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Effects of the Farm Input Subsidy Program on Maize: Identifying Maize Supply and Demand Elasticities in Malawi

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Effects of the farm input subsidy program on maize: identifying maize supply and demand elasticities in Malawi

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While Malawi's Farm Input Subsidy Program (FISP) has been the focus of numerous studies on the impacts of subsidies on farm-household income, yields, fertilizer use and adoption, there still has not been much empirical work quantifying the program's effects on maize supply and demand. In this study, we use the econometric framework proposed by Roberts and Schlenker (2013) to identify the effect of FISP on maize production as well as supply and demand price elasticities in Malawi. We use national aggregate data and find that the program has increased aggregate maize supply. Our results show that FISP has had an aggregate effect across years of about 3,746,870 metric tons from 2006-2013. We also find that the program has increased farmers' responsiveness to changes in fertilizer prices. However, our estimates suggest that higher prices lead to higher quantities of fertilizer demanded, a relationship that is not consistent with economic theory.

Key Words: Malawi FISP, Maize Supply and Demand, Elasticities

DEDICATION

I would like to dedicate this research to my late father, Mr. Charles Nindi and to my mother; Mrs. Grace Nindi and my siblings, Chimwemwe, Tionge and Charles Jr.

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CHAPTER I

INTRODUCTION

This chapter presents an overview of the research study. The chapter highlights the importance of maize in Malawi, the background of the Farm Input Subsidy Program, problem statement, justification, objectives, and organization of the study.

The Importance of Maize in Malawi

Malawi is a landlocked tropical country with a population of over 14 million. Its economy is greatly dependent on agriculture, which employs nearly eighty percent of the national labor force (Malawi Government, 2009). Maize is one of the important crops grown in the country in addition to tobacco, tea, cotton, coffee and sugar. Maize is a staple food crop that accounts for about fifty four percent of the daily caloric intake (FEWSNET, 2009). The crop is largely grown for subsistence by smallholder farmers, who comprise over eighty percent of the agricultural population. At the household level, the dynamics of the maize market in Malawi are very complicated as a majority of households are both producers and consumers of maize. Over sixty percent of these households are net buyers of maize as they are unable to produce enough for subsistence. As such, these households devote a substantial percentage of their incomes to buying maize (Mapila et al., 2013).

Almost all maize produced in the country is cultivated during the single rainy season from December to June. This, however, is subject to rainfall variability which can be particularly damaging when short dry spells occur during critical growth stages. Intensive cultivation by smallholders in the absence of significant fertilizer use has depleted soils of nutrients, mainly nitrogen. As such, there is generally low agricultural productivity in Malawi with national maize yields averaging about 1.6 metric tons per hectare (t/ha) over the last 20 years. This is about 17 percent of the average yields of rain-fed maize in Iowa in the United States (1994–2014)[1]. A majority of farming households in Malawi operate below subsistence with only about twenty percent of farmers producing a surplus (Mapila et al., 2013). Thus, maize availability and prices are crucial determinants of food security in Malawi.

Background of the Farm Input Subsidy Program in Malawi

Over the years, prices of major agricultural inputs like fertilizers and seeds have increased significantly while smallholder farmers' incomes have remained low. Credit opportunities for farmers in Malawi are generally very limited due to the high risk associated with agricultural production. As such, smallholder farmers in the country have a history of low usage of improved inputs such as hybrid seed, fertilizers, and pesticides. This is considered to be one of the major factors contributing to low agricultural productivity (Harrigan, 2005). In response to this, the government introduced the subsidy

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[1] Based on data from FAOSTAT and Iowa Office of USDA National Agricultural Statistics Service.

program with an intention of increasing smallholder farmers' access to, and use of, inorganic fertilizers and improved seed[2]. This program is expected to boost agricultural production as it intends to remedy the weak demand for these inputs.

Over the last decade, most developing countries in Africa have been implementing extensive agricultural subsidy programs targeting staple food crops like maize. One alleged benefit of subsidies, though not empirically verified in Malawi, is that by increasing farmers' usage of inputs, subsidies should increase production. This is expected to reduce prices for the advantage of consumers, especially poor households who are usually net buyers of maize (Lunduka et al., 2013). In the 1970's and 80's, the government engaged in general price subsidies together with subsidized credits in an effort to increase production of food crops. These subsidies targeted smallholder farmers who comprise the majority of the agricultural population. During this period, the majority of the population achieved self-sufficiency in maize, the country's main staple. As such, cases of food insecurity and malnutrition declined. However, the country's major development partners recommended elimination of these subsidies in the early 1990's through what was called the Structural Adjustment Programs (SAPs). According to Denning et al. (2009), the removal of subsidies in Malawi instigated a series of severe food crises in the 1990's.

In the last ten years, the government of Malawi has reintroduced subsidies with the purpose of increasing maize production, promoting household food security, reducing food prices, and enhancing rural incomes (Malawi Government, 2009). These subsidies

[2] Hybrid varieties and open pollinated varieties (OPV).

started with the Starter Pack Scheme (SPS) in 1998, through which every smallholder farmer[3] in the country was entitled to a free package containing sufficient fertilizer, hybrid maize seed, and legume seed to plant about 0.1 hectare of land. The purpose of this program was to increase agricultural productivity and improve soil fertility. This program was considered the mainstream of the Malawi Poverty Reduction Strategy (MPRS) intended to reverse some of the negative effects of the SAPs. However, the program was not sustained because it faced major problems including high operation costs and poor targeting.

In 2002, the government reformed SPS and renamed it the Targeted Inputs Program (TIP). Through this program, the government dropped the universal subsidy and reduced the number of beneficiaries (Harrigan, 2003; Levy, 2005). Similar to the SPS, TIP continued to offer hybrid maize seed, legume seed, and inorganic fertilizer to recipient households. The intention of the program was to enable beneficiary households to plant at least 0.5 hectares of maize.

Following dry spells that resulted in a poor harvest in the 2004/05 growing season, the government in the 2005/06 financial year decided to greatly increase the scale of its targeted input subsidy program for farmers. This was achieved through a new program called Agricultural Input Subsidy Program (AISP). This program was later renamed the Farm Input Subsidy Program (FISP). One of the key objectives of this program was to increase food production and ensure food security at the household and national level (Malawi Government, 2009; Mason and Ricker-Gilbert, 2012).

[3] Smallholder farmers comprise close to 80 percent of the population in Malawi.

The FISP has been, and still is, administered using a series of coupons that enable households to purchase inputs at greatly reduced prices (Dorward and Chirwa, 2009). Initially, this program was focused on maize and tobacco but due to concerns about promoting diversification, improving soil fertility, and human nutrition, the focus of the program later switched to maize and legumes. Other important food crops such as rice, sorghum, cassava, Irish potatoes, and sweet potatoes are, however, not included in the program. In terms of fertilizers, the program provides basal and top dressing fertilizers which mostly include nitrogen fertilizers like Urea, Calcium Ammonium Nitrate (CAN) and Nitrogen Phosphorus and Potassium (NPK) fertilizers such a 23:21:0+4S. As for seeds, hybrid varieties and open pollinated varieties of maize and legumes are also provided through the program. Since 2008, smallholder farmers have also been able to access subsidized pesticides to reduce post-harvest losses (Chirwa and Dorward, 2012).

The main criteria for identification of FISP beneficiaries are: (1) that the household must own land that could be cultivated during the relevant season; (2) that only one beneficiary should be eligible per household; and (3) that vulnerable groups, especially households headed by children, women, and the elderly should be given priority since they are usually resource constrained. The Ministry of Agriculture and Food Security (MoAFS) is responsible for identification of beneficiaries and distribution of FISP coupons. The process of selecting beneficiaries is facilitated by district agricultural offices with the support of local traditional authorities (TAs) and village heads, in collaboration with Village Development Committees (VDCs) (Doward et al., 2008).

Problem Statement

While most of the previous studies have focused on estimating various socioeconomic impacts[4] of FISP; not much has been done to uncover the effects of the FISP on national maize supply and demand. As such, this study advances literature on FISP by empirically quantifying the effects of the FISP on aggregate maize production and farmers' responsiveness to input prices. Malawi's FISP targets food crops including maize which is a key staple food in the country. Over 80 percent of the population in Malawi depends on grain crops like maize for their food. As such, significant changes in the production and prices of maize substantially affects food security in the country. Other important food crops[5] involved in the program include legumes such as soybeans and groundnuts. This study uses a framework that intends to empirically estimate both supply and demand elasticities for maize.

Justification of Study

Some previous studies on Malawi's FISP have shown that the program has influenced farmers' decisions to simplify their cropping patterns. For example, Chibwana et al. (2012) used farm–level data from two districts in the central region and found that households that received FISP coupons allocated 16 percent more land to maize than

[4] Like impact on inorganic fertilizer use and yield, household land allocation, household income and adoption of improved seed

[5] It is, however, important to note that the FISP excludes other important crops like rice, cassava and common beans. Rice and cassava are mostly consumed as a main food like maize and common beans as complements just like groundnuts and soybeans.

those who do not. These authors also found that the increased share of household's farmland allocated to maize occurred at the expense of other crops such as legumes, cassava, and sweet potato. It can, therefore, be implied that maize output has likely increased as a result of a shift toward maize. Similar findings are also reported by Chibwana et al. (2010).

On the contrary, other studies have reported that higher maize yields achieved under the program have encouraged farmers to diversify into other crops. For example, Holden and Lunduka (2010) using panel data for 2006, 2007, and 2009, reported that the total maize area among their sampled households had decreased from 0.73 in 2006 to 0.64 in 2009. These authors did not directly show that FISP caused maize area to decrease, but their analysis provided descriptive evidence suggesting that when FISP was scaled up, maize intensification might have facilitated crop diversification by releasing some maize areas. These results correlate with findings by Kankwamba, Mapila and Pauw (2012) who reported that FISP beneficiaries have a higher crop diversification index.

These studies provide interesting, yet contradictory, evidence on whether the program has caused a shift towards maize. Of course, the variation in the findings from these studies could be the result of the studies' differences in contexts (study areas), methods (different dependent variables), and data types (panel vs. cross sectional data). However, this still raises some questions on how the program has actually affected cropping patterns at the national level and its implications on aggregate maize supply in Malawi.

In addition, while national production estimates from the Ministry of Agriculture and Food Security (MoAFS) suggests dramatic increases in maize production and productivity, numerous studies using farm-level data suggest that there have been relatively modest increases in maize production and yields under FISP (Ricker-Gilbert and Jayne, 2011; Chibwana et al., 2010; Holden and Lunduka, 2010). Consistent with findings from these studies, the country has imported maize during many of the FISP years (FEWSNET, 2013). This also raises some questions on exactly how much the program has affected maize supply. Thus, there exists a need to further quantify the effects of the program on maize supply at the national level.

A vast majority of past studies quantifying the impacts of FISP on maize production have used household or farm-level data (see, Chibwana et al., 2014; Ricker-Gilbert and Jayne, 2012; Holden and Lunduka, 2012; Mason, 2011; Ricker-Gilbert and Jayne, 2011; Denning et al., 2009; Dorward and Chirwa, 2009 and Dorward et al., 2008). According to Arndt et al. (2014), the use of household surveys to evaluate government programs generally overlooks economy-wide program design elements. These elements include spillovers, scaling and macroeconomic effects, and risk factors such as weather and world price shocks which can be important, particularly for large-scale programs. Arndt et al. (2014) further points out that this is pertinent to Malawi's Farm Input Subsidy Program, which is a large-scale and costly program exposed to droughts and world prices.

Empirical assessment of the effects of FISP[6] on maize supply and demand elasticities using national level data is, therefore, very important. This is useful in understanding how maize[7] farmers respond to changes in output and input prices. In addition, this provides useful evidence towards understanding the behavior of farmers and the performance of agricultural sectors, in general with regard to agricultural policy. This study, thus, advances the literature on FISP by quantifying the effects of the FISP on maize through identification of maize supply and demand elasticities.

Objectives of Study

The underlying objective of this study is to empirically estimate maize supply and demand elasticities in Malawi and specifically to:

i. Estimate effects of FISP on aggregate maize supply.

ii. Estimate effects of FISP on maize input price elasticity of supply.

In order to achieve objectives (i) and (ii), an econometric framework proposed by Roberts and Schlenker (2013) that utilizes systems of equations estimators is used. This approach uses past and present yield shocks to identify supply and demand elasticities.

[6] Not all farmers benefit from the program as it targets productive but resource poor households and less privileged households like those headed by children and the elderly.

[7] Maize is a key crop in Malawi and with over 90 percent of the households growing it.

Outline of Study

The outline of the remainder if this document is as follows. Chapter two provides a review of literature and describes commonly employed empirical methods for estimating supply and demand. Chapter three presents the conceptual framework of the study. Chapter four describes the data and methods used to construct some key variables used in the study. Chapter five discusses the empirical results and chapter six concludes.

CHAPTER II

LITERATURE REVIEW

This chapter provides a general overview of past research on the impacts of FISP in Malawi. In the first section of the chapter, we review past studies on FISP focusing on the output measured, the data, and the empirical methods used. The second section of this chapter reviews some popular empirical methods used to estimate supply and demand and their drawbacks. Finally, the last part of the chapter introduces the model used in this study.

Past Studies on FISP in Malawi

The Government of Malawi has been implementing smaller input subsidy programs since the late 1990's. However, since 2006 close to fifty percent of the smallholder farmers in the country are provided with much larger packs of inputs at subsidized prices through the Farm Input Subsidy Program. The program is still being implemented in the country despite the controversy it attracted from both supporters (Dugger, 2007) and critics (The Economist, 2008). A number of countries in Africa, including Zambia and Kenya, have recently also started implementing subsidy programs with the aim of achieving greater food security. However, there is significant concern among development analysts and policy makers worldwide about the effects and costs of subsidies in general. As such, Malawi's FISP has been the center of a wide range of studies, with varying scope, objectives, data sources, empirical methods, and approaches. Chirwa and Doward (2013) argue that findings from most studies ought to be taken with caution as advocates, supporters, and critics of the program often draw on contradictory evidence to support their position.

For instance, there is a growing literature that quantifies the impacts of input subsidy programs on various socioeconomic aspects in Malawi (see, for example, Arndt et al., 2014; Chibwana et al., 2014; Fisher and Kandiwa, 2013; Chibwana et al., 2012; Holden and Lunduka, 2012; Ricker-Gilbert and Jayne, 2012; Chibwana et al., 2011; Ricker-Gilbert and Jayne, 2011; Ricker-Gilbert et al., 2011; Chirwa et al., 2011; Chirwa, 2010; and Denning et al., 2009). Of particular interest to this research study, however, are the studies that attempted to measure the impacts of subsidies on maize production, yields, and maize input demand (Chibwana et al., 2014; Ricker-Gilbert and Jayne, 2012; Holden and Lunduka, 2012; Mason, 2011; Ricker-Gilbert and Jayne, 2011).

Chibwana et al. (2014) used cross-sectional data from the 2008/2009 growing season to estimate the impacts of FISP on maize yields. The authors used a sample of 380 households from Kasungu district in the central region and Machinga district in the southern region. Using a series of two-stage instrumental variables regressions, the authors found that maize yields are positively associated with receipt of FISP coupons. Findings from their study may imply that there is a likely increase in maize supply in Malawi as result of increased maize yields[8]. This suggests that FISP has positively affected maize supply, *ceteris paribus.* However, extrapolating the results of this study to

[8] Maize supply is a function of maize yields (Nerlove, 1956; Nerlove, 1958).

the national level is difficult as it used farm-level data from just two[9] of the 28 districts in the country. In addition, the study used cross-sectional data for a single year (2009) despite the fact that the program has been in place for over eight years. As such, further research using aggregate data at the national level over a long time period to evaluate program impacts is warranted.

A study by Holden and Lunduka (2012) evaluated the impact of FISP on a number of aspects including maize production and food security using panel data for the years 2005/06, 2006/07 and 2008/09. This study collected data from 450 households covering two districts in central Malawi (Kasungu and Lilongwe) and four districts in southern Malawi (Chiradzulu, Machinga, Thyolo, and Zomba). Using ordered probit models and OLS to empirically estimate the impacts of FISP, the authors found that FISP has enhanced maize production and food security[10]. It is important to note, however, that similar to most previous quantitative studies on FISP, this study also used plot-level data to evaluate the impact of FISP. Much as this approach is plausible for generating reliable primary level data, there is a possibility that using such an approach may have overlooked some economy wide aspects that the subsidy program may be exposed to like droughts and world fertilizer prices.

Ricker-Gilbert and Jayne (2012) also estimated the impacts of FISP on maize production and the value of crop output using panel data for the years 2003/04, 2006/07

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[9] There is not much to support whether the data from these selected districts is representative.

[10] Further findings from this study showed that the programs does not really target the productive poor.

and 2008/09. Their study used a sample of 2,968 households from across the country. Quantile regression involving correlated random effects with a control function were used in the analysis. This study found that FISP had positive impacts on production with higher returns only for those at the top of the production distribution. Findings from this study suggest that the program only has a positive impact on maize production for a certain category of households. This study further suggests that negligible effects on production would be realized if the program targets unproductive[11] poor households. Findings from this study also showed that targeting resource rich farmers, who use FISP to replace their purchase of commercial fertilizer, would crowd-out the program's ability to boost production. These authors, thus, point-out that the FISP would only be able to boost production if productive but resource poor farmers are targeted. However, Malawi's FISP has serious targeting issues since beneficiaries are usually not the productive poor. Based on findings from this study, it is evidently challenging to get a clear picture on the direction and magnitude of the effects of FISP on aggregate maize production in the country. Besides, the panel data used in the study was compiled from different cross-sectional data sources with less than 20 percent attrition. As such, using time series data to further investigate the impacts of the program on aggregate maize production in Malawi is necessary.

Richer-Gilbert and Jayne (2011) also use farm-level data to assess the impacts of the program on maize production and the net value of crop production. In this study, the authors used first differences estimation with a control function and found that subsidized

[11] Those without cultivatable land and labor.

fertilizer has small positive effects on maize production. However, this study may also have overlooked some external factors like droughts and world prices, which could also affect FISP and the economy at large. Besides, estimates from their study are prone to suffer from the incidental parameters problem as they used many cross-sectional observations with very few time periods (Wooldridge, 2010). Clearly, there is still need to quantify the effects of FISP on aggregate maize supply in the country by using data that covers a longer time horizon.

On the demand side, it is also important to note that majority of past efforts that evaluated the effects of subsidies on input demand have mostly focused on determining the program's displacement effects on purchase of commercial inputs like fertilizer and seed (Mason and Ricker-Gilbert, 2012; Mason, 2011; Ricker–Gilbert et al., 2011; Ricker-Gilbert and Jayne, 2009; Xu et al., 2009). These studies generally report that the total input use increased after the advent of subsidy programs with subsidized inputs, however, displacing a certain proportion of commercial inputs. This is evident in that the increase in input usage is less than the amount of subsidized inputs distributed. So far relatively little attention has been paid to evaluate effects of the programs on farmers' responsiveness to changes in input prices. Ricker-Gilbert and Jayne (2009) in their study that evaluated the effects of FISP on fertilizer demand found that the existence of subsidies has made farmers who decide to participate in the commercial fertilizer market more likely to pay attention to input and output prices. Their study, however, does not provide the magnitude of the responsiveness of the farmers in terms of elasticities. By focusing on the effects of FISP on input price elasticities of supply, our study broadens the literature on the impacts of input subsidies in Malawi.

Popular Empirical Frameworks for Estimating Demand and Supply

Policy makers and analysts have always been interested in understanding how demand and supply responds to changes in various parameters in the economy. For a long time economists have been estimating supply and demand elasticities to determine such effects. Colman (1983) categorized methods of estimating supply response into four categories: programming or simulations models, two-stage estimation procedures, direct supply estimation functions, and direct partial supply models.

Programing or simulation models are numeric techniques that use built-in linear models that simulate production systems while taking into account randomness and interdependence that characterizes agricultural production. These models are often used to project possible supply response to various changes that affect agricultural production. The use of these approaches is often applied when there is need to predict future possible supply responses to policy or price changes. Some of the past studies that used this approach to estimate supply response include Wicks et al. (1978) and Jaeger (2004).

Two-stage estimation procedures are techniques that utilize the dual relationships within the neoclassical theory of firms. Typically, the Hoteling–Shepherd lemma is used to derive demand and supply functions. The dual relationships present a direct equivalence connecting production, cost, and profit functions. Studies that used this approach to estimate supply response include Huffman and Evenson (1989) and Arnade and Kelch (2007). The issue, however, with this approach is the choice of the functional form which has to be justifiable and done with care.

Another approach that Colman identifies as a procedure for estimating supply response includes the use of the neoclassical theory of the firm to directly estimate supply functions. This is based on the assumption that there is a fixed amount of resources within a given production period, which is then used to derive the agricultural production possibility frontier. This approach originates from the Constant Elasticity Transformation (CET) models developed by Powell and Gruen (1968). The drawback for this approach, however, is that the procedure tends to impose restrictions based on theory. This often times tends to be a simplification of reality. A study by Vincent et al. (1980) presents a good example of this approach.

Lastly, using the directly estimated partial commodity supply models, supply response at an aggregate level can also be estimated without applying profit maximization restrictions. This approach uses time series or pooled data which usually comprises a series of quantities supplied in the past. Such data is used to statistically explain the quantities supplied using a set of independent variables chosen on the basis of economic theory and knowledge of technical conditions of production. This procedure includes the widely used Nerlovian supply models which incorporate price expectation and output adjustment variables into the supply function to account for factors that affect agricultural supply. These factors include (i) inability to instantly adjust production to desired level and (ii) production time lag that poses price risk. Conclusions from studies that have used these approaches have significantly impacted the existing literature. The supply response models by Nerlove, for example, have been adopted by many researchers including some recent studies by Lunchansky and Monks (2009) and Richards (2012).

For consumer demand, however, the literature is filled with studies in which numerous models and estimation techniques of demand functions are applied. The two most commonly adopted models, particularly for studies focusing on demand for agricultural commodities, are (i) the Rotterdam model introduced by Theil (1965) and Barten (1969) and (ii) Deaton and Muelbauer's (1980) Almost Ideal Demand System (AIDS). All of these models are derived from consumer theory, and are used to impose or investigate behavioral restrictions that are inferred from theory. There are many versions of the AIDS model but one popular modification of this model is the LA/AIDS model. Some of the studies that applied the AIDS model include Tridimas (2000), Abdullah (1994) and Baharumshah (1993).

Simultaneous estimation of supply and demand elasticities is now very popular in economics. This started in the early 1920s, with Sewall Wright who developed "causal path analysis," a method-of moments-type technique for estimating recursive structural models and simultaneous equations. Applying this method to estimate supply and demand elasticities had always been challenging because of the identification problem. However, Wright (1928)[12] confronted this issue through the application of instrumental variables in estimating the elasticities of supply and demand for flaxseed. Wright points out that using the relationship between price and quantity alone was the source of the identification problem since price is endogenous. He suggested that instrumental variables can be used to solve the problem. Using instrumental variables to solve identification and endogeneity problems has, thus, been applied in various studies (see Chibwana et al., 2014; Robert and Schlenker, 2013; Angrist and Krueger, 2001).

In this paper, we adopt a framework by Roberts and Schlenker (2013) to estimate supply and demand elasticities. Data on maize production, consumption, inventories, and

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[12] Sewall Wright's father

prices are used to estimate maize demand and supply elasticities. Fertilizer prices are also used to evaluate whether FISP affected input price elasticities on the supply side. This approach extends previous methods by utilizing current and past yield shocks to identify the supply and demand equations.

CHAPTER III

CONCEPTUAL FRAMEWORK

This chapter explains the theoretical model upon which this study has been based. It also reports the empirical econometric framework that is used to estimate the supply and demand model.

Theoretical Model of Producer Behavior

We assume that maize producers maximize profit over four key inputs labor (*l*), land (*k*), fertilizer (*w*), and seed (*s*) given the production function *f(l,k,w,s)*:

$$\underset{l,k,w,s}{\text{Max}}\ \pi = pf(l,k,w,s) - v_l l - v_k k - v_w w - v_s s \tag{1}$$

Here, *p* is price of maize and *v* is used to represent the price of the various inputs. The first order conditions are then:

$$pf_l{}'(l,k,s,w) = v_l \tag{2}$$

$$pf_k{}'(l,k,s,w) = v_k \tag{3}$$

$$pf_w{}'(l,k,s,w) = v_w \tag{4}$$

$$pf_s{}'(l,k,s,w) = v_s \tag{5}$$

These equate marginal value product and marginal cost for each of the inputs. The general form for the optimal input demands are then:

$$l^*(p, v_l, v_k, v_s v_w) \qquad k^*(p, v_l, v_k, v_s v_w)$$

$$s^*(p, v_l, v_k, v_s v_w) \qquad w^*(p, v_l, v_k, v_s v_w)$$

Under this approach, the optimal firm-level supply of maize defined by:

$$y^* = f(l^*, k^*, s^*, w^*) \tag{6}$$

can be expressed in reduced form as a function of prices:

$$y^* = g(\, p, v_l, v_k, v_s v_w) \tag{7}$$

Considering that optimal maize input demand and maize supply are both functions of input prices and maize prices; we, therefore, focus on prices in this study in order to model maize supply. It is important to point out that in this study we focus on fertilizer because unlike prices of other inputs[13] like land, labor or seed, fertilizer prices really matter to most smallholder farmers in Malawi.

Econometric Supply and Demand Model

In order to estimate maize demand and supply elasticities, we adopt the econometric framework of Roberts and Schlenker (2013). This approach utilizes Three

[13] Majority of smallholders cultivate on customary land, using family labor and recycled seed from previous harvest. As such, prices of these factors of production may not be very important.

Stage Least Squares (3SLS), which accounts for endogenous prices and correlation across the supply and demand equations. According to Gujarati (2003), instrumental variables approaches – such as 3SLS - provide consistent estimates in the presence of simultaneity, a key concern for supply and demand analysis. .

Maize quantity supplied (q_t^s) is considered to be the amount of maize available in a given year. Producers make decisions at planting based on expected prices (ep_t). We also include a time trend to capture changes in technology over time and a dummy variable (z_t) for FISP taking on a value of one for the period after the program was introduced and a value of zero for the period before the program was introduced (i.e.1 if $t \geq 2006$ and 0 if $t < 2006$). The quantity and price variables are measured in log form, in which case the supply equation is expressed as:

$$ln(q_t^s) = \beta_1 + \beta_2\ ln(ep_t) + \beta_3\left(z_t^p\right) + \beta_4 trend + \beta_5 s_t + u_{1t} \tag{8}$$

As in Roberts and Schlenker (2013), we include the contemporaneous yield shock (s_t) for the effects of random weather outcomes on supply. The inclusion of this variable is key for identifying the FISP program effects as it controls for cases in which the introduction of the program might coincidentally overlap with uncommonly good or bad weather outcomes. A mean zero econometric error term (u_{1t}) is also included in the model. Here, β_2 measures the supply elasticity of changes in expected prices, and β_3 measures the effect of FISP on maize supply.

Maize demand (q_t^d) is measured as the amount of maize available to consumers in year *t*. It includes any changes in maize stocks (inventory adjustment) and trade flows, as such it might or might not be equal to supply in any given year. Consumers purchase maize after harvest at prevailing market prices (p_t). We also include a time trend to capture changes in preferences over time, and per capita income (z_t^d) to capture income effects. The quantity, price, and income variables are measured in log form, in which case the demand equation is expressed as:

$$ln(\, q_t^d) = \alpha_1 + \alpha_2 ln(p_t) + \alpha_3 ln(z_t^d) + \alpha_4 trend + u_{2t} \qquad (9)$$

A mean zero econometric error term u_{2t} is also included in the model. Here, α_2 measures the demand elasticity for changes in market prices, and α_3 measures the income elasticity.

SUR model

As the error terms u_{1t} and u_{2t} are potentially correlated, we estimate equations (8) and (9) using Seemingly Unrelated Regression (SUR) as it has an advantage of efficiency (i.e. small variance) compared to equation-by-equation OLS estimation. We, therefore, gain a more efficient estimator by estimating the two equations jointly, as was shown by Zellner (1962).

Considering *T* observations (years) in the data and having the two equations (i.e. supply and demand). Define t = 1… *T* to be the number of years (observations) and *j* = 1, 2 to be the number of equations. Then the supply and demand equations can be written as:

$$\underbrace{q_{1t}}_{1\times 1} = \underbrace{x'_{1t}}_{1\times k_1} \underbrace{\beta_1}_{k_1\times 1} + \underbrace{u_{1t}}_{1\times 1} \qquad \text{(Demand equation for period } t\text{)} \qquad (10)$$

$$\underbrace{q_{2t}}_{1\times 1} = \underbrace{x'_{2t}}_{1\times k_2} \underbrace{\beta_2}_{k_2\times 1} + \underbrace{u_{2t}}_{1\times 1} \qquad \text{(Supply equation for period } t\text{)} \qquad (11)$$

Assuming conditional expectation and variance–covariance of each period's error terms (u_{1t}, u_{2t}).

$$E\left[\begin{bmatrix} u_{1t} \\ u_{2t} \end{bmatrix} \middle| \; all\; x_{jt}\, for\;\; j = 1,2; t = 1, \dots, T\right] = \begin{bmatrix} 0_{1\times 1} \\ 0_{1\times 1} \end{bmatrix} = 0_{2\times 1} \qquad (12)$$

and

$$\underbrace{\varepsilon}_{2\times 2} = var\left[\begin{bmatrix} u_{1t} \\ u_{2t} \end{bmatrix} \middle| \; all\; x_{jt}\, for\;\; j = 1,2; t = 1, \dots, T\right] = \begin{bmatrix} \sigma_{11} & \sigma_{21} \\ \sigma_{12} & \sigma_{22} \end{bmatrix} \qquad (13)$$

We allow for the off-diagonal elements of this conditional variance matrix to be non-zero, which allows for the error terms (u_{1t}, u_{2t}) to be correlated. However, we assume that these errors are independent over time:

$$Cov\left[\underbrace{\begin{bmatrix} u_{1t} \\ u_{2t} \end{bmatrix}}_{\substack{period\; t \\ error\; terms}} , \underbrace{\begin{bmatrix} u_{1t'} \\ u_{2t'} \end{bmatrix}}_{\substack{period\; t's \\ error\; terms}} \middle| \; all\; x_{jt}\, for\; j = 1,2; t = 1,.,T \right] = \begin{bmatrix} 0_{1\times 1} 0_{1\times 1} \\ 0_{1\times 1} 0_{1\times 1} \end{bmatrix} = 0_{2\times 2} \qquad (14)$$

Simply, this is to say that period t's error vectors (u_{1t}, u_{2t}) and period t' error vectors ($u_{1t'}, u_{2t'}$) are not correlated (i.e. errors are uncorrelated across periods). In summary the error terms are correlated within periods across equations but uncorrelated across periods both within and across equations. The stacked version of this model is given by:

$$\underbrace{Q}_{2T\times 1} = \underbrace{X}_{2T\times(k1+k2)} \underbrace{\beta}_{(k1+k2)\times 1} + \underbrace{U}_{2T\times 1} \tag{15}$$

Where the elements of the above model are:

$$\underbrace{\begin{bmatrix} \underbrace{q_1}_{T\times 1} \\ \underbrace{q_2}_{T\times 1} \end{bmatrix}}_{2T\times 1} = \underbrace{\begin{bmatrix} \underbrace{X_1}_{T\times k_1} & 0_{T\times k_1} \\ 0_{T\times k_2} & \underbrace{X_2}_{T\times k_2} \end{bmatrix}}_{2T\times(k1+k2)} \underbrace{\begin{bmatrix} \underbrace{\beta_1}_{k_1\times 1} \\ \underbrace{\beta_2}_{k_2\times 1} \end{bmatrix}}_{(k1+k2)\times 1} + \underbrace{\begin{bmatrix} \underbrace{u_1}_{T\times 1} \\ \underbrace{u_2}_{T\times 1} \end{bmatrix}}_{2T\times 1} = \begin{bmatrix} \underbrace{X_1}_{T\times k_1} & \underbrace{\beta_1}_{k_1\times 1} + & \underbrace{U_1}_{T\times 1} \\ \underbrace{X_2}_{T\times k_2} & \underbrace{\beta_2}_{k_2\times 1} + & \underbrace{U_2}_{T\times 1} \end{bmatrix} \tag{16}$$

Applying Three Stage Least Square estimation (3SLS)

In our preferred model using SUR estimation, we apply instrumental variables for output price in the demand equation. This follows results from the Hausman test which indicate that the expected price in the supply equation is not endogenous, but the market price in the demand equation is. More details on this are provided in the results sections. We use the following first stage regression with current yield shocks as the instrumental variable:

$$ln(p_t) = \pi_1 + \pi_2\, ln\left(z_t^d\right) + \pi_3 s_t + \pi_4 trend + e_t \tag{17}$$

The estimated parameters are then used to construct the instrument:

$$\widehat{ln(p_t)} = \hat{\pi}_1 + \hat{\pi}_2\, ln\left(z_t^d\right) + \hat{\pi}_3 s_t + \hat{\pi}_4 trend \tag{18}$$

This instruments replaces p_t in the demand equation and then SUR is used to estimate the supply and demand equations jointly:

$$ln(q_t^s) = \beta_1 + \beta_2\ ln(ep_t) + \beta_3(z_t^p) + \beta_4 trend + \beta_5 s_t + u_{1t} \tag{8}$$

$$ln(q_t^d) = \alpha_1 + \alpha_2 \widehat{ln(p_t)} + \alpha_3 ln(z_t^d) + \alpha_4 trend + u_{2t} \tag{19}$$

Extension of our preferred model

We extend our preferred model in order to assess whether price of fertilizer, a key input in maize production, has a significant effect on maize supply. We directly include weighted fertilizer prices in our supply equation. We also include an interaction between the FISP dummy and fertilizer price to evaluate whether the program has affected input price elasticities in the supply equation. The following supply equations are considered:

$$ln(q_t^s) = \beta_1 + \beta_2\ ln(ep_t) + \beta_3(z_t^p) + \beta_4 s_t + \beta_5 trend + \beta_6 ln(z_t^s) + u_{1t} \tag{20}$$

$$ln(q_t^s) = \beta_1 + \beta_2\, ln(\mathrm{ep_t}) + \beta_3(z_t^p) + \beta_4 s_t + \beta_5 trend + \beta_6 ln(\mathrm{z_t^s}) + \beta_7[ln(z_t^s)(z_t^p)] + u_{1t} \tag{21}$$

CHAPTER IV

DATA AND METHODS

This chapter presents the data and methods that were used in the study. Specifically, the chapter explains the different variables that were used in the regression analysis, their sources, and the methods used to construct and organize these variables.

Maize Price Variable

Price expectations for the producers were formed from historical cash prices of maize using an autoregressive model. Autoregressive models work under the idea that past values have an effect on current values. As such, we regressed current prices of maize on previous periods' prices to construct a measure of expected price as a weighted sum of previous prices. Our preferred producers' price expectation was formed using the AR(3) model because it presented a relatively better goodness of fit for the sample data. The historical cash prices for maize were sourced from the Department of Agro-Economic Survey. However, we also considered expected price variables from the AR(1) and AR(2) models as robustness checks for the supply and demand estimates. As for the demand equation, the historical cash prices were used as consumers realized prices.

Futures prices

We also considered using maize futures prices for the July delivery contract from the Chicago Board of Trade (CBOT) and South Africa's Futures Exchange (SAFEX) as robustness checks. The July contract was chosen because harvesting in Malawi runs from May to July with June being the peak harvesting time. The contract's price at the time of planting were used as a proxy for farmers' expected prices in the supply model while the prices at the end of the contract were used as consumers' realized prices. Since few transactions occur towards the very end of the contract, consumer prices were constructed as an average of the contract price over a one month period prior to the expiration of the contract. As such, realized prices were based on the average prices in June, coinciding with the peak harvesting month for Malawi (see Figure 1 below).

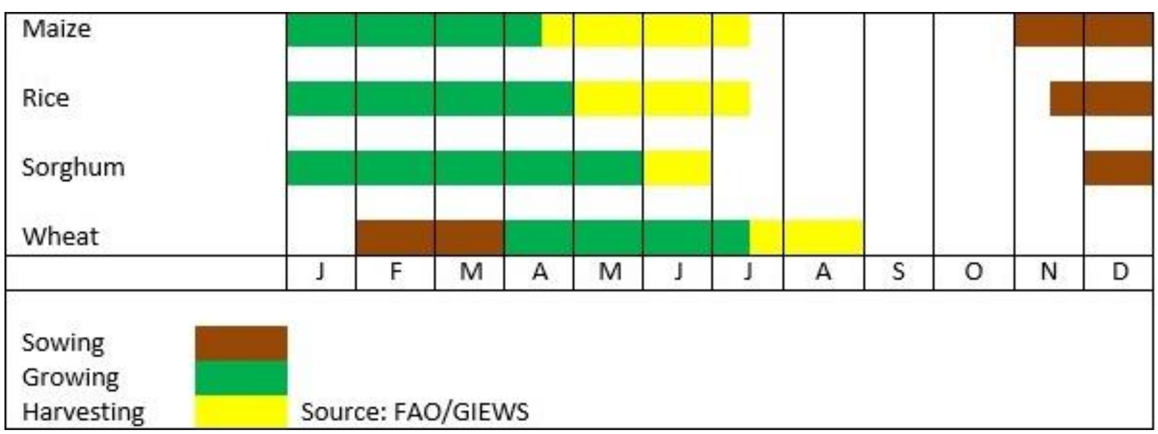

Figure 1 Crop Calendar for Malawi

The future maize prices obtained from CBOT run from 1960 to 2011. The prices from CBOT were used for testing robustness of the estimates because they are a good representation of world prices. Besides, CBOT prices are reasonably consistent and available in long time series. We also used prices from SAFEX because they were reasonably correlated with the historical cash prices of maize in Malawi. The downside of using these futures contracts are (i) CBOT contracts are written for yellow maize whereas Malawi supply/demand is for white maize, and (ii) data for SAFEX contracts were only available since 1996, which results in a much smaller sample size.

Maize Yield Shock Variable

The study used time series data for maize yields from the Food and Agriculture Organization of the United Nations (FAOSTAT: http:faostat.fao.org). Following Roberts and Schlenker (2013), yield shocks are the result of random weather shocks and can be used to identify both supply and demand equations. In the supply equation, the yield shock variable enters directly as a control variable whereas in the demand equation it is used as an instrumental variable for endogenous prices. In order to construct a measure for these yield shocks, we regressed the log of national maize yields on polynomial functions of a trend variable. We considered degrees of this polynomial ranging from one to five, and selected as optimal the one providing the smallest prediction error under a Leave-One-Out Cross Validation (LOOCV) exercise. We sequentially omit each sample year from the data, estimate the model using the retained years, predict the squared error for the omitted year, and then average these errors to construct the mean squared error (MSE). The model with the lowest MSE was chosen as the preferred trend model and the yield shocks were constructed as annual deviations from trend.

Maize Quantity Variables

Using time series data from FAOSTAT, we extracted data on the quantity of maize produced, quantity of maize imported, quantity of maize exported and maize inventory or stock variations for Malawi from 1960 to 2012. The quantity of maize supplied (q_t^s) is measured as the amount of maize produced in a given period while the quantity of maize demanded (q_t^d) in a given period was defined as the sum of total quantity supplied (q_t^s) and trade flows (I_t) minus amount stored (x_t) for future period.

$$q_t^d = q_t^s + I_t - x_t \tag{22}$$

FISP Policy Variable

The other variable involved in our analysis is a dummy variable for Malawi's FISP. This variable takes a value of one for the years in which the program is in place, and a value of zero otherwise. This variable is used in the supply equation to estimate the impact of FISP on maize supply. As an extension to our preferred model, we also include an interaction between the FISP dummy and fertilizer price to evaluate whether the program has affected input price elasticities in the supply equation.

Income Per Capita

Gross National Income (GNI) per capita was used as a measure for national income in the demand equation. We used annul average per capita GNI for Malawi from the World Bank's World Development Indicators (WDI).

Fertilizer Price Variable

Retail prices for inorganic fertilizers were obtained from Smallholder Farmers' Fertilizers Revolving Fund of Malawi (SFFRF). This included prices of various fertilizers since 1980 to 2014. For the study, however, our interest was on maize fertilizers; specifically, Urea, Calcium Ammonium Nitrate (CAN) and Nitrogen Phosphorus Potassium (NPK). Weighted average fertilizer prices were constructed based on nitrogen content. According to the Manual on Maize Production Intensification Technologies by Ministry of Agriculture and Food Security (2004), the recommendation or nutrient requirement for maize is 92 kilograms of nitrogen per hectare and 21 kilograms of phosphorus per hectare. Farmers are, therefore, recommended to use a combination of straight nitrogen fertilizers and NPK to meet these requirements.

The two popular fertilizer combinations for maize are (i) Urea (46 percent nitrogen) plus 23:21:0+4s and (ii) CAN (27 percent nitrogen) plus 23:21:0+4s. For the Urea combination, to meet the nutrient requirement for maize, a farmer needs 150 kilograms of Urea and 100 kilograms of 23:21:0+4s per hectare. This makes a Urea to NPK combination ratio of 3 to 2. As for the CAN combination, a farmer would require 250 kilograms of CAN and 100 kilograms of 23:21:0+4s per hectare to achieve the nutrient requirement for maize. This makes a CAN to NPK combination ratio of 5 to 2. These combination ratios were, consequently, used as weights when computing the weighted average price of fertilizer. In the empirical exercise, we focus on the Urea (46 percent nitrogen) plus 23:21:0+4s combination because it is the most popular combination among maize farmers in the country (see MoAFS's Manual on Maize Production Intensification Technologies, 2004, pp 27-33).

Converting Monetary Variables to Real Kwacha

All monetary variables that were originally measured in a foreign currency were converted to Malawi Kwacha using annual average exchange rates from the Reserve Bank of Malawi. In addition, nominal values were converted to 2011 Kwacha using annual Consumer Price Index (CPI) data from National Statistics Office of Malawi.

CHAPTER V

RESULTS AND DISCUSSIONS

This chapter reports and discusses the results from the study. The first subsection presents summary statistics and time series for the variables used in the analysis. The second subsection reports and discusses the empirical results for the supply and demand model. In this subsection we compare the results from our preferred model with several other specifications to evaluate the robustness of the findings across alternative specifications.

Summary Statistics

Table 1 reports the descriptive statistics for the data used in the study, spanning 1973-2013.

Table 1 Descriptive Statistics: 1973-2013

Variable Description	Units	Mean	Standard Deviation	Minimum	Maximum
Maize supplied	M. tons	1827741	832432	657000	3699147
Maize demanded	M. tons	1916281	999181	494344	4450253
Maize stock variation	M. tons	-38146.34	302931.1	-817000	788000
Maize yield	M. tons/ha	1.352	0.446	0.480	2.654
Maize yield shock	M. tons/ha	0.003	0.231	-0.840	0.493
Malawi GNI per capita	MK/capita	230409	66740	137139	396564
Maize cash price	MK/M. tons	169873	82384	83840	430193
CBOT realized price	MK/M. tons	9841	4340	5171	22834
CBOT expected price	MK/M. tons	9619	4804	4638	26853.
SAFEX realized price	MK/M. tons	194113	74597	94629	340586
SAFEX expected price	MK/M. tons	206068	80601	98946	386340
Weighted fertilizer price	MK/M. tons	25295	18322	5215	75481

Notes:M. tons denotes metric tons, ha denotes hectares and MK is Malawi Kwacha in real terms.

Figures 2 and 3 present time series for the maize supply, demand, stock variation, yield shock, GNI per capita, cash price, and fertilizer price data.

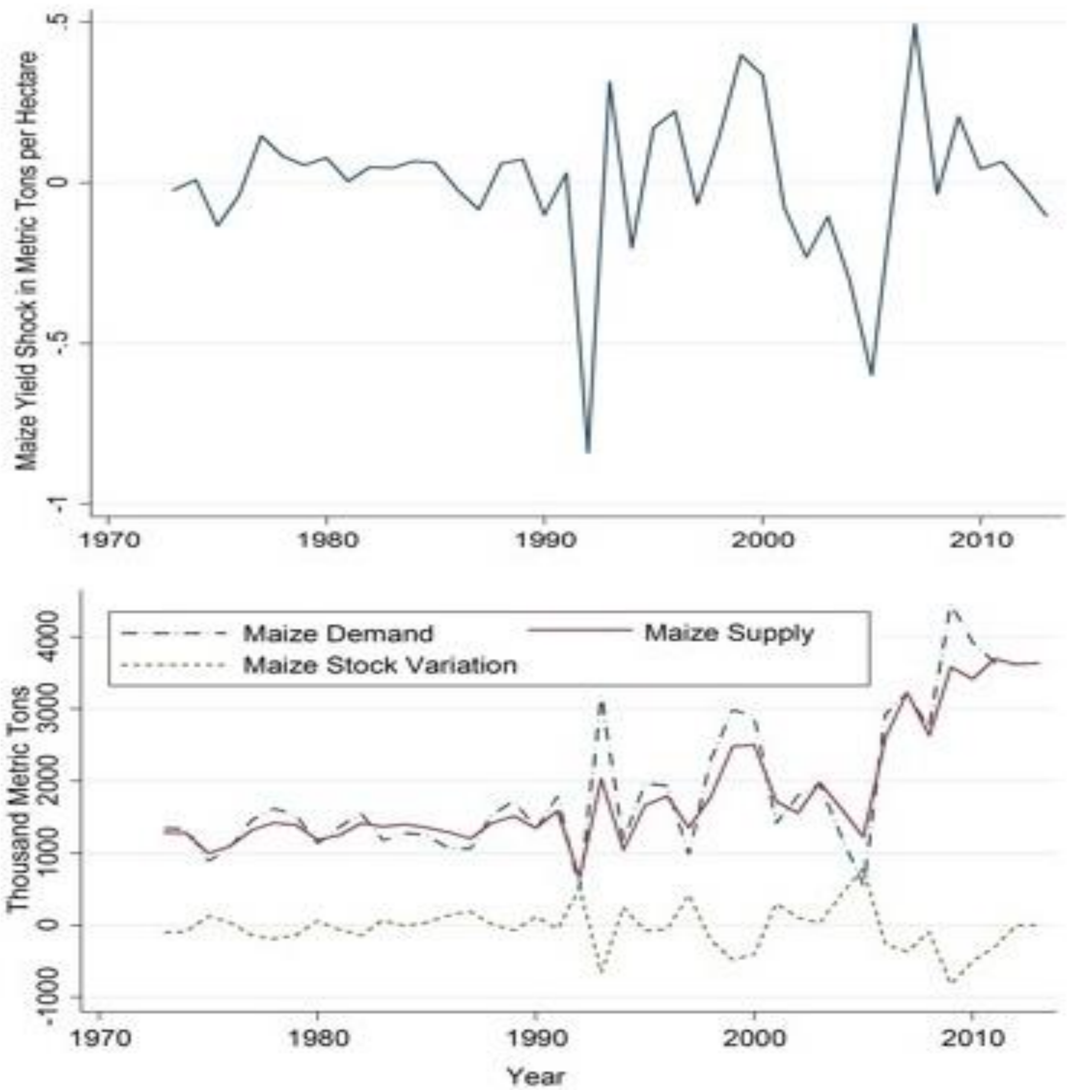

Figure 2 Maize Yield Shocks, Supply, Demand and Stock Variations

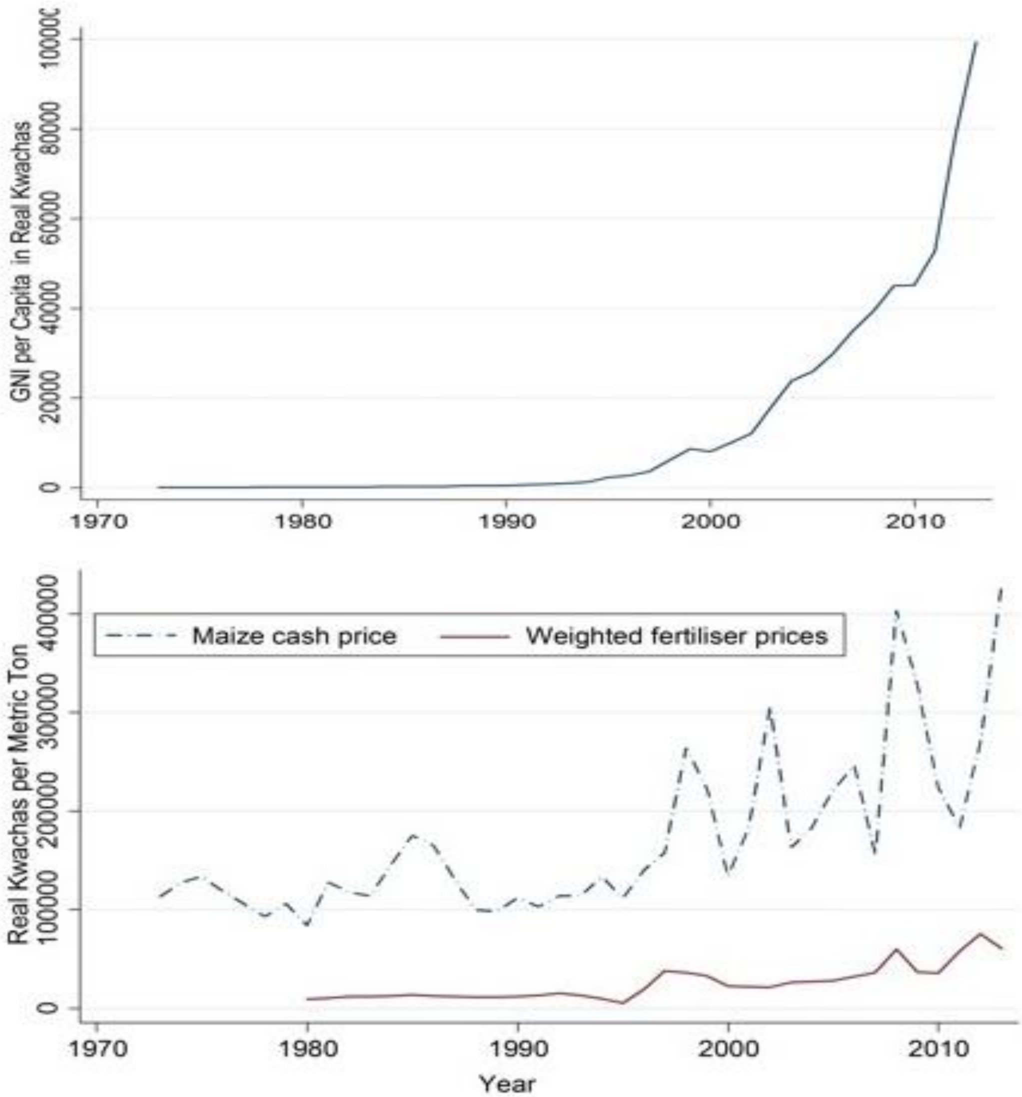

Figure 3 Per Capita GNI, Weighted Fertilizer Prices and Maize Cash Prices

Figure 2 shows that the quantity of maize demanded and supplied have been mostly increasing over time, with the majority of growth occurring after 1990. However, the figure shows that stock variations have generally remained stable over time. Figure 2 also shows that maize yield shocks have increased in absolute value over time, with the largest shocks occurring after 1990. Figure 3 shows that historical cash prices of maize and fertilizer prices have been increasing over time. Figure 3 also shows that the gross national income per capita for Malawi remained stable until the late 1990s when significant growth started occurring. Both figures illustrate the importance of controlling for trends in the supply and demand equations to avoid spurious correlations.

Empirical Results

Constructing the yield shock variable

In order to construct a measure for maize yield shock, we regressed the log of maize yields on polynomial functions of the sample year. Our objective was to identify the best yield trend model for our data and then use this trend to estimate shocks as annual deviations from trend. Since increasing the order of the polynomial necessarily increases in-sample fit (i.e. r-squared), we utilize a Leave-One-Out Cross Validation (LOOCV) exercise over sample years. We compare the mean squared error for the following models:

(i) $ln(y_t) = \beta_1 + \beta_2\, t + u_1$

(ii) $ln(y_t) = \beta_1 + \beta_2\, t + \beta_3 t^2 + u_2$

(iii) $ln(y_t) = \beta_1 + \beta_2\, t + \beta_3 t^2 + \beta_4 t^3 + u_3$

(iv) $ln(y_t) = \beta_1 + \beta_2\, t + \beta_3 t^2 + \beta_4 t^3 + \beta_4 t^4 + u_4$

(v) $ln(y_t) = \beta_1 + \beta_2\, t + \beta_3 t^2 + \beta_4 t^3 + \beta_4 t^4 + \beta_4 t^5 + u_5$

Where y_t is maize yield in year t.

Table 2 Mean Square Errors For The LOOCV Exercise

	(1)	(2)	(3)	(4)	(5)
	Linear	Quadratic	Cubic	Quartic	Quintic
Mean Square Error	0.0658	0.0576	0.0512	0.0530	0.0547
Observations	56	56	56	56	56

Table 2 reports the results from the LOOCV exercise and we find that the third order polynomial (i.e. cubic model) provides the most precise maize yields predictions for the data. The series in Figure 2 corresponds to this model.

Constructing the expected price variable

Producers' price expectations were constructed from historical cash prices of maize using an autoregressive model in which the current period price is regressed on prices from previous periods. This allows us to construct a measure of expected price as a weighted sum of previous prices. We consider three models, AR(1) – AR(3):

(i) $ln(p_t) = \beta_1 + \beta_2\, ln(p_{t-1}) + u_t$

(ii) $ln(p_t) = \beta_1 + \beta_2\, ln(p_{t-1}) + \beta_3 ln(p_{t-2}) + u_t$

(iii) $ln(p_t) = \beta_1 + \beta_2\, ln(p_{t-1}) + \beta_3 ln(p_{t-2}) + \beta_4 ln(p_{t-3}) + u_t$

Where p_t is the cash price of maize in year t. Model (i) corresponds to a naïve expectations model in that the current expected price is solely a function of last year's price. Models (ii) and (iii) allow for prices in more distant years to also affect the price expectation.

Table 3 presents a summary of the results from the three autoregressive models. The most recent price has a statistically significant effect across all three models. The AR(2) model suggests that more distant prices are not relevant in forming price expectations, however the AR(3) model suggests otherwise. We adopt the latter as our preferred price expectation model as the 3rd period lagged price is statistically significant and the model provides a large increase in r-squared relative to the AR(1) and AR(2) models. Figure 4 provides time series of the historical and expected prices.

Table 3 Price Expectation Using Autoregressive Models

	AR(1)	AR(2)	AR(3)
lnHPrice_1lag	0.760***	0.674***	0.607***
	(0.117)	(0.171)	(0.166)
lnHPrice_2lag		0.131	-0.105
		(0.203)	(0.181)
lnHPrice_3lag			0.417***
			(0.152)
P-value for Joint Significance Test,		<0.001	<0.001
R-Squared	49.08	49.83	57.08
Observations	41	41	41

Notes: Robust standard errors are in parentheses. *, **, and *** denote significance at 10%, 5%, and 1% levels

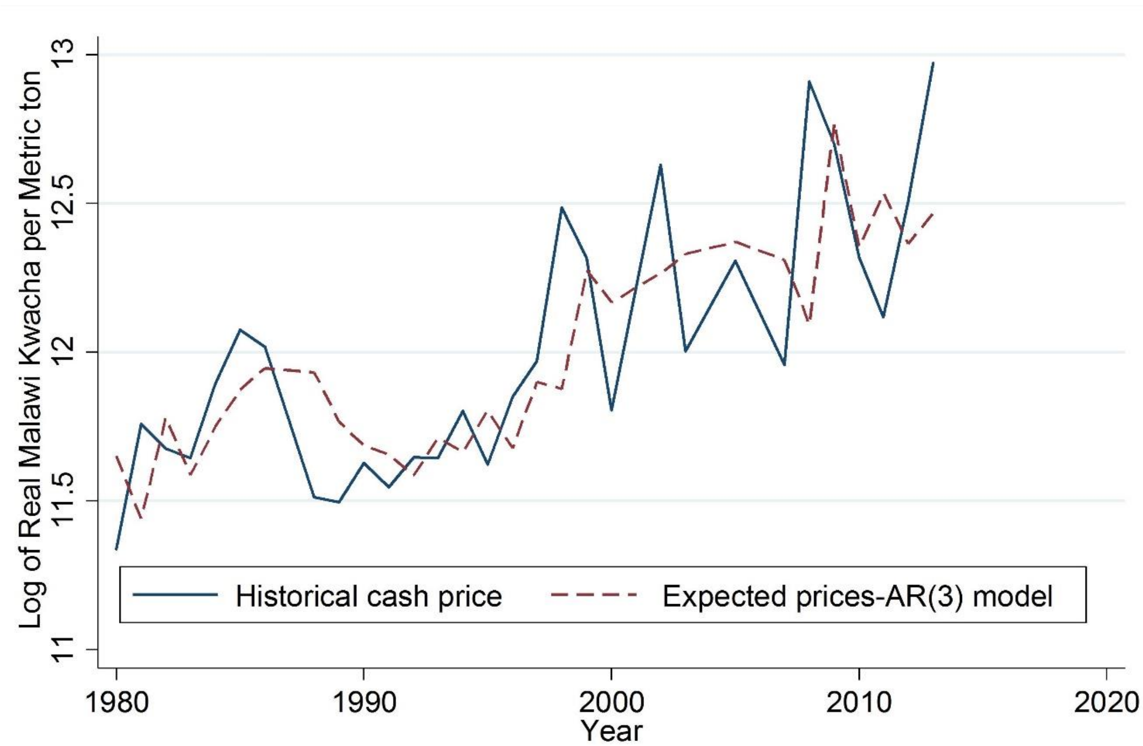

Figure 4 Historical Cash Prices and Expected Prices of Maize

Main results

A summary of the main results are reported in Table 4. These results include parameter estimates from OLS and SUR models, each with various specifications. The price expectations for producers are formed using the AR(3) model from the previous section, while the historical cash price is used in the demand equation. To account for the supply and demand trends evident in Figure 2, we include a separate linear trend in each equation. All variables except for the yield shock and the FISP dummy variable for the subsidy policy are measured in logs.

Model (2) demonstrates the importance of controlling for yield shocks in the supply equation. The effect of these shocks are of the expected sign (positive) and are statistically significant. We find that failure to control for these shocks leads to overestimated supply elasticity and FISP estimates, which further demonstrates the importance of including shocks as a control variable. The pattern of results for models (2) and (3) are similar, which implies that cross-equation correlation of the error term is not a major concern. The Hausman test shows that expected price is not endogenous in the supply equation, thus we do not instrument for it. This is not surprising as Hendricks et al (2014) find that including current yield shocks as a control variable in supply regressions reduces endogeneity bias. However, the Hausman test for the demand equation suggests that the historical cash price is endogenous. As such, we instrument for it using the current period yield shock. Model (4) utilizes 3SLS to account for this endogeneity and represents our preferred model.

Results indicate that supply elasticity estimates are positive and generally stable across different specifications ranging from 0.255 to 0.337. Results based on our preferred model suggests that holding all other factors constant, a 1 percent increase in maize price induces a 0.28 percent increase in maize supply. Roberts and Schlenker (2013) also used 3SLS and found elasticities for world's combined caloric supply of maize, wheat, rice and soybean ranging from 0.097 to 0.116. Our supply elasticity estimates are relatively higher compared to those from Roberts and Schlenker's (2013) study. These differences are likely driven by locational differences as Roberts and Schlenker (2013) focused on all countries whereas the current focus is Malawi.

Our results indicate that the FISP had a positive and statistically significant effect on maize supply. Under our preferred model, the estimated effect of FISP is a 28.9 percent increase in supply. This implies that the program has on average increased maize production by about 468,358[14] metric tons per year since its introduction in 2006. From 2006-2013, this implies an aggregate effect of 3,746,870 metric tons. Our results also indicate that maize yield shocks have a statistically significant positive effect on maize supply. Hendricks et al. (2014) found that estimates from OLS with current yield shocks as a control variable are almost identical to those from 2SLS, where past yield shocks are used as an IV. Our results are consistent with their finding that there is little need to apply instrumental variable estimation in supply once current yield shocks are controlled for, as the Hausman test suggests that expected prices are not endogenous.

On the demand side, the Hausman test for model (3) suggests that maize cash prices are endogenous. As such, we instrument for these prices using current period yield shocks. Under our preferred model (4), we find that a one percent increase in maize prices leads to an 11 percent decrease in demand. This estimate of the demand elasticity suggests that consumers are very price sensitive, which corresponds to findings from Ecker and Qaim (2008). Our estimates also indicate a large, positive income elasticity for maize, as a 1 percent increase in income is associated with 5.5 percent increase in demand. This is similar to findings by Ecker and Qaim (2011) who reported that food demand in Malawi is highly income-responsive for the main food groups like maize as rising incomes lead to large increases in demand for staples and animal products.

[14] Calculated based on the average production of maize for the last five years before introduction of FISP.

Table 4 Supply and Demand Estimates

	(1)	(2)	(3)	(4)
	OLS	OLS	SUR	3SLS
Panel A. Supply Equation				
Supply elasticity	0.337	0.255***	0.262***	0.282***
	(0.261)	(0.081)	(0.088)	(0.080)
FISP	0.491***	0.361***	0.346***	0.289***
	(0.125)	(0.058)	(0.058)	(0.054)
Shock		0.776***	0.694***	0.795***
		(0.084)	(0.070)	(0.071)
Panel B. Demand Equation				
Demand elasticity	0.112	-0.142	-0.102	-11.211***
	(0.199)	(0.172)	(0.268)	(1.077)
Income elasticity		0.524***	0.398	5.550***
		(0.171)	(0.265)	(0.516)
P-value for Hausman test, supply	0.962	0.621	0.903	0.983
P-value for Hausman test, demand	<0.001	<0.001	<0.001	
Observations	41	41	41	41
Linear trend	Y	Y	Y	Y

Notes: Column (1) to (2) use ordinary least square estimates. Column (2) includes shock and income in the supply and demand equation respectively while (1) doesn't. Columns (3) and (4) comprise SUR estimates. Column (3) uses uninstrumented cash price in demand equation while (4) uses an instrumented cash price. Panel A presents results for supply equations while panel B gives demand equation results. Robust standard errors are in parentheses. *, **, and *** denote significance at 10%, 5%, and 1% levels.

Comparing linear trend with quadratic and cubic trend variables

We evaluate the robustness of our findings under alternative specifications for the trends in the supply and demand equations. Table 5 reports estimates using quadratic and cubic trends. For the specification that used the squared trend variable, the find that the squared trend variable is significant in the supply equation, but not in the demand equation. However, the squared and cubed trend variables are both significant in the supply and demand equations for the specification that used the cubic trend variable.

Table 5 Supply and Demand Estimates

	Preferred Model	Quadratic Trend	Cubic Trend
	3SLS	3SLS	3SLS
Panel A. Supply Equation			
Supply elasticity	0.282***	0.091	0.101*
	(0.080)	(0.067)	(0.059)
FISP	0.289***	0.057	-0.021
	(0.054)	(0.056)	(0.056)
Shock	0.795***	0.881***	0.896***
	(0.071)	(0.059)	(0.054)
Panel B. Demand Equation			
Demand elasticity	-11.211***	-11.174***	-11.307***
	(1.077)	(1.032)	(1.043)
Income elasticity	5.550***	5.817***	5.777***
	(0.516)	(0.580)	(0.573)
P-value for Hausman test, supply	0.983	0.807	0.633
P-value for Hausman test, demand			
Observations	41	41	41

Notes: Panel A presents results for supply equations while panel B gives demand equation results. Robust standard errors are in parentheses. *, **, and *** denote significance at 10%, 5%, and 1% levels.

Under the quadratic trend, the estimates for the supply elasticity and the FISP coefficient remain positive but are not statistically significant. Under the cubic trend, the supply elasticity remains positive and significant but is much smaller in magnitude, while the FISP effect is again not significant. Thus, we find that our reported supply side estimates are not robust to alternative trend specifications. It is likely that either (i) the additional flexibility of the nonlinear trends is inappropriately capturing the FISP effect, or (ii) that there is no FISP effect. Further research on this issue is warranted. On the demand side, we find that our results in Table 4 are robust to these alternative trend specifications.

Comparison to alternative models of producer price expectations

Our preferred results in Table 4 are based on the AR(3) price expectations model. However, maize producers in the country may be creating their price expectations using various other models. As such, we replicate our results using the AR(1) and AR(2) models from Table 3.

Table 6 Supply and Demand Estimates

	Preferred Model	AR(1)	AR(2)
	3SLS	3SLS	3SLS
Panel A. Supply Equation			
Supply elasticity	0.282***	0.180**	0.214**
	(0.080)	(0.085)	(0.088)
FISP	0.289***	0.328***	0.318***
	(0.054)	(0.058)	(0.057)
Shock	0.795***	0.778***	0.776***
	(0.071)	(0.077)	(0.076)
Panel B. Demand Equation			
Demand elasticity	-11.211***	-11.209***	-11.209***
	(1.077)	(1.077)	(1.077)
Income elasticity	5.550***	5.559***	5.557***
	(0.516)	(0.516)	(0.516)
P-value for Hausman test, supply	0.983	0.966	0.880
P-value for Hausman test, demand			
Observations	41	41	41
Linear trend	Y	Y	Y

Notes: Panel A presents results for supply equations while panel B gives demand equation results. Robust standard errors are in parentheses. *, **, & *** denote significance at 10%, 5%, & 1% levels.

In both scenarios, the historical cash price of maize is used in the demand equation, while predicted prices are used in the supply equation. The results are reported in Table 6, and are similar in both magnitude and statistical significance to those of our preferred model. Thus, we find that our results are robust to these alternatives.

Comparison to price expectations from futures prices

In Table 7 we report estimates using futures prices from Chicago Board of Trade (CBOT) and South Africa's Futures Exchange market (SAFEX). The former were used in Roberts and Schlenker (2013) as proxies for producers' price expectations and consumers' realized prices when identifying supply and demand elasticities. To evaluate this possibility, we model producers' expected price using the July contract at the time of planting in the supply equation, and the average price for a month period before expiration as the realized price in the demand equation.

Table 7 Supply and Demand Estimates

	Preferred Model	CBOT Futures Price	SAFEX Futures Price
	3SLS	3SLS	3SLS
Panel A. Supply Equation			
Supply elasticity	0.282***	0.148***	-0.063
	(0.080)	(0.046)	(0.057)
FISP	0.289***	0.213***	-0.044
	(0.054)	(0.065)	(0.076)
Shock	0.795***	0.835***	0.924***
	(0.071)	(0.072)	(0.098)
Panel B. Demand Equation			
Demand elasticity	-11.211***	12.992***	21.447***
	(1.077)	(1.250)	(3.313)
Income elasticity	5.550***	-16.419***	-18.559***
	(0.516)	(1.618)	(2.869)
P-value for Hausman test, supply			
	0.983	0.345	0.629
P-value for Hausman test, demand			
Observations	41	41	17
Linear trend	Y	Y	Y

Notes: Panel A presents results for supply equations while panel B gives demand equation results. Robust standard errors are in parentheses. *, **, and *** denote significance at 10%, 5%, and 1% levels.

The supply side estimates for the CBOT prices are consistent with our preferred model results, however the results using SAFEX prices are markedly different. The demand side estimates are not robust under either alternative. Which set of results are accurate depends on the true, but unknown, price expectations process. An advantage of our preferred approach is that it utilizes an empirically identified weighted average of previous cash prices for white maize in Malawi, and thus reflects localized supply and demand conditions. Conversely, the CBOT prices reflect world supply and demand conditions for yellow maize, which is typically used as a feed grain and thus could introduce significant measurement error into the analysis. While the SAFEX contracts are for white maize, they might not accurately reflect economic conditions in Malawi.

Effects of FISP on input price elasticity

In order to test whether FISP influenced the input prices/output relationships on the supply side, we include a measure of fertilizer price as an additional regressor in the supply equation. We focus on fertilizer as it is a key input that accounts for the large share of the FISP budget.[15] The fertilizer price is a weighted average of Urea and NPK based on nitrogen content for the most popular maize fertilizer combination in Malawi. We include this variable directly in the supply equation, and also consider interacting it with the FISP variable.

[15] We were unable to get historical cash price for hybrid maize seed in Malawi as the hybrids varieties evolve almost every year

Table 8 Supply and Demand Estimates

	Preferred Model	Without Slope Shifter	With Slope Shifter
	3SLS	3SLS	3SLS
Panel A. Supply Equation		`	
Supply elasticity	0.282***	0.249***	0.302***
	(0.080)	(0.090)	(0.087)
FISP	0.289***	0.244***	-2.700**
	(0.054)	(0.065)	(1.276)
Shock	0.795***	0.803***	0.827***
	(0.071)	(0.078)	(0.071)
Fertilizer elasticity		0.080*	0.037
		(0.046)	(0.045)
FISP slope shifter			0.275**
			(0.118)
Panel B. Demand Equation			
Demand elasticity	-11.211***	-10.273***	-10.257***
	(1.077)	(1.164)	(1.164)
Income elasticity	5.550***	5.570***	5.604***
	(0.516)	(0.628)	(0.626)
P-value for Hausman test, supply	0.983	0.328	0.289
P-value for Hausman test, demand			
Panel C. Effects of FISP			
Marginal effects on aggregate supply			0.284
Effects on input elasticity			0.275
Observations	41	30	30
Linear trend	Y	Y	Y

Notes: Panel A presents results for supply equations while panel B gives demand equation results. Panel C presents some calculated parameters of interest. Robust standard errors are in parentheses. *, **, and *** denote significance at 10%, 5%, and 1% levels.

Our findings from both specifications show positive and significant supply elasticities which are similar to the results from our preferred model in Table 4. Results show positive input elasticities for both specifications, which is not consistent with economic theory. It could be that the quality of the fertilizer has increased over time, thus reflecting both higher prices and input demand. This would indicate the need to account for quality differences over time in the fertilizer prices and suggests a path for future research to consider. Estimates for supply, demand, and income elasticities from these two specifications are also similar to the estimates from our preferred model.

Based on the specific objectives of the study, the two parameters of interest (i.e. the implied effects of the policy on aggregate maize supply and effects on input price elasticity) for this study are derived from the supply equation as follows:

Marginal effects of FISP on aggregate maize supply:

$$\frac{\delta \ln(q_t^s)}{\delta\,(z_t^p)} = \beta_4 + \beta_5 \ln(z_t^s) \tag{23}$$

Effects of FISP on input price elasticity of supply:

$$\varepsilon = \frac{\delta \ln(q_t^s)}{\delta \ln(z_t^s)} = \beta_3 + \beta_5 (z_t^p) \tag{24}$$

These are calculated as partial derivatives of our supply equation (21) from Chapter 3. The results suggest that FISP has increased maize production by 28.4 percent each year. This estimate is nearly identical to that from our preferred model in Table 4.

Our results also indicate that FISP has increased the input price elasticity of fertilizer. This elasticity was estimated to be 0.037 before FISP and 0.312 after, thereby signifying a large increase in price responsiveness. However, as noted above both estimates suggest that higher prices lead to higher fertilizer demand, a relationship that is not consistent with economic theory.

CHAPTER VI

CONCLUSIONS AND LIMITATIONS

One of the stated policy aims for the re-introduced input subsidy program in Malawi is to increase maize production and ensure food security. Considering that this program costs as much as 16 percent of the government's budget in some years, it is crucial to quantify its effects on maize production. While most of the previous studies have focused on estimating various socioeconomic impacts[16] of FISP (Lunduka et al., 2013; Fisher and Kandiwa, 2013; Chibwana et al., 2012; Holden and Lunduka, 2012; Ricker-Gilbert and Jayne, 2012; Chirwa et al., 2011; and Denning et al., 2009), this study contributes to the existing literature by quantifying the effects of FISP on aggregate maize supply. We find that FISP has substantially increased maize production. For instance, we estimate a 28.9 percent increase, which corresponds to an additional 468,358[17] metric tons. This additional supply has been realized in each year since the

[16] Like impacts on inorganic fertilizer use and yields, household land allocation, household income and adoption of improved seeds

[17] Calculated based on the average production of maize for the last five years before introduction of FISP.

introduction of FISP in 2006[18], which implies an aggregate increase of 3,746,870 metric tons up through 2013.

Our study also estimates maize supply and demand elasticities for Malawi. Our results suggest that holding all other factors constant, a one percent increase in maize price induces a 0.28 percent increase in maize supply. Our results also suggest that maize consumers in the country are very price sensitive, as we find that a one percent increase in maize prices leads to an 11 percent decrease in demand. Our demand elasticity findings corresponds to findings from Ecker and Qaim (2008) and Ecker and Qaim (2011).

Our study also broadens the frontiers of existing literature by estimating input elasticities for maize supply. Our findings, however, indicate positive input elasticities which is not consistent with economic theory. This may suggest that the quality of fertilizer has increased over time, thus reflecting both higher prices and input demand. Further research needs to be carried out to account for quality differences over time in the fertilizer prices. We also quantify the effects of FISP on input price elasticity and our results indicate that FISP has increased the input price elasticity of fertilizer. This elasticity was estimated to be 0.037 before FISP and 0.312 after, thereby signifying a large increase in price responsiveness. However, the input demand to price relationship depicted here is not consistent with economic theory.

It is worth pointing out that this study encountered a number of limitations. First, we were unable to get historical cash prices for maize seed since hybrid seed varieties in

[18] Effects calculated for up to year 2013.

Malawi evolve almost every year. As such, we only used fertilizer prices to capture the effect of input prices on supply. In addition, our constructed measure of fertilizer price did not account for any changes in quality that might have evolved over time. Both of these limitations are important considerations for future research. Second, our measure of producers' price expectations was based on a model of previously observed cash prices. This might or might not reflect the actual expectations process used by producers. We also considered using futures prices as measures for these expectations, which could be unreliable as Malawi does not have its own futures market and the prices from international futures markets may not accurately reflect economic conditions in Malawi. Third, we do not consider the effect of substitutable outputs in the supply equations. The majority of smallholder farmers within the maize-based farming system are also consumers of their own crop and hence do not produce solely for the market, which suggests that this might not be a major concern. However, there may still be some significant substitution effects and thus further research to quantify maize cross-price elasticities of supply may be of interest to policy makers.

In addition, this study used secondary data from FAOSTAT which is reported as aggregate data at the national level. It is not clear whether the reported data on production accounts for all the producers in the maize production system, specifically very small producers and/or households producing maize for their own consumption. A clearer understanding about whether production practices of the producers targeted by FISP are accounted for in the FAOSTAT data is warranted. Similarly, it is also unclear if the maize import/export measures account for all traders in the maize market including independent and illegal traders of maize. We assume that the data is reported for all relevant agents in the maize value chain. Nevertheless, if these variables do not account for all the players in the maize market or value chain system, then this might have introduced significant measurement error into the regression framework.

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