%	10%
Adoption rates (%)						
Local seed and fertilizer	3%	2%	4%	3%	2%	4%
Imp. seed only	0%	15%	26%	29%	0%	0%
Imp. seed and fertilizer	31%	18%	30%	27%	23%	40%
Imp. seed and fertilizer loan	0%	0%	0%	0%	0%	0%
Total	33%	35%	60%	59%	26%	44%

Source: Base model results (2016).
Notes: C.V. = coefficient of variation; MK = Malawian kwacha; ha = hectare; kg = kilogram.
* Daily earnings are simply the annual earnings divided by 365 days. All values are in constant 2014 Malawian kwacha.

Farmers in Mchinji who choose to grow tobacco apply only one-fourth of the recommended fertilizer dosage (accounting for about 37 percent of total fertilizer purchased), preferring to allocate the limited fertilizer they purchase at a subsidized price to maize. In this regard, by intensifying subsistence maize production, the fertilizer subsidy helps farmers reduce the area planted to maize, thereby releasing land for higher-value crops such as tobacco.

It is especially noteworthy to observe how farmers allocate their residual land when we introduce risk to the model, that is, after satisfying their maize and groundnut subsistence requirements. For example, with-risk farmers in Lilongwe would drop tobacco in favor of soybeans. The opposite occurs in Mchinji, where farmers switch from soybeans (and groundnuts) in the risk-neutral case to tobacco and beans when risk suddenly matters. For Mzimba, risk causes farmers to switch toward beans. Such a comparison emphasizes how farmers will opt for cultivating a crop that offers lower risk, as measured by the extent to which it exhibits a higher variability in gross margins, relative to alternative crops. The actual means and variability of gross margins by crop were presented in the previous section.

Because of the switch in crop allocations as risk comes into the picture, agricultural intensification (that is, adoption rates of improved seeds or fertilizer use, or both) will change, as the bottom part of Table 3.1 shows. For Lilongwe, for example, risk-averse farmers will intensify more as they shift some area away from groundnuts to soybeans (choosing to adopt the high-yielding combination of improved soybean seeds and an inoculant). For Mchinji and Mzimba, the opposite occurs as farmers switch away from soybeans to beans and tobacco.

Examining the overall returns to land and labor of the whole farm (that is, across the crop activities selected by the farmer) can shed further light on why farmers make these choices. Table 3.2 summarizes these across the crops that come into the solution. From Table 3.2, the values in factor returns are naturally lower in Mzimba given that district's lower farm incomes on average. Across the crop activities, the returns to both labor and land tend to be higher for tobacco, soybeans, and the maize-groundnut intercrop. Maize sole cropping has the lowest returns. Soybeans provide higher returns to both labor and land in Mchinji relative to Lilongwe—despite the limited choice for growing the crop in Mchinji when we consider risk. This is most likely because Mchinji reported the highest volatility in soybean returns and Lilongwe the least. Due to the greater uncertainties of future returns, risk-averse farmers in Mchinji, therefore, prefer not to grow soybeans and to grow beans and groundnuts instead.

To explore the extent to which soybean production has the potential to expand in Malawi we introduced a number of policy simulations, as described earlier in Section 2. We now turn to those results—focusing on each location separately before concluding with a summary of the results and their implications for policy.

Table 3.2 Base model crop returns to land and labor (with risk only)

Labor (MK ,000/day)	Lilongwe	Mchinji	Mzimba
Beans	-	1.83	1.57
Groundnuts	1.56	1.75	1.50
Maize	1.20	1.22	1.15
Maize-groundnuts	1.89	1.95	1.75
Soybeans	1.56	-	-
Tobacco	-	1.71	1.23
Total	1.48	1.69	1.39
Land (MK ,000/ha)			
Beans	-	143	119
Groundnuts	134	151	122
Maize	94	105	94
Maize-groundnuts	193	198	169
Soybeans	142	-	-
Tobacco	-	273	192
Total	128	147	121

Source: Base model results (2016).

Notes: Where any values are missing, these were crops not in the model solution. All values are in constant 2014 Malawian kwacha (MK). ha = hectare.

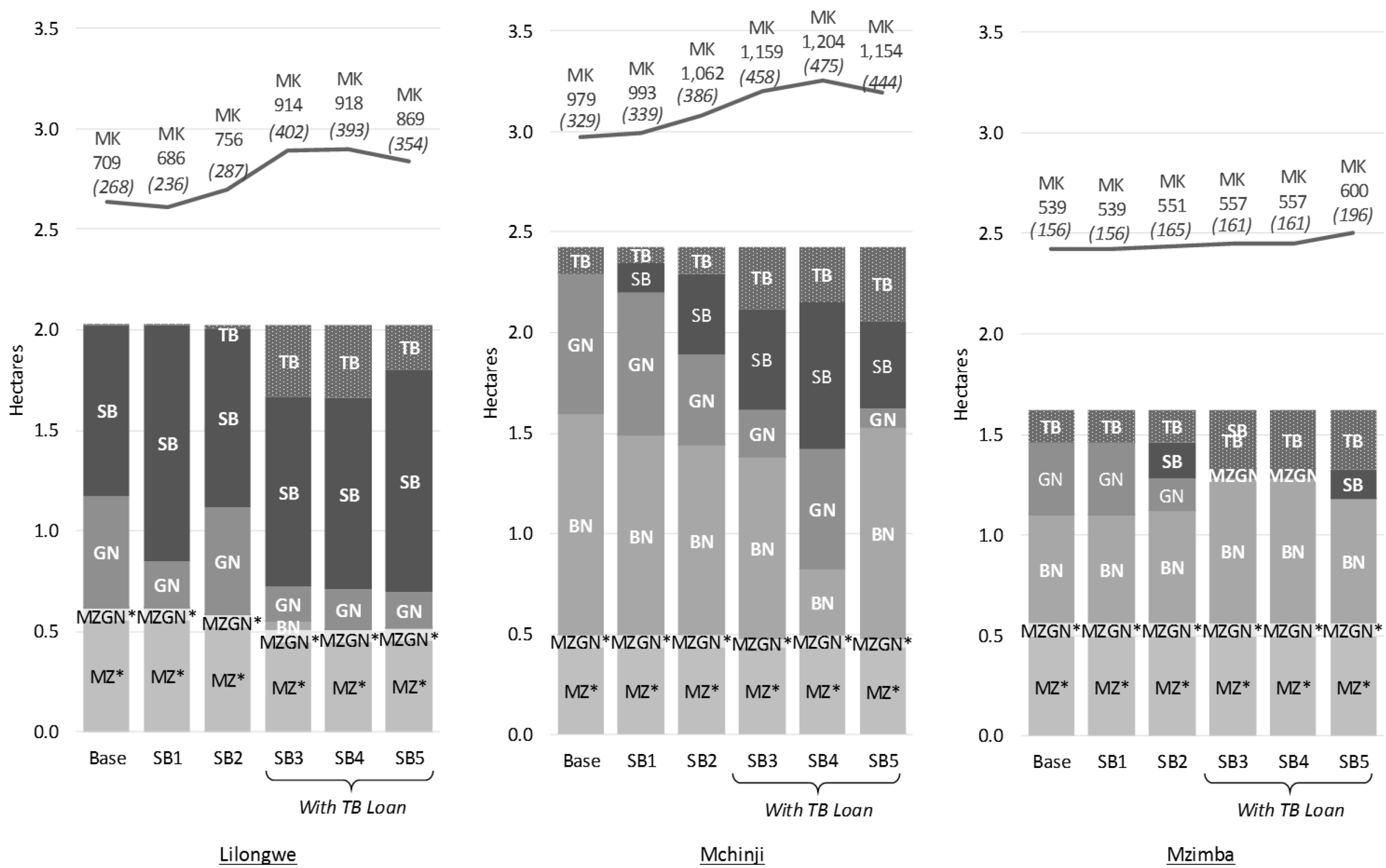
Assessing the Potential for Promoting Soybean Production

Results for the soybean simulations (SB1 to SB5) with regard to incomes and area allocations in each of the three locations in our study are presented in Figure 3.1, with corresponding tables in Appendix C. Additionally, Figures 3.2 and 3.3 present corresponding results for production and technology adoption, respectively. We present and discuss results for the with-risk scenarios only, as we assume Malawian farmers are concerned about market and production risk when they make their cropping choices each year, at least beyond meeting their subsistence requirements.

Reducing the volatility in soybean markets by at least 25 percent (simulation SB1) incentivizes farmers in Lilongwe to expand their acreage under soybeans quite significantly, from about 0.85 hectare to 1.18 hectares. In both cases they use improved seeds and inoculant. However, at much higher risk levels (using a maximum risk premium not shown here), they avoid the seeds and inoculant altogether, choosing to use recycled seed instead. This is a practice observed among some farmers who cannot purchase seed and the inoculant.

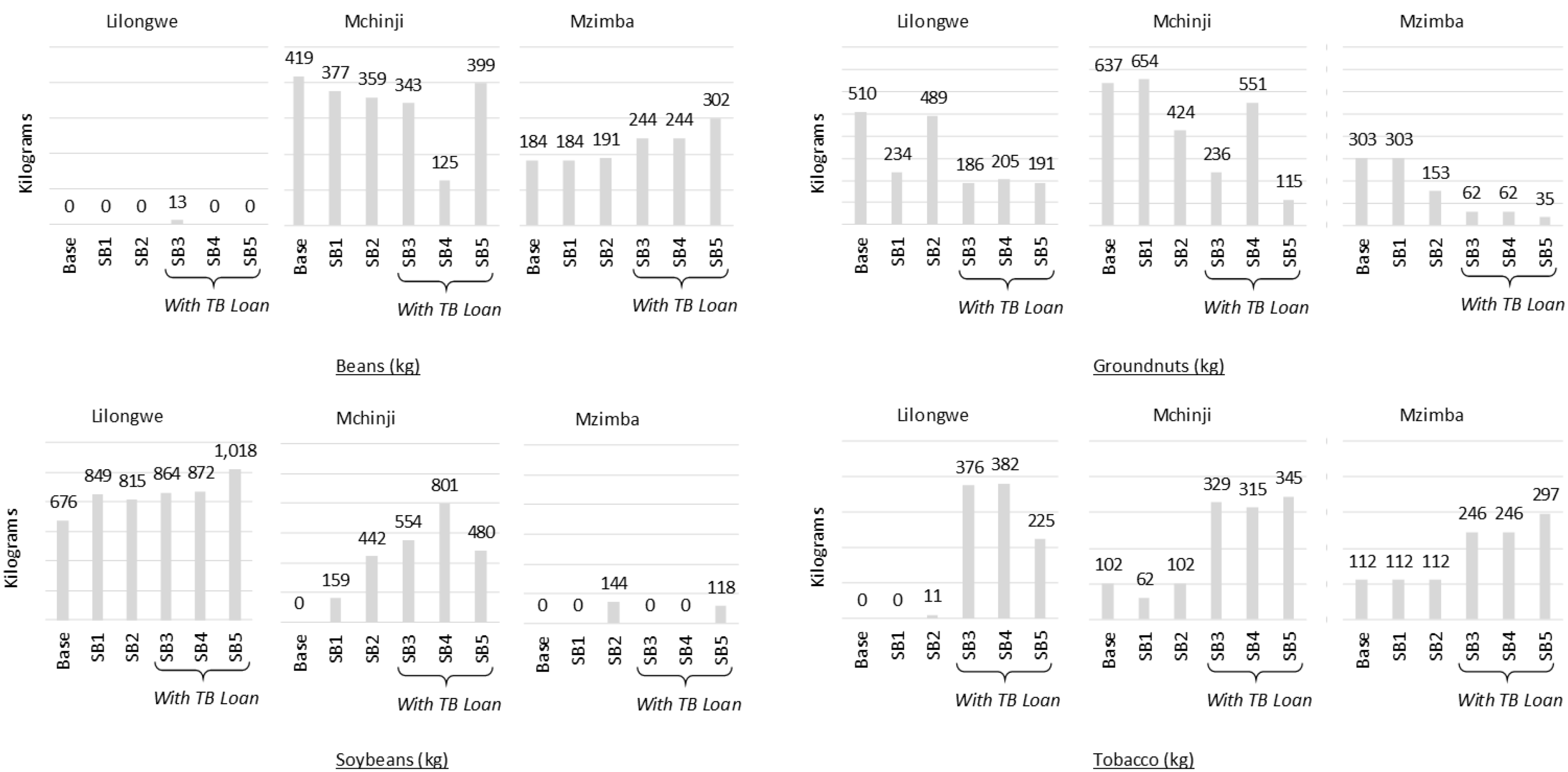
Relative to Lilongwe, we expect the effects of SB1 to be quite significant in Mchinji given Mchinji has been witnessing higher price volatility, as pointed out earlier. In other words, we would expect farmers to produce more soybeans if soybean markets are more stable—as would be the case if the market risks were unimportant to farmers (as previously shown in Table 3.1). According to the model, however, soybean production increases marginally in response to a 25 percent reduction in price variability, from zero in the base model to 0.15 hectare, and on land previously allocated to tobacco and beans. For Mzimba, soybeans prove to be far less profitable as an alternative to other crops. Even if soybean price variability is reduced by 25 percent, farmers continue to avoid soybean production and instead allocate their limited resources to inputs for tobacco and maize.

Figure 3.1 Farm incomes and area allocations for all soybean simulations (with risk only)



Source: Model results (2016).
Notes: The charts are based on the numeric results reported in Table C.6 in Annex C. All values are in constant 2014 Malawian kwacha (MK). BN = beans, GN = groundnuts, MZ = maize, MZGN = maize-groundnut intercrop, SB = soybeans, and TB = tobacco. Simulations: base = current; SB1 = improved SB market; SB2 = SB loan package; SB3 = TB loan package; SB4 = TB loan package and improved SB market; SB5 = TB loan package and SB loan package. MK numbers represent daily farm earnings (based on the annual farm income and divided by 365), while the numbers underneath them in brackets and italics are the standard deviation of the daily earnings. * Indicates crop area cultivated for subsistence only.

Figure 3.2 Total production output for all soybean simulations (with risk only)

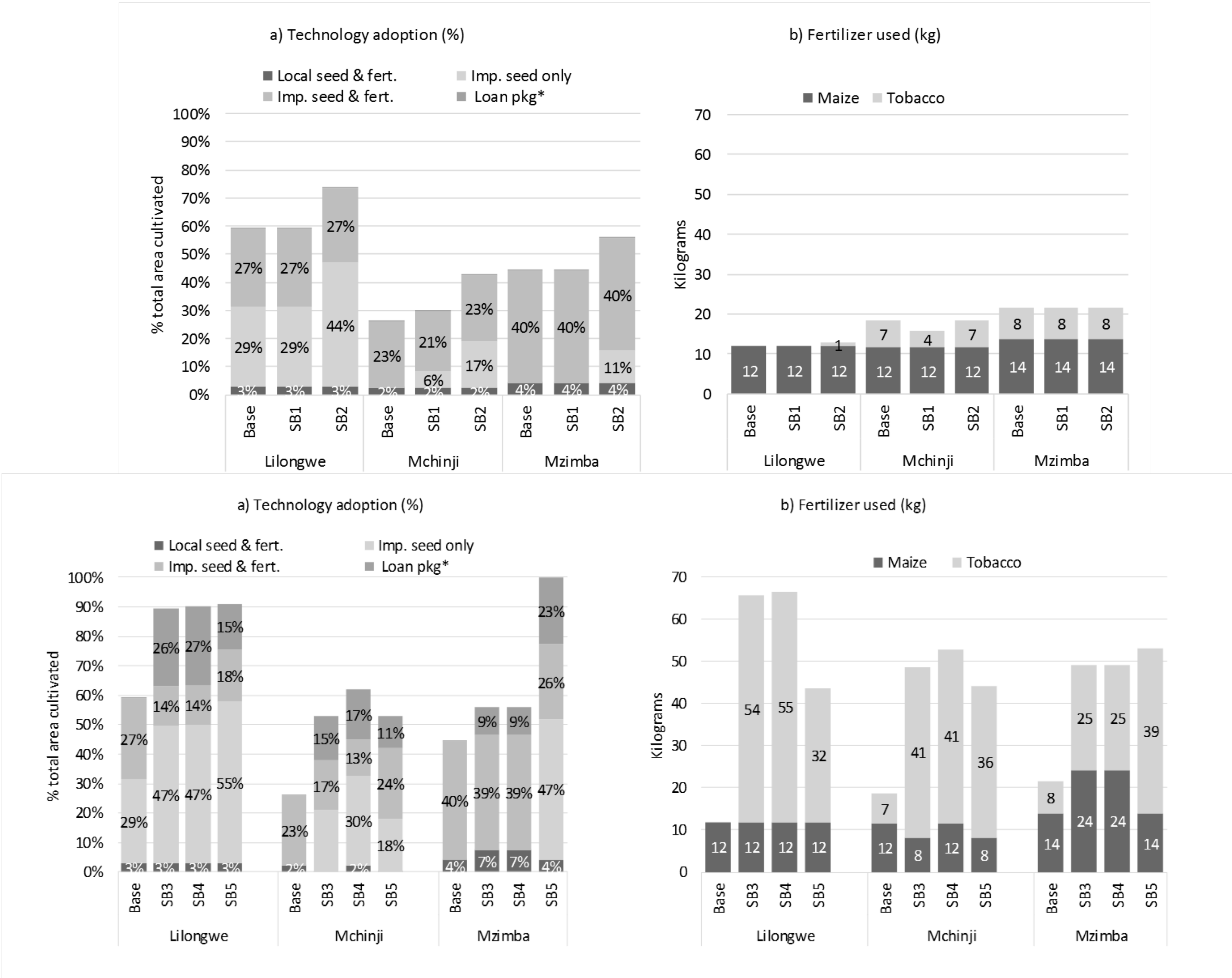


Source: Model results (2016).

Notes: SB = soybeans; TB = tobacco; kg = kilograms. Simulations: base = current; SB1 = improved SB market; SB2 = SB loan package; SB3 = TB loan package; SB4 = TB loan package and improved SB market; SB5 = TB loan package and SB loan package. SB loan package involves both improved seed and inoculant. TB loan package involves both improved seed and fertilizer application at ¾ or full rates—for up to an acre for tobacco and ½ an acre for maize. Maize was purposefully left out as this does not change (at 1.06 metric tons for all locations).

Figure 3.3 Technology adoption and use for all soybean simulations (with risk only)

a) For first two soybean simulations (SB1 and SB2)



Source: Model results (2016).

Notes: Simulations: base = current; SB1 = improved SB market; SB2 = SB loan package; SB3 = TB loan package; SB4 = TB loan package and improved SB market; SB5 = TB loan package and SB loan package. SB loan package involves both improved seed and inoculant. TB loan package involves both improved seed and fertilizer application at ¾ or full rates—for up to an acre for tobacco and half an acre for maize. kg = kilograms.

In simulation SB2, farmers are given an input loan package sufficient for 1 acre of planting. This simulation attempts to address cash constraints reported by farmers in our fieldwork. The loan has an annual interest rate of 25 percent[2] and is repayable at harvest. The total value of the loan for an acre of soybeans is about MK 11,116 (for seed and inoculant).

[2] This interest rate is based on the annual average bank rate for 2014 as published by the Reserve Bank of Malawi (www.rbm.mw) and accessed on May 26, 2016. It is conservative for our purposes as rates faced by smallholder farmers are typically higher.

The effects of the soybean loan package (SB2) vary from the effects of reducing soybean price volatility (SB1); in particular, SB2 is relatively more effective at stimulating soybean production in Mchinji and Mzimba. It has a smaller effect in Lilongwe, despite lower loan amounts (roughly MK 5,800 for 1 acre). One interpretation is that farmers are sufficiently cash constrained at planting time to benefit from this relatively small loan amount. In fact, the soybean loan package (SB2) turns out to be the only intervention that incentivizes soybean production in Mzimba (from zero to about half an acre, or 0.18 hectare). For Mchinji, even in the presence of higher output price variability relative to Mzimba and Lilongwe, the soybean loan package has a relatively larger impact compared with the other two locations studied. In addition, the soybean loan package stimulates increased tobacco production—most likely because farmers reallocate land to soybeans from groundnuts, which frees up labor to produce more tobacco.

The SB1 and SB2 interventions to promote soybean production have mixed results with regard to their effect on total farm earnings. Reduced soybean price volatility (SB1) increases farmer incomes in Mchinji, most likely due to the reduced opportunity costs of reallocating land from tobacco and beans to soybeans, but earnings fall slightly in Lilongwe as groundnut production declines more in part due to its higher market volatility relative to the now more stable soybean market; in Mzimba, incomes remain unchanged as farmers do not change land allocated to soybeans relative to the base scenario. The soybean input loan package (SB2) on the other hand results in higher incomes across all three regions, but more so in Lilongwe and Mchinji than in Mzimba. The weaker income effect in Mzimba is primarily due to the limited response in allocating acreage to soybeans—and evidently earning only slightly more than previous earnings from groundnuts, which the soybeans have now displaced.

Complementarity and Substitutability of Soybean and Tobacco Production

The results of the SB1 and SB2 simulations indicate that farmers are likely to allocate more land to soybeans if they are provided with improved market stability or access to a loan package for seeds and an inoculant, or both. However, farmers generally also have tobacco production under a contract farming arrangement as a production option. For Malawi's smallholder farmers, tobacco remains an important cash crop option, especially given the existing market structure and the contractual-type arrangements already in place. It is therefore important to also consider the effects of interventions designed to stimulate soybean production in the presence of existing incentives to produce tobacco. To investigate the effects of soybean interventions in the presence of incentivized tobacco production, we introduce a tobacco loan package in simulation SB3. The tobacco loan package includes a sufficient quantity of improved seeds, chemicals, and other materials to cultivate 1 acre of tobacco. The tobacco loan package also includes maize seed and fertilizer sufficient to plant half an acre to contribute to a household's food security requirements.[3] In total, the tobacco loan value amounts to MK 138,174, which is much larger than the soybean loan package. Farmers can pay off their loan package at harvest at an annual interest rate of 25 percent, just like the soybean package. With the tobacco loan package in place, we then introduce reduced soybean price volatility (SB4) and the soybean loan package (SB5), along the lines of the soybean interventions described above. Simulation results are reported in Figure 3.1 and corresponding tables in Appendix C.

The tobacco loan package (SB3) clearly incentivizes farmers to grow more tobacco. Lilongwe farmers increase land allocated to tobacco from a base of zero hectares to 0.65 hectare. Area allocated to tobacco increases from 0.14 hectare to 0.43 hectare in Mchinji and 0.16 to 0.49 hectare in Mzimba. Incomes also rise substantially—by about 3 percent on average in Mzimba to 29 percent in Lilongwe.[4] In all three locations, much of the shift to tobacco displaces groundnut production—with varying effects on beans. For example, Mzimba actually moves out of sole-cropped groundnut production and expands both

[3] Note that the provision of inputs for half an acre of maize only partially meets the food security requirement of about an acre (recall previous discussion on this requirement).

[4] This is a simple percentage change between the base and SB3 of earnings in Figure 3.1. For Mchinji this was an increase of about 18 percent for SB3.

tobacco and beans; Mchinji displaces a significant amount of acreage that was in beans in favor of tobacco and soybeans.

One important result from adopting the tobacco package is the increased intensification in tobacco and maize production through increased use of inputs, especially fertilizer (Figure 3.3). This effect is particularly pronounced in Mzimba and Lilongwe, with about half of the increase in intensification (percent adoption) attributed to the tobacco loan package.

Another important—and unexpected—result of the introduction of a tobacco loan package (SB3) is an expansion of soybean production in both Lilongwe (from 0.85 hectare to 0.94 hectare) and Mchinji (from zero hectares to 0.31 hectare)—and in the case of Mzimba an expansion into beans. Evidently, the tobacco package has the effect of relaxing the cash constraint at planting faced by farmers in all three locations—leading them to purchase inputs for other crops. Farmers in Lilongwe and Mchinji choose to do this for soybeans by purchasing improved seeds and the inoculant, while in Mzimba farmers purchase improved bean seeds.

Next, we introduce lower soybean price volatility in the presence of the tobacco loan package (SB4). For farmers in Mchinji, reducing soybean price volatility in the presence of the tobacco loan package results in a notable increase in soybean production compared with the scenario in which there is no tobacco loan on offer (Figure 3.2, SB4). This is after all a region that has more to gain from an improved soybean market structure and lowered price volatility. Recall that the tobacco loan package includes some maize seed and fertilizer for consumption purposes. By being able to access inputs in advance for both tobacco and maize, farmers will intensify the land cultivated to both crops, releasing more land to other crops such as soybeans. Additionally, as pointed out earlier, the loan also increases available cash reserves for farmers to purchase their own inputs, and in the case of Lilongwe and Mchinji, they choose to buy soybean seeds and an inoculant. Meanwhile, the increased demand for labor on tobacco fields makes labor that much more costly and in short supply—and farmers choose to allocate the residual labor to soybeans, which demands slightly less labor than groundnuts (Figure 3.1, SB4).

In Lilongwe, however, combining reduced soybean price volatility and the tobacco loan package does not result in increased soybean production relative to reducing soybean price variability on its own; the combined effect is actually smaller than without it (that is, comparing SB4 with SB1). In Mzimba, the average soybean gross margins remain too low to be profitable, and therefore we see no effect in the presence of a tobacco loan or not.

Next, we introduce the soybean loan package in the presence of the tobacco loan package (SB5). The combined effect of the loan packages increases soybean production in Lilongwe and Mzimba relatively more than the soybean loan package on its own. Those two areas are less affected by a high volatility of soybean prices, but are cash strapped like Mchinji. For Mchinji, on the other hand, area allocated to *beans* increases (at the expense of groundnuts) when loan packages for both soybeans and tobacco are available. One explanation could be that the market risk associated with soybeans makes farmers reluctant to increase soybean production too rapidly. Rather, they allocate a conservative amount of land to soybeans and use the labor savings from intensified tobacco and soya production to invest in beans, which have relatively high returns to labor (Table C.4 in Appendix C).

The combined effect of the two loan packages (SB5) on tobacco production also varies by location. In Lilongwe, tobacco production declines when the soybean loan package is introduced; in Mchinji, on the other hand, tobacco production actually increases. One explanation for this differential effect could be that tobacco prices are relatively more volatile than soybean prices in Lilongwe compared with Mchinji. In other words, highly risk-averse farmers in both locations will shift more land to the less risky crop (soybean for Lilongwe, tobacco for Mchinji) when adopting both loan packages. In Mzimba, the combined loan packages result in increased soybean production while tobacco production remains unchanged.

One implication of these results is that while policy interventions designed to incentivize soybean production, either through improved markets or input loan packages, can potentially reduce smallholder farmer reliance on tobacco as a cash crop, this shift is less likely to take place if tobacco production incentives remain in place. Rather, the combined effect of soybean and tobacco production incentives results in more intensified production of both crops and more intensified maize production as well (Figure 3.3, bottom panel).

Revisiting the Dominance of Maize and Constraints for Commercialization

One of the clearest challenges for Malawian smallholder farmers is the concern for food security, which limits how much they can expand into high-value crops. One would expect that with greater intensification on their plots, farmers can allocate more acreage to higher-value crops. But as seen in the previous results, farmers are unlikely to intensify given the high costs of inputs. It is for that reason that fertilizer subsidies have played such an important role in Malawi, and have become an essential part of the food security equation in the country.

In this section, we turn to examining in more depth the challenges that arise as a result of both the quest to ensure maize self-sufficiency and the subsidies that come with it. A motivation for this is to determine to what extent this has important implications for the higher-value crops, but also whether even the maize sector has the potential to generate a surplus. After all, Malawi has exported maize in the past during years of bumper harvests.

As discussed earlier in "Model Simulation Strategy," we introduce three simulations to better understand the effect that policy shifts and price changes have on maize's market potential—that is, beyond its requirement for satisfying the food security objective. Those include MZ1, wherein we remove the fertilizer subsidy in the base model; MZ2, in which we determine the price at which maize becomes profitable as a marketed crop without a fertilizer subsidy; and MZ3, in which using the price derived from simulation MZ2, we explore the extent to which farmers produce maize when the consumption constraint is removed (that is, farmers rely on the market to satisfy their maize consumption requirements). Effects of incomes and area allocations are summarized in Figure 3.4, followed by production output in Figure 3.5 and technology adoption rates in Figure 3.6. Corresponding tables are also available in Appendix C.

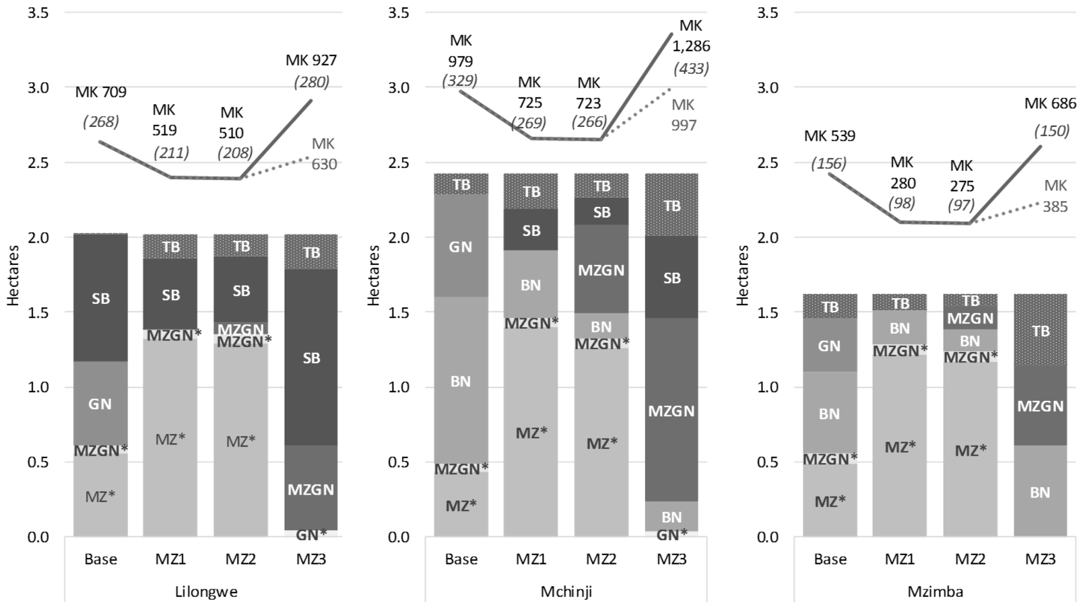
When the fertilizer subsidy is removed (MZ1), farmers reduce the intensification of maize production and, as a result, allocate dramatically more land to maize in order to meet their household food consumption needs (Figure 3.4). In the process, the return to labor for maize drops significantly—from about MK 120 per day to MK 72 per day (Table C.9 in Appendix C). One interpretation of these results is that smallholder farmers are unlikely to intensify maize production without input subsidies. The results have obvious implications for land available for marketed crops. In fact, farmers shift completely out of groundnut production and instead choose to intensify soybean and tobacco production on the little land they have left (see Figure 3.5 on adoption rates and fertilizer use, as well as Table C.7 in Appendix C). In the meantime, crop diversification deteriorates as the bulk of the land is allocated to maize.

For maize to become profitable as a marketed crop without the fertilizer subsidy (MZ2), farmgate prices would need to increase by 35 percent.[5] In this scenario, farmers would allocate some land to the maize-groundnut intercrop purely for market purposes—but without intensifying either as they also mostly do for consumption (Figure 3.5 and Table C.8 in Appendix C). In the absence of input subsidies, the combined cost of fertilizer and seeds is just too high and farmers would rather allocate their limited cash reserves to the more profitable cash crop, tobacco.[6]

[5] This is possible when a rise in retail prices is combined with reduced marketing margins—that is, between farmgate and retail price—which is what we do in our model. With an initial assumption of an 80 percent farmgate-to-market price ratio, halving the margin to make the price ratio 90 percent and increasing market prices by 20 percent results in our 35 percent increase in farmgate prices.

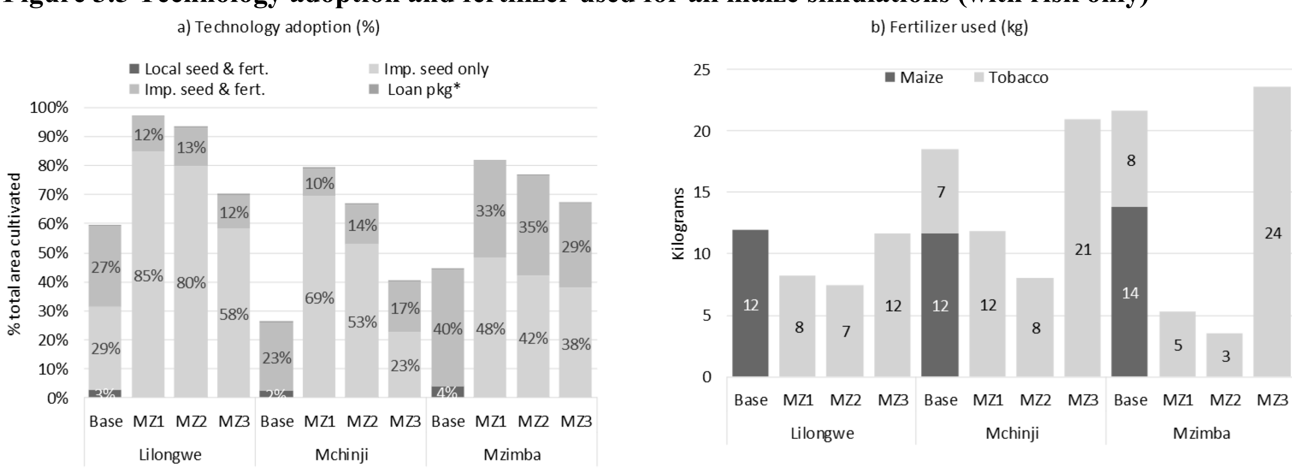
[6] It is possible that if we introduced the tobacco loan package, this could change some, but it would not likely be significant.

Figure 3.4 Farm incomes and area allocations for all maize simulations (with risk only)



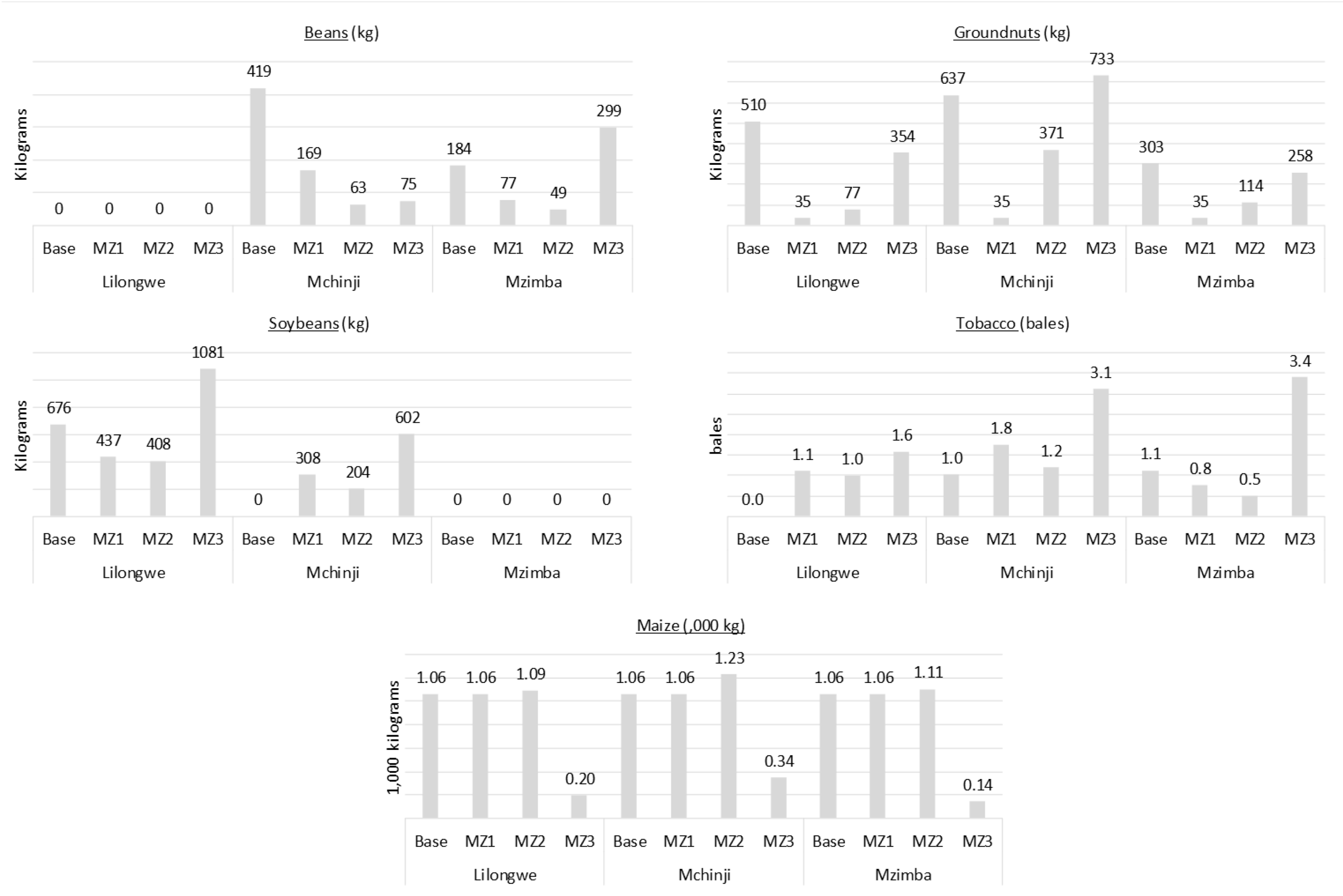
Source: Model results (2016).
Notes: Simulations: base = current with fertilizer subsidy and consumption constraint (as in Figure 3.4); MZ1 = still with consumption constraint but fertilizer subsidy removed; MZ2 = same as MZ1, but market prices for maize increased by 20 percent; MZ3 = same as MZ2, but now consumption constraint removed. BN = beans, GN = groundnuts, MZ = maize, MZGN = maize-groundnut intercrop, SB = soybeans, and TB = tobacco. Malawian kwacha (MK) numbers represent daily farm earnings (based on the annual farm income and divided by 365), while the numbers underneath them in brackets and italics are the standard deviation of the daily earnings. The lighter-colored figures and dotted line for MZ3 represent a residual farm income after subtracting required maize consumption purchases (for 1,063 kilograms per household per year) with the higher price. All values are in constant 2014 Malawian kwacha. The price increase under MZ2 and MZ3 includes a reduced marketing margin of 50 percent between the farmgate and market prices. Market prices were increased to a level such that it is just sufficient to bring maize into the solution for any of the three locations (whether as an intercrop with groundnuts or as a sole crop). This turned out to be a 20 percent increase—and mostly affected Mchinji and Mzimba. * Indicates crop area cultivated for subsistence only.

Figure 3.5 Technology adoption and fertilizer used for all maize simulations (with risk only)



Source: Model results (2016).
Notes: Simulations: base = current with fertilizer subsidy and consumption constraint (as in Figure 3.4); MZ1 = still with consumption constraint but fertilizer subsidy removed; MZ2 = same as MZ1, but market prices for maize increased by 20 percent; MZ3 = same as MZ2, but now consumption constraint removed.

Figure 3.6 Total production output for all maize simulations (with risk only)



Source: Model results (2016).

Notes: Simulations: base = current with fertilizer subsidy and consumption constraint (as in Figure 3.4); MZ1 = still with consumption constraint but fertilizer subsidy removed; MZ2 = same as MZ1, but market prices for maize increased by 20%; MZ3 = same as MZ2, but now consumption constraint removed.

Finally, we simulate how farmers respond when the maize consumption constraint is removed—that is, farmers rely on the market to satisfy maize consumption requirements, in the presence of higher maize market prices (MZ3). This simulation allows us to gauge the extent to which household consumption and welfare may be affected as a result (especially given the higher market prices for maize).

In this simulation, farmers shift land allocation to maize-groundnut intercropping, tobacco, and soybeans, completely displacing sole maize cropping, to which farmers had previously allocated land for consumption purposes when the consumption constraint was in place (Figure 3.4); in the process, overall maize production drops dramatically (Figure 3.5). This effect is especially strong in Lilongwe, accounting for the bulk of area cultivated. In Mchinji and Mzimba, bean production also increases.

When farmers cultivate their land for profit only, the income effect is quite significant, increasing by about 30 percent in general from the current state of affairs (this is comparing farm incomes between the base and MZ3 model results in Figure 3.4). However, because farmers now have to purchase their maize from the market for home consumption, households in Lilongwe and Mzimba are actually made worse off as a result (Figure 3.4). Welfares of farmers in Mchinji improve, most likely due to their larger farm sizes relative to farmers in Lilongwe and Mzimba.

Overall, the results in all three locations are quite revealing with regard to the unprofitability of maize in general for the majority of smallholder farmers in Malawi. As Table C.9 in Appendix C shows, the return to both labor and land for maize drops significantly as subsidies are removed—implying that the crop is less attractive if the motive for growing it is profit. Even if prices rise by 20 percent in general, including improvements in marketing margins to raise the farmgate price higher than the 20 percent increase at retail, it remains insufficient to maintain the current levels of maize production if the farmers are only going to grow for the market. While farmers will grow some maize for market when prices increase, they can hardly afford to rely on the market for their maize consumption needs. In this regard, they will prefer to maintain the bulk of their maize production for subsistence. This also means that without access to affordable inputs for maize production, less land will be available for other high-value crops such as tobacco, soybeans, groundnuts, and beans. In this regard, the current input subsidies continue to play a critical role in promoting the production of higher-value crops, as well as the potential for diversifying the portfolio of crops grown.

4. CONCLUSION

The paper investigates the potential for oilseeds, and specifically soybeans, to replace tobacco as a commercial crop for Malawian smallholder farmers. We hypothesize that the presence of high price volatility reduces the rate at which farmers are willing to expand into soybeans relative to tobacco or other high-value crops.

Using a mathematical programming farm-level risk model for a range of farmers in three districts—Lilongwe, Mchinji, and Mzimba—we empirically evaluate the extent to which the observed volatility in markets affects the choices a risk-averse smallholder farmer makes in allocating land to different crops. Based on the model results, we find that uncertain markets in part explain Malawian farmers' propensity to diversify into soybean production. More stable soybean markets in Lilongwe make the crop attractive even at high levels of risk aversion. The higher volatility of soybean prices in Mchinji, on the other hand, prevents farmers from allocating more land to soybeans versus farmers in Lilongwe; rather, these farmers prefer to produce crops, such as groundnuts and beans, that have more certain returns.

Based on the empirical results of our farm risk model, soybeans have strong potential as a source of income for smallholder farmers in Malawi if soybean markets become more stable or farmers receive input loan packages to relax cash constraints. However, the effectiveness of such policy interventions does depend on market conditions and degrees of uncertainty faced by farmers. Farmers in Lilongwe, for example, are far more responsive to policy interventions designed to promote soybean production, most likely due to Lilongwe's relatively more stable soybean markets compared with Mchinji and Mzimba. The least responsive farmers are those in Mzimba, where the combination of lower prices and market uncertainties makes soybeans less competitive with other cash crops such as tobacco, groundnuts, and beans. Farmers in Mchinji, on the other hand, have the most to gain from improvements in the market structure for soybeans as that district has faced the highest volatility in soybean prices in the past.

In examining the potential effects of having a well-established tobacco market structure already in place, we unexpectedly find that it actually incentivizes risk-averse farmers in Lilongwe and Mchinji to further expand their acreage under soybeans. This surprising result occurs because the tobacco loan package, by including maize inputs as well, frees up resources for more intensified soybean production. Another factor that makes soybean production relatively more attractive is soybeans' lower demand for labor relative to tobacco.

Generally, our findings imply that policies that promote soybeans will not necessarily displace tobacco altogether—although tobacco production does decline some. On the other hand, the presence of a more structured market for tobacco enhances the effect of policies introduced to promote soybean production by incentivizing farmers to access more financial resources to expand their land allocated to soybeans. One important tradeoff is the effect on groundnut production. Because of the closer similarities between the legumes (soybeans and groundnuts) with regard to demand for labor, land, and purchased inputs (for example, they require no fertilizer), policies promoting soybean production will come at the expense of reduced groundnut production unless farmers can expand their access to land.

A key result—and one supported by previous studies—is how fertilizer subsidies have actually played an instrumental role in releasing land for higher-value crops. This is because the subsidies help farmers intensify their maize production.

Finally, the potential for maize commercialization turns out to be less feasible. Relative to the other crops, maize remains the least profitable crop in the districts studied while only maintaining its significance as a subsistence crop. We also find that fertilizer subsidies have played an instrumental role in helping to release land for other higher-value crops as they allow farmers to intensify their maize production. Even a 20 percent bump in maize prices would be highly unlikely to spur much additional production among smallholder farmers, with or without fertilizer subsidies. Meanwhile, any rise in maize prices is detrimental to the food security of net buyers of maize and is therefore politically sensitive. The very essence that "maize is life" in Malawi implies that its value as a basic staple for consumption will always outweigh its market value among the majority of poor, food-deficit smallholder farmers.

APPENDIX A: SMALLHOLDER FIELD SURVEY REPORT[7]

Districts covered: Lilongwe, Mchinji, and Mzimba
Dates of fieldwork: October 27 to 30, 2015

Background

This study is premised on building a case for making changes in production patterns of agricultural crops by smallholder farmers in three districts of central Malawi. Tobacco still commands the lion's share of Malawi's export earnings despite several interventions by both the government and nongovernmental organizations to diversify the economy from tobacco. However, legumes (soya in particular) have shown a capability to have similar income effects for both the country and households. The study therefore investigates the potential of legumes, specifically soybeans and groundnuts, to replace tobacco as the main cash crop.

A comparison was hence made among Malawi's most competitive cash crops (tobacco, red beans, and soya) to determine if there have been changes in the production patterns and to model their production systems. Focus group discussions and key informant interviews were conducted, and the following are some of the key findings from the field.

<u>Land Allocation</u>

When allocating land to specific crops, farmers start by looking at the type of soil. Different soils require different cropping types. After looking at the soil, farmers then consider the inputs available. Due to a paucity of inputs, most farmers allocate more land to crops that do not require much input use, such as soybeans and groundnuts. Maize is grown on very small pieces of land solely for food security reasons. In Lilongwe, most land is allocated to cassava, sweet potato, soya, and groundnuts. In Mchinji and Mzimba, farmers allocate most land to soybeans, groundnuts, and beans. Only a few farmers grow tobacco and maize commercially.

<u>Input Use</u>

Even though the Malawian government supports maize production through the farm input subsidy program, few farmers benefit from the program. Farmer expert interviews reveal that a package that is intended for one farmer is being shared among up to three households. Most farmers are using recycled seeds that are kept from the previous season.

Tobacco farmers have the opportunity for contract farming, where they are given inputs (seeds, chemicals, and fertilizers) to grow tobacco on the condition that they will sell their leaf to the contracting company. However, that arrangement has some drawbacks like high loan interest rates and no price quotation in the contractual agreement between the farmers and the buying companies. This causes some farmers to still opt for a self-sponsored arrangement.

<u>Coping Mechanisms for Labor Shortages</u>

The study also found that some farmers use communal labor rotation to cope with labor shortages during peak periods. This arrangement involves having households from neighboring houses mobilize their labor and jointly work on their respective fields one by one. This enables farmers to finish their fields within a short time since more hands are involved at one farm until the work is done. Then they move to the next farm.

<u>Market Options for Inputs and Commodities</u>

The study revealed changes in the pattern of marketing options for farmers on both the input and output sides. From the discussions, we learned that with the removal of state power from the management of the Agricultural Development and Marketing Corporation, farmers now face limited access to both inputs and output markets. Currently, farmers access their inputs through private agro-dealers and sell their commodities to profiteering vendors and middlemen. This leaves farmers facing high prices for

[7] Prepared by Cynthia Kazembe, senior research assistant, IFPRI-MSSP, Lilongwe, Malawi.

inputs and low prices for outputs and some rarely break even. The only cash crop that has a well-organized market was found to be tobacco.

Detailed Information from Focus Group Discussions

As mentioned, we conducted the study in three districts: Lilongwe (Chitsime Extension Planning Area [EPA]), Mchinji (Kapiri EPA), and Mzimba (Khosolo EPA). Below are the issues discussed during the focus group discussion at each study site.

1. Lilongwe (Chitsime EPA)

The main crops grown in Lilongwe, ranked by area allocation, are maize, soybeans, cassava, groundnuts, and tobacco. Average size of land owned by a household is 3 acres. Tobacco is not common in the area because of small landholding sizes and the lack of inputs required for growing tobacco.

More land is allocated to soybeans, groundnuts, or cassava. A greater share of land is allocated to crops that bring in cash than before. The increase in land share is because life these days is dependent on money, so it is wise to invest more in cash crops than food crops. The cash crops include soybeans, groundnuts, and cassava. Youthful households are more involved in cash crop production than mature households. Crop rotation is practiced, and this is one of the determinants of crop allocation. No land is ever left fallow because there is a shortage of land.

Crop allocation decisions are also based on the type of soil and availability of inputs. Some people in the village rent farms when they do not have enough or when they want to increase their investment in cash crop production. Those who rent out do so when they do not have enough resources to use all the land they have.

In farming, risk and uncertainties are inevitable. The most critical risks faced by farmers in Lilongwe include:

i) *Market access and market prices.* Tobacco-planting decisions are based on last season's prices. The farmers, however, are not assured of the same prices in the current season. So they take a risk to plant tobacco again. This also applies to crops like maize, groundnuts, and soybeans. There is also an issue of markets. There is no structured market for soya and groundnuts; they sell to vendors at very unfavorable prices. The prices are dictated by the vendors. The farmers grow groundnuts and soya without assurance of a market or price.

ii) *Unreliable rainfall.* There is a fear of dry spells during the cropping season and sometimes floods. But farmers grow crops anyway.

iii) *Lack of inputs.* Most farmers do not have the necessary inputs when planting crops like tobacco, considering it needs fertilizing two to three times. Some farmers rely on organizations to give them inputs, which most times come late. Sometimes these organizations bring seeds that are not suitable for the soils in the area. In this area, soybeans have the potential to replace tobacco. In the past, soybeans had no potential, but now many industries need soybeans as a raw material. Although there is not a well-defined market, there is hope for one considering the increase in its demand. Value addition is one way farmers are thinking of investing, so that they create a market for soybeans. Soybean used to be intercropped, but now it is grown as a monocrop.

iv) *Periods of scarcity for labor, food, and cash.* Farmers/households face significant labor, cash, and food constraints in some months of the year. These are as follows: January, February, and March (cash and labor constraints); April, May, June, and July (labor constraints); November and December (labor and cash constraints); and October (cash constraints).

2. Mchinji (Kapiri EPA)

The main crops grown in Mchinji are maize, groundnuts, and tobacco. The average land size owned by a household is 6 acres, but some farmers have up to 30 acres. More land is allocated to maize, followed by groundnuts, and lastly tobacco.

Crop allocation decisions are based on availability of inputs, both seed and fertilizer, labor availability, and market availability and market prices. Land is not an issue in Mchinji, as people have good-size pieces of land. Farmers practice crop rotation, and many leave parts of their farms fallow. They do this because of lack of inputs, but sometimes they do it for the soil to regain fertility. Farmers have access to virgin land.

The following are the risks and uncertainties that farmers assume:

i) *Market access and market prices.* Unavailability of markets forces farmers to sell to vendors who offer very low prices. In the last growing season, the prices they got from vendors were as follows: maize—MK 80 to MK 120 per kilogram; groundnuts—MK 500 per kilogram; and soya—MK 140 to MK 250 per kilogram. The low prices are offered at harvest, which is when most farmers sell their produce. The prices for the commodities go up near planting season, but then no farmer has produce to sell. Farmers cannot afford to keep the produce until this time to fetch high prices because they are constrained by problems at home and lack of storage facilities. Market prices for the previous season determine investment decisions for the current season. For instance, because tobacco did not fetch a good price last season many farmers are shifting to groundnuts and soya production.

ii) *Unreliable rainfall.* Farmers face the problem of poor rainfall, dry spells, and floods. This is one of the bigger risks they take. Even those under tobacco contract farming do not get insurance for damages caused by weather conditions. The farmers in Mchinji highlighted that farming is not progressing. Most of them were used to growing tobacco, but it is not profitable anymore. It requires more inputs and is labor intensive. For those reasons, farmers believe tobacco as a main cash crop can be replaced with groundnuts (and not soybeans). Groundnut is more labor intensive than soybeans, but farmers prefer groundnuts because it commands a higher price per kilogram than soybeans and it is a ready food.

iii) *Periods of scarcity for labor, cash, and food.* The months during which farmers or households are labor, cash, or food constrained are as follows: January and February (labor, cash, and food constrained); May (cash constrained); September (cash constrained); October (labor constrained); November and December (labor, cash, and food constrained).

<u>3. Mzimba (Khosolo EPA)</u>

The main crops grown in Mzimba in order of importance are maize, beans, and soybeans. As for farm sizes, the largest a farmer has is 4 acres, the smallest is 0.5 acre, and the average is 2 acres.

Ninety percent of farmers allocate more land to maize for food security reasons; this is followed by beans and lastly soya. Most farmers rent an extra acre to grow soybeans. Maize is grown solely for food security and beans for cash. A farmer with 2 acres would allocate 1 acre to maize and the other to beans. Farmers do not maximize soya production because of lack of soya seed.

The challenges faced include unavailability of labor (it is mostly women who bear the work and the costs, as men only come in when selling); lack of inputs, especially seed (they have to use recycled seed); lack of storage facilities; and no mechanization (they cannot afford it and also the land is hilly). However, the National Smallholder Farmers' Association of Malawi is now giving seed on a loan. When farmers receive 5 kilograms of seed they give back 12.5 kilograms. Also they have two growing seasons in a year—rain fed and irrigated.

The following are the uncertainties and risks farmers assume:

i) *Market access and market prices.* The area has no structured markets, so farmers sell all their produce to vendors. The vendors buy the commodities at very low prices. However, the farmers have a choice—either they sell to vendors or join a cooperative, aggregate the commodities, and sell in bulk at a good price. So the vendors target only individual farmers.

ii) *Pests.* There is an issue of pest (stalk baller) infestation in beans and maize.

iii) *Unreliable rainfall.* There is a great potential of replacing tobacco as a main cash crop with soybeans. Soybeans require fewer inputs than tobacco does. This is on the condition that they create a market for soybeans.

iv) *Periods of scarcity for labor, food, and cash.* During the farming calendar, farmers face the following constraints: January and February (labor, food, and cash constraints); December (labor constraints).

Conclusion

Findings from the three study areas suggest that there is potential for replacing tobacco as the main cash crop in Malawi. To make that possible, however, someone needs to create markets for the different commodities, provide agricultural loans, provide civic education, and provide mechanization. In addition, farmers need storage facilities so that they can sell their produce when prices are high.

APPENDIX B: MATHEMATICAL DESCRIPTION OF SMALLHOLDER FARM RISK MODEL

The mathematical programming model adopted here incorporates risk (as a farm risk model) and is applied to the three study locations in Malawi, calibrated to field surveys and secondary data sources. Altogether, there are three individual representative farm risk models for each location.

The key decision variables of the model are allocation of land and labor across a variety of cropping activities, including intercropped production systems. Labor can be own family labor or hired from elsewhere at the going daily wage rate. A typical farm is assumed to have a fixed amount of land available.

In the model, an aggregate objective function maximizes the net of total expected returns less a risk parameter and the variance-covariance of gross margins across cropping activities and by technology. The variance-covariance serves as the risky outcome determined by the variability (and cross-variability) of output prices and yields by technology used among the various crops. Therefore, on-farm returns are subject to expected (or mean) gross margins, across activities and other farm-specific resource constraints (labor, land, and credit).

The model is developed using the general algebraic modeling system, or GAMS (Brooke, Kendrick, and Meeraus 1992) using nonlinear programming approaches. The choice variables in the model (to be capitalized) include land area (X_{ij}) allocated by a farmer in location i to activities j (by crop and technology type) and labor (own and hired). Six crop activities j are included with assumed area allocation to those activities.

Mathematically, the objective for each average farmer in each location i is represented by z_i in equation 1 below—to maximize net profits (π_i) given the expected gross margin (μ_{ij}) and its covariance (σ_{ijk}) across activities (X_{ij}), and a risk parameter (ρ_i) whose values can be adjusted to reflect the degree of risk aversion among farmers in each location, such that

$$z_i = \pi_i - \rho_i \sqrt{\sigma_{ijk}}, \forall i \tag{1}$$

where

$$\pi_i = \sum_j \left(\mu_{ij} - \sum_t c_{ijt} \right) X_{ij} - \sum_t w_t H_{it} - \sum_j rL_{ij}, \forall i \tag{2}$$

$$\sigma_{ijk} = \frac{1}{N} \sum_{n=1}^{N} \left(p_{nij} y_{nij} - \mu_{ij} \right) \left(p_{nik} y_{nik} - \mu_{ik} \right), \forall ijk \tag{3}$$

and

$$\mu_{ij} = \frac{1}{N} \sum_{n=1}^{N} p_{nij} y_{nij}, \forall ij \tag{4}$$

For the risk parameter values ρ_i, we use $\rho_i = 0$ to reflect the risk-neutral case and a median value of $\rho_i = 1.19$ for the risk-aversion case in reporting our results. The full range of ρ_i values in the model are 0.00, 0.83, 1.19, 1.49, and 1.65 (from risk neutrality to maximum risk aversion). The value of 1.65 serves as a maximum if we assume incomes are distributed normally (Hazell and Norton 1986). As Hazell and Norton explain, this is because for the specific value of $\rho_i = 1.65$, the value of z_i in the objective function of equation 1 translates into measuring the 5 percent income fractile when the income is normally distributed. Extremely risk-averse farmers, with $\rho_i = 1.65$, therefore would choose cropping activities that maximize their incomes, or π_i^*, while minimizing the probability of income falling below this value (that is, $Pr\{\pi_i \leq \pi_i^*\} = 0.05$).

The symbols μ_{ij} and σ_{ijk} in equations 3 and 4 are the expected mean and covariance of on-farm gross margins, respectively, across cropping activities *j* (and by type of technology), and based on annual observations (*N* years). While not shown here for brevity, these are distinguished in the model by whether the crop is grown for own consumption (as in maize and groundnuts) or for market. In calculating gross margins and their variances over time, farmgate prices for marketed crops were set at 80 percent of local retail market prices. For consumption crops, local market prices were chosen as the appropriate shadow price of the farmgate price.

The prime of *j* (or *k*) associates the covariants between all activities adopted in the choice set, respectively. The subscripts *i* in the mean profits (π_i) and variances of profits (σ_{ijk}) represent the three locations: Lilongwe, Mchinji, and Mzimba. The *j* cropping activities include the six choice crop activities and by technology types available. The subscript *t* represents months of the year (that is, *t* = 1,…,12).

$X_{ij}$and H_{it} are choice variables as follows: X_{ij} is the acreage allocation to each cropping activity and by technology type; and H_{it} is labor hired in by farmer in location *i* and in month *t*. Fixed parameters include the following: w_{it} is the going wage rate for hiring in labor; p_{ij} represents the average farmgate price of each crop by activity *j*[8] (all in constant 2014 Malawian kwacha values); y_{ij} represents crop yields by activity *j* (crop and by technology type). Finally, c_{ijt} represents per unit costs for purchased inputs under each activity *j* in season *t* (also in constant 2014 Malawian kwacha values).

The objective function from equations 1 through 3 is subjected to four resource constraints representing an upper bound on the supply of labor, land, a minimum amount of production to satisfy own consumption for maize and groundnuts, and supply of credit (own cash and/or a loan package). In mathematical terms, the resource constraints are as follows:

$$\sum_j \left[\alpha_{jt} + \alpha_{jt}^h\left(\bar{y}_{ij}\right)\right] X_{ij} \leq f_t + H_{it}^{in}, \forall it \quad (5)$$

[Labor supply constraint in period *t*]

$$\sum_j X_{ij} \leq a_i, \forall i \quad (6)$$

[Land availability constraint]

$$\sum_t \left(X_{ij} c_{ijt} - w_t H_{it}\right) \leq c_i, \forall i \quad (7)$$

[Cash availability constraint]

$$\sum_{j \notin j^c} X_{ij}\, \bar{y}_{ij} \leq q_j^c, \forall i, \forall j \in j^c \quad (8)$$

[Consumption constraint, j^c = any activity with maize and groundnuts]

[8] Only comes in if the farmer accepts a loan package for inputs, especially for tobacco or soybeans, as in contractual farming.

Equation 5 is the main labor demand and supply equation—that is, labor required across all production activities and land clearing for new land can be sourced only from own family labor (f_t) and labor hired in (H_{it}). The term α_{jt} represents labor use coefficients (person hours) under each cropping activity for land preparation, planting, and weeding. Person hours for harvesting (including other activities such as bunching, threshing, and collection in the field) are captured by the term α_{jt}^{h}, which is a function of yields $\bar{y}_{ij}$ (annual average yields by crop and technology).

The upper bound on own family labor (f_t) is based on a household size of six: two adults (male and female), two youth, and two children. Assuming a work day of eight hours and 20 days per month, the total hours per month for each farm household was fixed at 330 person hours—that is, assuming a person hour equivalent of 1.00 for an adult male, 0.75 for an adult female, and 0.50 for youth. For simplicity, we assume there is no upper bound for hired labor (H_{it}^{in}).[9]

Equation 6 is a simple land constraint that imposes upper limits on total land available on the farm—that is, total cultivated area cannot exceed what the farmer already has access to on the farm as a_i.

Access to credit is often cited as a limiting factor to adoption in developing countries (Feder, Just, and Zilberman 1985), and we have also introduced it here. Nevertheless, given the response from several farmers in each location, and evidence from the district-level data, farmers typically have very little cash reserves for purchasing inputs. We therefore limit cash availability to a small amount of MK 48,000 (about US$115 in 2014). Equation 7 illustrates this upper bound on cash availability as c_i for purchasing hired labor and inputs—which may also include a loan amount for specific crops (not shown here).

Finally, equation 8 imposes a simple consumption constraint for maize and groundnuts, not to be less than or exceed a certain minimum amount of output (kilograms) in each location and based on the household size. For maize, the amount is set for one 50-kilogram bag of milled maize for a family of four (one adult male, one adult female, one youth, and one child)—which translates to about 1,062.5 kilograms per year for a household of six as the value for q_{ij}^{c} in equation 8. We adjust consumption requirements by type of family member as follows: one adult male (1), one adult female (0.75), two youths (0.75 each), and two children (0.50 each). For groundnuts we kept this at a small amount of 25 kilograms for the same family of four, which translates to 35.4 kilograms for our family of six.

[9] Earlier attempts to restrict it proved redundant given the small-size acreages and thus the small quantity of hired labor demanded when own family labor becomes binding.

APPENDIX C: ADDITIONAL TABLES OF FARM MODEL RESULTS

Table C.1 Calculating own consumption requirements for a single household of six

Variable	Adult equivalent scale	Adult equivalent (kg/month)	Household size	Monthly requirement (kg)	Monthly requirement (kg)	Annual requirement (kg)
Maize		*(Milled)*			*(Unmilled)*	
Child	0.50	8.33	2	16.67	20.83	250.0
Youth	0.75	12.50	2	25.00	31.25	375.0
Female	0.75	12.50	1	12.50	15.63	187.5
Male	1.00	16.67	1	16.67	20.83	250.0
Total	*3.00*	*50.00*	*6*	*70.83*	*88.54*	*1,062.5*
Groundnuts		*(Unshelled)*				
Child	0.50	0.35	2	-	0.69	8.3
Youth	0.75	0.52	2	-	1.04	12.5
Female	0.75	0.52	1	-	0.52	6.2
Male	1.00	0.69	1	-	0.69	8.3
Total	*3.00*	*2.08*	*6*	-	*2.95*	*35.4*

Source: Author's calculations.
Notes: Based on the assumption of one 50-kilogram (kg) bag of milled maize per month for a family of four (two adult parents with one youth and one child), plus about 2 kg of unshelled groundnuts per month for the same family (based on an estimate of 25 kg per year, or 8.3 kg per adult equivalent; Derlagen and Phiri [2012] estimated it at about 4.7 kg per capita or about 19 kg per family of four). A conversion factor of 80 percent was used for milled maize.

Table C.2 Area allocations for base simulations by technology type

		No risk			*With risk*		
Crop/seed	Fertilizer (rate)	Lilongwe	Mchinji	Mzimba	Lilongwe	Mchinji	Mzimba
Beans							
s1	none	-	-	-	-	1.11	0.54
Groundnuts							
s1	none	1.35	1.57	0.64	0.56	0.69	0.37
Maize							
s2	1/2	-	-	-	0.56	-	-
s2	3/4	0.46	0.43	0.49	-	0.43	0.49
Maize-groundnuts							
s1	1	0.06	0.06	0.07	0.06	0.06	0.07
Soybeans							
s1	none	-	-	-	0.27	-	-
s2	none	-	0.37	0.42	0.58	-	-
Tobacco							
s2	1/4	0.16	-	-	-	0.14	0.14

Source: Model results (2016).
Notes: s1 = local recycled seeds; s2 = improved varieties.

Table C.3 Farm incomes and area allocations for all soybean simulations (with risk only)

Location	Lilongwe			Mchinji			Mzimba		
Simulation	*Base*	*SB1*	*SB2*	*Base*	*SB1*	*SB2*	*Base*	*SB1*	*SB2*
a) Farm income									
Mean (MK ,000)	258.8	250.4	276.1	357.2	362.4	387.7	196.6	196.6	201.1
S.D. (MK ,000)	98.0	86.1	104.9	119.9	123.8	140.8	56.8	56.8	60.3
b) Subsistence (ha)									
Maize	0.56	0.56	0.52	0.43	0.43	0.43	0.49	0.49	0.49
Maize-groundnuts	0.06	0.06	0.06	0.06	0.06	0.06	0.07	0.07	0.07
Groundnuts	-	-	-	-	-	-	-	-	-
c) Marketed (ha)									
Beans	-	-	-	1.11	1.00	0.95	0.54	0.54	0.56
Maize-groundnuts	-	-	-	-	-	-	-	-	-
Groundnuts	0.56	0.23	0.53	0.69	0.71	0.45	0.37	0.37	0.16
Soybeans	0.85	1.18	0.89	-	0.15	0.40	-	-	0.18
Tobacco	-	-	0.02	0.14	0.08	0.14	0.16	0.16	0.16
Total	*2.02*	*2.02*	*2.02*	*2.43*	*2.43*	*2.43*	*1.62*	*1.62*	*1.62*

With tobacco loan									
Location	Lilongwe			Mchinji			Mzimba		
Simulation	*SB3*	*SB4*	*SB5*	*SB3*	*SB4*	*SB5*	*SB3*	*SB4*	*SB5*
a) Farm income									
Mean (MK ,000)	*333.5*	*335.1*	*317.0*	*422.9*	*439.5*	*421.4*	*203.4*	*203.4*	*218.9*
S.D. (MK ,000)	*146.6*	*143.3*	*129.1*	*167.0*	*173.3*	*162.1*	*58.6*	*58.6*	*71.4*
b) Subsistence (ha)									
Maize	0.45	0.45	0.45	0.43	0.44	0.43	0.49	0.49	0.49
Maize-groundnuts	0.06	0.06	0.06	0.04	0.06	0.04	0.07	0.07	0.07
Groundnuts	-	-	-	-	-	-	-	-	-
c) Marketed (ha)									
Beans	0.04	-	-	0.91	0.33	1.05	0.72	0.72	0.62
Maize-groundnuts	-	-	-	-	-	-	0.05	0.05	-
Groundnuts	0.18	0.20	0.18	0.23	0.59	0.09	-	-	-
Soybeans	0.94	0.95	1.11	0.51	0.73	0.44	-	-	0.15
Tobacco	0.36	0.36	0.22	0.31	0.28	0.37	0.29	0.29	0.29
Total	*2.02*	*2.02*	*2.02*	*2.43*	*2.43*	*2.43*	*1.62*	*1.62*	*1.62*

Source: Model results (2016).
Notes: Simulations: base = current; SB1 = improved soybean market; SB2 = soybean loan package; SB3 = tobacco loan package; SB4 = tobacco loan package and improved soybean market; SB5 = tobacco loan package and soybean loan package. All values are in constant 2014 Malawian kwacha (MK).

Table C.4 Area allocations by technology type for all soybean simulations (with risk only)

		Lilongwe			Mchinji			Mzimba		
Crop/seed	Fertilizer (rate)	Base	SB1	SB2	Base	SB1	SB2	Base	SB1	SB2
Beans										
s1	none	-	-	-	1.11	1.00	0.95	0.54	0.54	0.56
Groundnuts										
s1	none	0.56	0.23	0.53	0.69	0.71	0.45	0.37	0.37	0.16
Maize										
s2	1/2	0.56	0.56	0.37	-	-	-	-	-	-
s2	3/4	-	-	0.15	0.43	0.43	0.43	0.49	0.49	0.49
Maize-groundnuts										
s1	1	0.06	0.06	0.06	0.06	0.06	0.06	0.07	0.07	0.07
Soybeans										
s1	none	0.27	0.60	-	-	-	-	-	-	-
s2	none	0.58	0.58	0.48	-	0.15	-	-	-	-
s3	none	-	-	0.40	-	-	0.40	-	-	0.18
Tobacco										
s2	1/4	-	-	0.02	0.14	0.08	0.14	0.14	0.08	0.14
With tobacco loan										
		Lilongwe			Mchinji			Mzimba		
Crop/seed	Fertilizer (rate)	SB3	SB4	SB5	SB3	SB4	SB5	SB3	SB4	SB5
Beans										
s1	none	0.04	-	-	0.91	0.33	1.05	0.72	0.72	-
s2	none	-	-	-	-	-	-	-	-	0.62
Groundnuts		-	-	-	-	-	-	-	-	-
s1	none	0.18	0.20	0.18	0.23	0.59	0.09	-	-	-
Maize										
s2	3/4	0.28	0.28	0.35	0.35	0.31	0.39	0.44	0.44	0.37
s3	3/4	0.17	0.17	0.10	0.08	0.13	0.04	0.05	0.05	0.12
Maize-groundnuts										
s1	1	0.06	0.06	0.06	-	0.06	-	0.12	0.12	0.07
s3	1	-	-	-	0.04	-	0.04	-	-	-
Soybeans										
s2	none	0.94	0.95	0.71	0.51	0.73	0.04	-	-	-
s3	none	-	-	0.40	-	-	0.40	-	-	0.15
Tobacco										
s2	1/4	-	-	0.01	0.06	-	0.20	0.06	-	0.20
s3	3/4	0.36	0.36	0.21	0.25	0.28	0.18	0.10	0.10	0.25

Source: Model results (2016).

Notes: s1 = local recycled seeds; s2 = improved varieties; s3 = improved varieties with loan package. Simulations: base = current; SB1 = improved soybean market; SB2 = soybean loan package; SB3 = tobacco loan package; SB4 = tobacco loan package and improved soybean market; SB5 = tobacco loan package and soybean loan package.

Table C.5 Returns to labor and land for all soybean simulations (with risk only)

Location	Lilongwe			Mchinji			Mzimba		
Simulation	*Base*	*SB1*	*SB2*	*Base*	*SB1*	*SB2*	*Base*	*SB1*	*SB2*
a) Labor (MK ,000/day)									
BN	-	-	-	1.83	1.83	1.83	1.57	1.57	1.57
GN	1.56	1.56	1.56	1.75	1.75	1.75	1.50	1.50	1.50
MZ	1.20	1.20	1.22	1.22	1.22	1.22	1.15	1.15	1.15
MZGN	1.89	1.89	1.89	1.95	1.95	1.95	1.75	1.75	1.75
SB	1.56	1.51	1.55	-	2.16	1.99	-	-	1.50
TB	-	-	1.68	1.71	1.71	1.71	1.23	1.23	1.23
Total	1.48	1.45	1.49	1.69	1.72	1.74	1.39	1.39	1.39
b) Land (MK ,000/ha)									
BN	-	-	-	143	143	143	119	119	119
GN	134	134	134	151	151	151	122	122	122
MZ	94	94	97	105	105	105	94	94	94
MZGN	193	193	193	198	198	198	169	169	169
SB	142	133	155	-	226	223	-	-	147
TB	-	-	253	273	273	273	192	192	192
Total	128	124	136	147	149	160	121	121	124
With TB loan									
Location	**Lilongwe**			**Mchinji**			**Mzimba**		
Simulation	***SB3***	***SB4***	***SB5***	***SB3***	***SB4***	***SB5***	***SB3***	***SB4***	***SB5***
a) Labor (MK ,000/day)									
BN	1.48	-	-	1.83	1.83	1.83	1.57	1.57	1.73
GN	1.56	1.56	1.56	1.75	1.75	1.75	-	-	-
MZ	1.24	1.24	1.25	1.18	1.17	1.19	1.14	1.14	1.13
MZGN	1.86	1.86	1.87	2.08	1.92	2.09	1.57	1.57	1.73
SB	1.64	1.64	1.56	2.16	2.16	2.00	-	-	1.50
TB	1.38	1.38	1.43	1.45	1.41	1.54	1.07	1.07	0.90
Total	1.49	1.49	1.49	1.71	1.73	1.69	1.30	1.30	1.29
b) Land (MK ,000/ha)									
BN	113	-	-	143	143	143	119	119	144
GN	134	134	134	151	151	151	-	-	-
MZ	105	105	105	101	100	102	93	93	92
MZGN	190	190	191	251	195	251	151	151	167
SB	158	158	155	226	226	223	-	-	148
TB	274	274	280	290	296	282	186	186	176
Total	165	166	157	174	181	174	126	126	135

Source: Model results (2016).
Notes: BN = beans, GN = groundnuts, MZ = maize, MZGN = maize-groundnut intercrop, SB = soybeans, and TB = tobacco. Wage rates in the model are 1.50, 1.45, and 1.40 for Lilongwe, Mchinji, and Mzimba, respectively (in MK ,000). See Table C.3 r definition of simulations SB1 though SB5.

Table C.6 Total production output, fertilizer used, and technology adoption for all soybean simulations (with risk only)

Location	Lilongwe			Mchinji			Mzimba		
Simulation	*Base*	*SB1*	*SB2*	*Base*	*SB1*	*SB2*	*Base*	*SB1*	*SB2*
Production output (kg)									
BN	0	0	0	419	377	359	184	184	191
GN	510	234	489	637	654	424	303	303	153
MZ	1,063	1,063	1,063	1,063	1,063	1,063	1,063	1,063	1,063
SB	676	849	815	0	159	442	0	0	144
TB	0	0	11	102	62	102	112	112	112
Fertilizer used (kg)									
MZ	12	12	12	12	12	12	14	14	14
TB	0	0	1	7	4	7	8	8	8
Total	12	12	13	19	16	19	22	22	22
Adoption rates by technology type (% of area)									
Local seed and fertilizer.	3%	3%	3%	2%	2%	2%	4%	4%	4%
Imp. seed only	29%	29%	44%	0%	6%	17%	0%	0%	11%
Imp. seed and fertilizer	27%	27%	27%	23%	21%	23%	40%	40%	40%
Loan package*	0%	0%	0%	0%	0%	0%	0%	0%	0%
Total	59%	59%	74%	26%	30%	43%	44%	44%	56%
With TB loan									
Location	Lilongwe			Mchinji			Mzimba		
Simulation	*SB3*	*SB4*	*SB5*	*SB3*	*SB4*	*SB5*	*SB3*	*SB4*	*SB5*
Production output (kg)									
BN	13	0	0	343	125	399	244	244	302
GN	186	205	191	236	551	115	62	62	35
MZ	1,063	1,063	1,063	1,063	1,063	1,063	1,119	1,119	1,063
SB	864	872	1018	554	801	480	0	0	118
TB	376	382	225	329	315	345	246	246	297
Fertilizer used (kg)									
MZ	12	12	12	8	12	8	24	24	14
TB	54	55	32	41	41	36	25	25	39
Total	66	67	44	49	53	44	49	49	53
Adoption rates by technology type (% of area)									
Local seed and fertilizer	3%	3%	3%	0%	2%	0%	7%	7%	4%
Imp. seed only	47%	47%	55%	21%	30%	18%	0%	0%	47%
Imp. seed and fertilizer	14%	14%	18%	17%	13%	24%	39%	39%	26%
Loan package *	26%	27%	15%	15%	17%	11%	9%	9%	23%
Total	89%	90%	91%	53%	62%	53%	56%	56%	100%

Source: Model results (2016).

Notes: BN = beans, GN = groundnuts, MZ = maize, MZGN = maize-groundnut intercrop, SB = soybeans, and TB = tobacco. Simulations: base = current; SB1 = improved SB market; SB2 = SB loan package; SB3 = TB loan package; SB4 = TB loan package and improved SB market; SB5 = TB loan package and SB loan package. * Loan package involves both improved seed and fertilizer application at three-quarters or full rates.

Table C.7 Farm incomes and area allocations for all maize simulations (with risk only)

Location	Lilongwe				Mchinji				Mzimba			
Simulation	*Base*	MZ1	MZ2	MZ3	*Base*	MZ1	MZ2	MZ3	*Base*	MZ1	MZ2	MZ3
a) Farm income												
Mean *(MK ,000)*	258.8	189.3	186.1	338.3	357.2	264.8	264.0	469.5	196.6	102.1	100.4	250.3
S.D. *(MK ,000)*	98.0	77.1	76.0	102.1	119.9	98.1	97.1	157.9	56.8	35.6	35.3	54.8
b) Subsistence crop (ha)												
MZ	0.56	1.32	1.29	-	0.43	1.40	1.26	-	0.49	1.21	1.17	-
MZGN	0.06	0.06	0.06	-	0.06	0.06	0.06	-	0.07	0.07	0.07	-
GN	-	-	-	0.04	-	-	-	0.04	-	-	-	-
c) Marketed crop (ha)												
BN	-	-	-	-	1.11	0.45	0.17	0.20	0.54	0.23	0.14	0.61
MZGN	-	-	0.07	0.57	-	-	0.59	1.22	-	-	0.16	0.53
GN	0.56	-	-	-	0.69	-	-	-	0.37	-	-	-
SB	0.85	0.48	0.44	1.18	-	0.28	0.19	0.55	-	-	-	-
TB	-	0.16	0.15	0.23	0.14	0.24	0.16	0.42	0.16	0.11	0.07	0.47
Total	*2.02*	*2.02*	*2.02*	*2.02*	*2.42*	*2.43*	*2.43*	*2.43*	*1.62*	*1.62*	*1.62*	*1.62*

Source: Model results (2016).
Notes: All values are in constant 2014 Malawian kwacha (MK). BN = beans, GN = groundnuts, MZ = maize, MZGN = maize-groundnut intercrop, SB = soybeans, S.D = standard deviation, and TB = tobacco. Simulations: base = current with fertilizer subsidy and consumption constraint (as in Figure 3.4); MZ1 = still with consumption constraint but fertilizer subsidy removed; MZ2 = same as MZ1, but market prices for maize increased by 20 percent; MZ3 = same as MZ2, but now consumption constraint removed. The price increases under MZ2 and MZ3 include a reduced marketing margin of 50 percent between the farmgate and market prices. Market prices were increased to a level such that they were just sufficient to bring maize into the solution for any of the three locations (whether as an intercrop with groundnuts or as a sole crop). This turned out to be a 20 percent increase—and mostly affected Mchinji and Mzimba.

Table C.8 Area allocations by technology type for all maize simulations (with risk only)

		Lilongwe				Mchinji				Mzimba			
Crop/seed	Fertilizer (rate)	Base	MZ1	MZ2	MZ3	Base	MZ1	MZ2	MZ3	Base	MZ1	MZ2	MZ3
Beans													
s1	none	-	-	-	-	1.11	0.45	0.17	0.20	0.54	0.23	0.14	-
s2	none	-	-	-	-	-	-	-	-	-	-	-	0.61
Groundnuts													
s1	none	0.56	-	-	0.04	0.69	-	-	0.04	0.37	-	-	-
Maize													
s2	none	-	1.24	1.17	-	-	1.40	1.10	-	-	0.78	0.68	-
s2	1/4	-	0.08	0.12	-	-	-	0.17	-	-	0.43	0.49	-
s2	1/2	0.56	-	-	-	-	-	-	-	-	-	-	-
s2	3/4	-	-	-	-	0.43	-	-	-	0.49	-	-	-
Maize-groundnuts													
s1	none	-	0.06	0.14	0.57	-	0.06	0.65	1.22	-	0.07	0.23	0.53
s1	1	0.06	-	-	-	0.06	-	-	-	0.07	-	-	-
Soybeans													
s1	none	0.27	-	-	-	-	-	-	-	-	-	-	-
s2	none	0.58	0.48	0.44	1.18	-	0.28	0.19	0.55	-	-	-	-
Tobacco													
s2	1/4	-	0.16	0.15	0.23	0.14	0.24	0.16	0.42	0.14	0.24	0.16	0.42

Source: Model results (2016).
Notes: s1 = local recycled seeds; s2 = improved varieties; See Table C.7 for definitions of simulations base, MZ1, MZ2, and MZ3.

Table C.9 Returns to labor and land for all maize simulations (with risk only)

Location	Lilongwe				Mchinji				Mzimba			
Simulation	*Base*	MZ1	MZ2	MZ3	*Base*	MZ1	MZ2	MZ3	*Base*	MZ1	MZ2	MZ3
a) Labor (MK ,000/day)												
BN	-	-	-	-	1.83	1.83	1.83	1.83	1.57	1.57	1.57	1.73
GN	1.56	-	-	1.95	1.75	-	-	2.19	1.50	-	-	-
MZ	1.20	0.78	0.72	-	1.22	0.74	0.65	-	1.15	0.59	0.53	-
MZGN	1.89	1.61	1.65	1.74	1.95	1.71	1.83	1.85	1.75	1.49	1.55	1.61
SB	1.56	1.64	1.64	1.64	-	2.16	2.16	2.16	-	-	-	-
TB	-	1.68	1.68	1.68	1.71	1.71	1.71	1.71	1.23	1.23	1.23	1.23
Total	1.48	1.20	1.18	1.67	1.69	1.37	1.37	1.89	1.39	0.87	0.87	1.48
b) Land (MK ,000/ha)												
BN	-	-	-	-	143	143	143	143	119	119	119	144
GN	134	-	-	167	151	-	-	189	122	-	-	-
MZ	94	48	45	-	105	45	41	-	94	38	34	-
MZGN	193	139	143	151	198	148	158	159	169	123	128	133
SB	142	158	158	158	-	226	226	226	-	-	-	-
TB	-	253	253	253	273	273	273	273	192	192	192	192
Total	128	94	92	167	147	109	109	193	121	63	62	155

Source: Model results (2016).
Notes: BN = beans, GN = groundnuts, MZ = maize, MZGN = maize-groundnut intercrop, SB = soybeans, and TB = tobacco. Simulations: base = current with fertilizer subsidy and consumption constraint (as in Figure 3.4); MZ1 = still with consumption constraint but fertilizer subsidy removed; MZ2 = same as MZ1, but market prices for maize increased by 20 percent; MZ3 = same as MZ2, but now consumption constraint removed. All values are in constant 2014 Malawian kwacha (MK).

Table C.10 Total production output, fertilizer used, and technology adoption for all maize simulations (with risk only)

Location	Lilongwe				Mchinji				Mzimba			
Simulation	*Base*	MZ1	MZ2	MZ3	*Base*	MZ1	MZ2	MZ3	*Base*	MZ1	MZ2	MZ3
a) Production output (kg)												
BN	0	0	0	0	419	169	63	75	184	77	49	299
GN	510	35	77	354	637	35	371	733	303	35	114	258
MZ	1,063	1,063	1,088	198	1,063	1,063	1,228	345	1,063	1,063	1,106	144
SB	676	437	408	1,081	0	308	204	602	0	0	0	0
TB	0	110	101	158	102	175	120	310	112	77	50	340
b) Fertilizer use (kg)												
MZ	12	0	0	0	12	0	0	0	14	0	0	0
TB	0	8	7	12	7	12	8	21	8	5	3	24
Total	12	8	7	12	19	12	8	21	22	5	3	24
c) Technology adoption rates (% of area)												
Local seed and fertilizer	3%	0%	0%	0%	2%	0%	0%	0%	4%	0%	0%	0%
Imp. seed only	29%	85%	80%	58%	0%	69%	53%	23%	0%	48%	42%	38%
Imp. seed and fertilizer	27%	12%	13%	12%	23%	10%	14%	17%	40%	33%	35%	29%
Loan package*	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Total	59%	97%	93%	70%	26%	79%	66%	40%	44%	82%	77%	67%

Source: Model results (2016).
Notes: BN = beans, GN = groundnuts, MZ = maize, MZGN = maize-groundnut intercrop, SB = soybeans, and TB = tobacco. Simulations: base = current with fertilizer subsidy and consumption constraint (as in Figure 3.4); MZ1 = still with consumption constraint but fertilizer subsidy removed; MZ2 = same as MZ1, but market prices for maize increased by 20 percent; MZ3 = same as MZ2, but now consumption constraint removed.

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