Contribution of Policy Change on Maize Varietal Development and Yields in Kenya

Latha Nagarajan
IFDC, Washington, District of Columbia, USA
lnagarajan@ifdc.org

Anwar Naseem
Department of Agricultural, Food and Resource Economics
Rutgers University, New Brunswick, New Jersey, USA
anwar.naseem@rutgers.edu

Carl Pray
Department of Agricultural, Food and Resource Economics
Rutgers University, New Brunswick, New Jersey, USA
cpray@sebs.rutgers.edu

Abstract

Purpose – Since the start of seed and other market reforms in the 1990s, the annual number of improved varietal releases for maize in Kenya has increased substantially. Prior to the reforms, private firms were restricted in introducing new varieties, could not protect their intellectual property, and farmers had to rely exclusively on the improved seeds developed and marketed by the public sector. Reforms have resulted in not only private firms entering the market and releasing improved varieties, but also an increase in varietal releases by the public sector. This paper reviews some of the key policy reforms related to maize in Kenya, and their impacts on varietal development and yields.

Introduction

Raising productivity is essential to sustain economic and income growth. In turn, technical change is the main driver of increased productivity, underlining the ongoing importance of focusing on technology as a primary change agent. The experience of industrialized countries confirms this insight where empirical findings consistently show that technical advances have been the main contributor to growth. This has also been the case within agriculture where rapid increases in productivity is often due to the adoption of specific technologies, such as hybrid maize, genetically modified crops, mechanization, and the use of chemical inputs.

Despite the recognition that technology is important for growth, it remains under-utilized in many countries, particularly in sub-Saharan Africa (SSA). Modern input use remains low, exemplified by the low rates of fertilizer application. For SSA, fertilizer use intensity averaged less than 16 kg/ha of arable land in 2014, whereas it averaged 160, 345, and 130 kg/ha for South Asia, East Asia, and Latin America, respectively (FAO, 2016). The use of improved seed varieties (IVs)--a key ingredient to the success of the Asian Green Revolution--is also low, accounting for 35% of all food crops grown in SSA in 2010 (Walker and Alwang, 2015).

The low use of farm inputs in SSA is at odds with the considerable farm-level evidence that shows SSA farmers benefit when they use improved varieties, especially for maize (Doss et al., 2003; Mathenge, Smale, and Olwande, 2014; Nyangena and Juma, 2014; Gitonga and De Groote, 2016; Muraoka et al. (2016). Studies of cross-country adoption and yield data also suggest a positive association between the two (Evenson and Gollin, 2003; Renkow and Byerlee, 2010; Fuglie and Marder, 2015). Evenson and Gollin (2003) estimate that 88% of the cereal yield growth in Asia between 1960 and 1986 was due to crop genetic improvements and the use of IVs, but only 28% for SSA, reflecting the limited role that IVs

have played in yield growth in SSA. Increasing the adoption of modern inputs is therefore considered an important policy goal.

There are many reasons for the low use of modern inputs and technology in African agriculture and significant differences exist across and even within countries (Sheahan and Barrett, 2017). Ultimately, the non-adoption of productivity improving technologies rests on a combination of economic (the technology is not profitable), institutional (regulatory barriers and poor governance may limit availability), and social constraints. Policy--or lack thereof-- can also be an important determinant of technology adoption. Providing subsidies and other incentives are the most direct ways that governments encourage IV adoption. More subtle are policies related to market competition and innovations that can lower prices and increase choices for farmers to suit their specific economy and agro-ecological needs.

Whether or not a given a policy or a set of policies has the desired outcome is an empirical question and is the focus of this study. Specifically. our interest is to understand the role that policy changes have had on the supply of improved maize varieties in Kenya. In particular, we examine whether market-friendly policies designed to encourage private sector participation in Kenya's seed sector have contributed to the improvements in maize productivity. Since the late 1990s, Kenya's market reforms have resulted in the entry of a number of private firms in the maize seed market and a marked increase in the number of IVs that have been released (Swanckaert, 2012). As shown in the following sections, of the 354 IVs of maize released between 1964 and 2015, 333 (94%) were introduced after 1999. One of the reasons is because number of IVs from public and private sector research has accelerated rapidly. Identifying the role of policy change in increasing the number of maize IVs and maize yields is the main objective of this paper.

Such an analysis is important for a number of reasons. First, the main rationale for liberalizing agricultural input markets has been to encourage competition, innovation, and

higher productivity. An analysis of productivity trends before and after liberalization will help establish whether this occurred in Kenya. Second, some have suggested that the liberalization policies for Kenya's seed markets have only been partially implemented as evidenced by the continued dominance of the Kenya Seed Company (a public sector firm) in the market (Swanckaert, 2012) and the presence of older maize varieties (Smale and Olwande, 2014). If it can be shown that there is an association between the number of new maize varieties released and increased productivity, it would lend support to further reforms that enable greater varietal releases in Kenya, as well as in other countries. For example, Gisselquist et al. (2013) contend that regulatory hurdles discourage firms from releasing new varieties in Africa, with the implication that it limits productivity. Finally, while there are a number of studies that assess the impacts of modern inputs, nearly all have been at the farm-level, seeking to understand either farm impacts or determinants of farm adoption. To our knowledge there has been no assessment of policies designed to increase input use at the macro-level of productivity in SSA.

As such in this paper, the macro-level determinants of maize productivity in Kenya are examined, with a focus on policies to encourage private sector participation and the role of improved varieties. The analysis consists of first examining production and yield trends to see whether yields changed post-liberalization by employing a yield model to relate national maize yields with a number of exogenous factors. As one of the explanatory variables--the number of varieties--is likely endogenous with yield. As a result, public research and development (R&D), the number of plant breeder's rights issued, and the years since the introduction of varieties as instrument variables for the number of varieties are presented in a two stage least square (2SLS) regression.

This paper proceeds by providing a background to maize production in Kenya, in particular a description of the maize seed system and policies and institutions affecting maize

development. Section 3 presents the empirical model relating policy change ion innovation and maize productivity to innovation. The results are discussed in section 4. Section 5 concludes the paper.

1. Background

2.1. *Maize in Kenya*

Maize is the main staple in Kenya, accounting for nearly 40% of the cultivated area, 2.4% of Kenya's GDP, and 12.65% of the agricultural GDP (FAO, 2016). More than 75% of the maize production comes from small farms, although only 20% of what is produced by smallholders is sold in the market (Chemonics International, 2010). Kenya's per-capita maize consumption (measured in kilograms [kg]) is estimated to average 103 kg/person/year (average for 2012-2014), compared to 73 kg/person/year for Tanzania, 52 kg/person/year for Ethiopia, and 31 kg/person/year for Uganda (FAO, 2016).

In spite of maize's importance for food security and Kenya's economy, maize productivity and production growth rates are well below global averages. Figure 1 plots the trends in production, area, and yields, while Figure 2 presents the same trends as indices (with 1961=100). As is evident from these trends, while production has increased from 1 MT in 1961 to 3.5 MT in 2015, much of it was due to the increase in area (increased by 180%) rather than yields (increased by 32%) (FAO, 2016).

[Insert Figure 1]

[Insert Figure 2]

Compared to other regions, Kenya's maize yield is below that for SSA as a whole, and even below the regional average for East Africa (Table 1). Maize yields in Kenya are even lower than what U.S. farmers were able to obtain prior to the widespread adoption of hybrid maize. Adoption rates of IVs appear to have leveled off at 70% since the mid-1990s in spite of the large number of new varieties that have been released since 1999 (Figure 3).

[Insert Table 1]

[Insert Figure 3]

The low yield growth, in spite of the increasing adoption of IV is peculiar, could be due to a variety of reasons. First, it could be that many farmers are using older varieties, even though modern varieties are available. Varietal turnover--not just simply seed replacement-- has been found to be important for increasing productivity (Smale and Olwande, 2014; Spielman and Smale, 2017). New varieties not only allow farmers to maintain the yield gains of the previous generation, but also help farmers to withstand new forms of pests and diseases, as well as drought and floods. The optimal rate of varietal turnover depends not only on the crop in question and environmental factors, but more importantly on economic factors. A weighted average[1] (WA) age of less than 10 years and adoption rates of 35% are generally considered indicators of good progress in plant breeding (Walker and Alwang, 2015)

Studies on varietal turnover for maize in Kenya suggest that the WA age has been declining but is still above 10 years. Smale and Olwande (2014) using a panel survey from 2004-2010 estimate the WA age at 17.3 years in 2010, while a more recent survey by Abate et al. (2017) estimate the WA age at 13 years for 2013. Our own estimates based on 2009 survey data from DIIVA[2] suggest the WA age at 19 years, with nearly 43% of the area cultivated by varieties that are 10 years old or less (Table 2)

[Insert Table 2]

Second, the new varieties that are adopted may not significantly improve yields of the varieties they replace (Figure 4). Karanja (1996) found for the 1960-1990 period that some

---

[1] Weighted average (WA) age is defined as $\sum_i p_{it} A_{it}$ where p_{it} is the proportion of the crop's area cultivated in variety i in year t,

[2] DIIVA--or the Diffusion and Impact of Improved Varieties in Africa--is a CGIAR led project that seeks to collect improved varietal adoption data in Africa. Details about the project and associated dataset is available from https://www.asti.cgiar.org/diiva

of the newer released varieties have small yield advantages, with research yields exhibiting a 'plateau' effect. For example, H626, which was released in 1989, had only a 1% yield advantage over H625, which had been released eight years earlier.

[Insert Figure 4]

Figure 5 presents more recent data on average research yields of released varieties as documented by KEPHIS. Average yields of high-altitude, late-maturing varieties have increased more than all varieties combined, although yields across all varieties have been stagnating and have even declined in more recent years.

[Insert Figure 5]

Finally the mere release of new IVs--whether private or public—on its own will not positively affect yields. To have a positive impact on overall yields, the new varieties have to be superior to what is currently being grown, widely adopted, and complemented with other inputs, especially fertilizer. Based on a survey of smallholder maize farmers in Kenya, Nyangena and Juma (2014) find that inorganic fertilizers and improved varieties result in an increase in maize yields if adopted as a package, rather than separately. Similarly, Muraoka et al. (2016) find significant positive impacts on land productivity in the highlands of Kenya from agricultural intensification (i.e., the use of high-yielding varieties, fertilizer and intercropping).

2.2. *Seed development and policies*

Maize has been grown in Kenya since the sixteenth century when it was introduced by Arab traders to the coastal areas; it expanded farther with the arrival of European settlers. By the mid-twentieth century, nearly 44% of Kenya's agricultural land was under maize cultivation-- a proportion that has not changed much since then. Formal development of the seed industry began in the 1950s when the colonial government initiated a maize research program in

western Kenya. Since then the industry has gone through distinct development phases that can be delineated by productivity growth.[3]

The initial phase, a period spanning from the early 1960s to the early 1980s saw relatively high productivity growth, averaging around 3% per year. The period was characterized by a strong national maize program involving inputs and supportive policies (Karanja, 1996, 2007). Pre-independence maize development was geared to the needs of large-scale farmers with the first hybrid (H611) being released in 1965 and widely adopted, especially in the high potential Highlands (Gerhart, 1975). After Kenya gained independence in 1963, additional varieties suitable for other agro-ecological conditions were released. The government's maize seed program was complemented by an extension program that introduced farmers to best agronomic practices (Karanja, 2007). This led many smallholders to adopt improved varieties. Their yields were lower than large-scale farmers due in part to the limited use of fertilizer (Karanja, 1996; Hassan and Karanja, 1997). This may explain why even though IV adoption was increasing in the initial periods, maize yields were fairly stagnant, averaging around 1200 kg/ha for much of the late 1960s and early 1970s. Productivity improved for the 1975 to 1982 period as IV adoption expanded to other areas. By the end of 1982, seven improved varieties were released as documented by the varietal registration records of KEPHIS.[4]

The second phase--from 1983 to 1999--experienced a decline in productivity even though there were more varieties released (Table 3). The new varieties, however, had a small yield advantage over the ones that they were intended to replace (Karanja, 1996). Other factors that have been cited for the decline in productivity growth include a decrease in maize

---

[3] Hassan and Karanja (1997) also characterize Kenya's maize industry going through different phases, but for different periods of time since their analysis was only up to 1991.

[4] There is some discrepancy in the literature as to how many varieties were released. Data from KEPHIS suggests 7 varieties were released between 1962 and 1982, while Karanja (2007) reports 17 were released and Hassan and Karanja (1997) report 13 were released.

research funding, reduced competitiveness of maize, droughts, and political instability (Hassan and Karanja, 1997; Karanja, 2007). During the 1980s, Kenya faced deteriorating macroeconomic conditions and a balance of payment problems that forced it to cut back on agricultural research, including research on maize. Real maize R&D expenditure fell from a peak of 232 thousand Kenyan shillings in the 1970s to 133 thousand by the mid-1980s (Karanja, 2007). This was also the period of Structural Adjustment programs and the general liberalization of the economy, whereby agricultural markets were deregulated and privatized, trade barriers were reduced, price distortions were removed, exchange rates were adjusted, and decentralization occurred. While liberalization was meant to encourage competition in markets and more efficient use of resources, it led to a weakening of some government institutions coping with limited resources (Gitau et al., 2009). Moreover, the private sector did not have the capacity to undertake the role that was formerly being performed by the government sector, resulting in poor performance of the agricultural sector and the economy as a whole (MAFAP, 2013)

The most recent phase--from 2000 onwards--can be regarded as a period of renewal, with productivity growth reversing the trends of the prior decade. This post liberalization period involved measures that sought to rationalize and consolidate the policies instituted during earlier periods (MAFAP, 2013). Munyi and Jonge (2015) document 131 pieces of legislation that have been overhauled since 2000, many of them through a consultative process of the different stakeholders involved as noted by Gitau et al. (2009). Some of these changes were part of the government's Strategy for Revitalizing Agriculture that was initiated in 2005. There were two notable shifts that occurred under SRA (MAFAP, 2013; Poulton and Kanyinga, 2014). First, Kenya was to move away from the goal of achieving food self-sufficiency (the objective that guided much of the agricultural policy in earlier periods) to one that emphasized wealth creation and employment generation as a way to ensure food security.

Second, private and public sectors were to play complentary roles to ensure efficient functioning of markets and optimal resource allocation. Under SRA, the public sector was to provide a limited number of goods and services, and a reduced but more focused approach to regulating the market that cannot be achieved through private self-regulation (Alila and Atieno, 2006; MAFAP, 2013).

Policies that directly affect the supply and demand of improved maize varieties have also evolved over the years. Many of these policies relate to varietal trade, registration, and eventual release of varieties to farmers as most varieties are developed abroad and need to be imported. Prior to liberalization, while foreign germplasm and knowledge transfer was encouraged, the import of maize varieties was severely restricted. Like many import substitution policies, the goal was to promote the development of a local seed industry, but in reality only the Kenya Seed Company (KSC)--a government-owned parastatal created in 1956--benefited. It had exclusive rights to market maize varieties developed by the Kenyan Agricultural Research Institute (KARI). Even to this day almost two decades after liberalization, KSC maintains exclusive rights to popular varieties developed by public breeding programs. Nevertheless, by 2015, there were 19 companies that had released 157 varieties and accounted for 32% of the market share (TASAI [The African Seed Access Index], 2016).

The focus of policy reform has been on the ease and speed by which new varieties are made available to farmers. In Kenya, the introduction of new seed varieties is regulated under the 1972 Seed and Plant Varieties Act (SPVA) and its subsequent amendments, which require that firms submit them for official tests for value in cultivation and use (VCU). Varietal testing and registration is meant to ensure the genetic identity of a variety while protecting consumers, farmers, and the environment from inferior varieties. Prior to liberalization, the approval and certification process was under the domain of KARI's National Seed Quality

11

and Control Board. Reforms during the late 1990s relegated these responsibility to KEPHIS-- a newly created independent regulatory body.

Despite the administrative change, the process of the registration of new varieties in Kenya is long and costly (Gisselquist et al., 2013; Smale et al., 2013). According to a survey by TASAI it took, on average, 32 months for a variety to go through the release process in 2016 in Kenya, but only 19.5 months in neighboring countries such as (TASAI, 2016). The total cost of registering and releasing a new variety is estimated to be nearly US$3,240, or about 123% of Kenya's per-capita income (World Bank, 2017).

A key provision of the 1972 SPVA was plant breeder's rights (PBRs) as a way to protect the intellectual property of breeders and growers. However it was not until 1995 that regulations relating to PBR provisions in the 1972 SPVA were put in place, leading to the first granting of such rights in 1997 (Munyi and Jonge, 2015). Initially, Kenya acceded to UPOV under the 1978 convention and to the 1991 UPOV convention when the SPVA was amended in 2012. Kenya's PBR legislation allows for the use of protected material for research, but prohibits the unauthorized marketing of "essentially derived varieties"; that is, varieties that are distinct from, but based almost entirely upon protected varieties (Swanckaert, 2012). Furthermore, it recognizes "farmers' privilege" allowing them to save seeds of a protected variety, but not exchange it with other farmers (Munyi and Jonge, 2015).

Besides South Africa, Kenya is the only other country in Africa to have a system in place to grant PBRs that are issued by KEPHIS and are available for all new plant varieties as long as they meets the criteria of being distinct, uniform, and stable (DUS). From the time PBRs came into force in 1997 and up until 2014, a total of 1384 PBRs were issued, of which 154 were for maize (or 11%) (Figure 5). PBRs for maize account for the majority of the PBRs issued for food crops.

Advocates for PBRs argue that they will stimulate research investments, and will allow for greater flows of foreign-sourced technology and a more competitive market. This will eventually lead to a greater number of yield-increasing varieties. The evidence on the productivity impacts of PBRs in the United States and Canada suggests that there may be a small positive impact, but this may depend on the crop being studied (Spielman and Ma, 2014). For example, Perrin et al. (1983), Carew and Devadoss (2003), and Naseem et al. (2005) find limited positive yield impacts of PBRs on soybean, cotton, and canola, respectively. However the evidence is more mixed for wheat, where Alston and Venner (2002) find no evidence of a positive impact of PBRs on yields, while Kolady and Lesser (2009) do.

Along with policy and regulatory changes that affect the introduction of new maize varieties, policies related to the marketing and trade of maize were also being reformed. Before liberalization, maize prices were heavily controlled and set by the government that affect everyone along the maize value chain. Maize was marketed by the government's National Cereals and Produce Board (NCPB), which had a monopoly over all aspects of internal and external trade. Private trade across districts was illegal, except for permit holders. Such a regulated environment severely distorted the maize market and reduced the incentives for farmers to innovate and adopt productivity enhancing technologies.

Maize market reforms that were initiated in the late 1980s intensified during much of the 1990s (Nyangito and Karugia, 2002; Ariga and Jayne, 2009; Aylward et al., 2015). Early on, the reforms under the Cereal Sector Reforms Program were designed to allow for interdistrict private trade and a reduced role for NCPB in the procurement of maize. However, prices were still controlled by NCPB and rather than increasing the margin between purchase and selling price to encourage private participation, margins declined (Sheahan et al., 2016). Further reforms were implemented in the mid-1990s that allowed for

the free movement of maize, and the removal of both price controls and direct subsidies to millers.

The private sector was allowed to import maize but faced a changing tariff structure. Initially, the maize import tariff was removed in 1993, but was reimposed in 1995. Jayne et al. (2008) find that the maize import tariff over the 1995-2004 period raised average domestic prices by roughly 4%, although in several particular years, the import tariff caused domestic prices to increase by well over 10%. More recent trade measures have included the removal of tariff barriers with neighboring countries. Nevertheless, the government continues to impose tariffs and export bans often in an unpredictable fashion.

Alongside reforms specific to the maize market, the fertilizer market has also been subject to considerable policy changes. Before market reforms, the market was controlled by government-run agencies with limited private trade and controlled (subsidized) prices. Due to mismanagement, weak distribution networks, and poor coordination, fertilizer did not reach many farmers. Reforms introduced in the early 1990s sought to address this as restrictions on private traders, tariffs, and price controls were either abolished or considerably relaxed. As a result, by 1996, there were 12 major importers, 500 wholesalers, and nearly 5,000 retailers (Ariga and Jayne, 2011). Fertilizer consumption grew at nearly 10% per year between 1990 and 2005, nearly double the rate 15 years prior (FAO, 2016).

More recent policies and programs directed at maize and fertilizer markets have sought to target resource-poor smallholders, often by providing input subsidies. In particular, after the 2008 world food price crisis and 2009 post-election violence, the government intervened to aid farmers. Nearly 30,000 tonnes of fertilizer were imported and distributed via NCPB branches and private retailers at a 40% subsidy. However, the subsidies through NCPB have been found to lack clear targeting criteria and have been diverted to non-targeted beneficiaries by as much as 33% (Jayne et al., 2013).

3. Empirical analysis

Crop productivity is a function of a number of exogenous factors, such as the types and amount of inputs used, agro-climatic conditions, technology employed, and the incentives/disincentives created by the policy environment. It is hypothesized that the policy reforms that led to the opening of markets, technology development (in the form of new varietal releases), and PBRs all had an impact on maize yields. Testing this hypothesis, however, is challenging for a number of reasons. First, the process of reforms takes time and its effects may not be evident until years later. As discussed earlier, liberalization of the agricultural sector in Kenya began in the late 1980s but was enacted slowly and with considerable hesitancy, especially with regards to maize marketing and trade. Second, policy reform is a broad concept that involves changes to a number of different specific policies that may or may not have an impact on productivity. It is unclear, for example, whether reforms directed at removing price distortions (price policy) have the same impact on productivity as those that seek to improve access to technology to farmers (technology policy). If technology policy is more important to increasing productivity than price policy, and the latter is implemented first in the reform process, then the impacts of policy reforms may not be evident until after the technology policy comes into force. As such, there needs to be clarity in terms of what is meant by policy reforms and when a specific policy change occurs. Third, data required to perform such a hypothesis test may not be available. For example, in a model that relates national maize yields to input use over time would require actual inputs (fertilizer, pesticides, labor) used by maize farmers, details on their use of improved varieties (how old, whether private or public, whether hybrid or not), and the agro-climactic conditions faced. Although farm-level surveys of input use have been carried out by different researchers, consistent aggregate-level data specific for maize production is not available.

With these considerations in mind, the following general yield model can be used:

$$Y_t = \beta_{0t} + \beta_{1t}RAINFALL_t + \beta_{2t}FERTILIZER_t + \beta_{3t}IV\_MAIZE_t +$$

$$\beta_{4t}P\_MAIZE_{t-1} + \beta_{5t}VAR\_MAIZE_t + u_t,$$

(1)

where Y_t is the national maize yield for Kenya in kg/ha in year t. $RAINFALL_t$ is the total

rainfall amount (mm) for Kenya in year t. Almost all agricultural production in Kenya is

rainfed, since less than 0.5% of the arable land is irrigated. While rainfall is an important

factor in yield, the aggregate nature of this specific variable may misrepresent the actual

rainfall received in maize-growing regions located in the western (Highlands) part of the

country, which are likely to be higher, as they benefit from bi-modal rainfall patterns (from

short and long rain seasons). In the absence of such more detailed micro level rainfall data for

the time period under study, average rainfall is used as a proxy. $FERTILIZER_t$ is the amount

of total fertilizer consumed (kg/ha of maize area) in year t and is constructed by dividing the

total fertilizer nutrient (NPK) consumed in Kenya by the maize area.. The variable

$FERTILIZER_t$ is an approximation for the actual fertilizer used by maize farmers as the

consumption is for all crop production, not just maize. However since 50% of the fertilizer

consumption is for maize (Oseko and Dienya, 2015) and maize is the most widely grown

crop by area, it is likely to be a good approximation of fertilizer use for maize. Indeed, the

fertilizer consumption variable constructed here corresponds to those reported in farm-level

surveys (Ariga and Jayne, 2011). IV_MAIZE_t is the share of maize area under improved

varieties. The data for this variable come from the DIIVA project, which uses secondary

sources and survey data to create a time series of area under modern varieties for different

crops. It is assumed that the share for all years between the two survey points is constant,

resulting in the step-wise logistic curve as depicted in Figure 3. Given the lack of continuous

and reliable time series on improved varietal adoption, total maize area ($AREA_t$) is used as an

alternative measure of maize cultivation P_MAIZE_{t-1}, which is the average producer price of maize in year *t-1*. Finally, VAR_MAIZE_t is the total number of new maize varieties released in year *t*.

There are two issues with the last of these variables that need further elaboration. First, the number of maize varieties released provides little information on their adoption, as many released varieties may never get adopted. Data limitations prevent obtaining an annual estimate of how many of the released varieties are being adopted, but estimates from DIIVA from 2009 provide some indication. Of the 204 varieties that had been released and approved for cultivation up to that year, only 65 varieties were being grown. Of these, 5 varieties accounted for 65% of the cultivated area (see Table 1).

A second issue is that VAR_MAIZE_t is likely to be endogenous in equation (1) and the point estimates will be biased and inconsistent. Endogeneity is suspected here because there may be unobservable factors that jointly determine yield (Y_t) as well as the number of varieties (VAR_MAIZE_t). For example, greater spending on research and technology development would lead to an increase in higher yielding varieties, and to more varieties and varietal choice. In order to control for such endogeneity, a two-stage least squares (2SLS) regression approach is used to introduce instrumental variables that are determinants of the number of varietal releases, but do not affect maize yields directly.

A two-stage least squares estimation involves a first-stage regression of VAR_MAIZE_t on all exogenous variables plus variables to be used as instruments. Some candidates for exclusion restrictions are: R&D expenditures related to maize development (or alternatively the number of researchers), varieties released by private firms, and varieties protected by PBRs. All three variables are also related to policy change. Greater R&D--both public and private--would be suggestive of a policy shift that seeks to focus on increasing the productivity of agriculture and maize specifically. Unfortunately, a continuous time series for

17

private R&D is fairly recent. Even so, the amount of private R&D expenditure is estimated to be extremely small relative to public R&D (US\$1.6-US\$3.2 million vs. US\$263 million in 2008 as reported by Pray et al., 2011). We also do not have research expenditures by commodity. Given these limitations, total agricultural expenditures by the public sector in year t is used as one of the instruments (denoted as $RESEARCH_t$ measured in constant 2011 U.S. million dollars).

As noted earlier, in the pre-reform period, there were no private firms developing or marketing maize seeds. This changed around 1996 with the first private variety being released. The presence of private firms is captured by a dummy variable ($PRIVATE_t$) to indicate the release of varieties by private firms since 1996 (1 for ≥1996; 0 otherwise). Finally, PBRs are a policy tool in their own right--would also indicate the availability of productive and valuable varieties. Kenya has been providing PBRs since 1996, issuing 154 PBRs for maize between 1996 and 2014. However, not all PBR-protected varieties are released and not all released varieties have a PBR associated with them. Since only released varieties would impact productivity, we use the cumulative number of released varieties with PBRs in year t as the instrument (denoted as PBR_t).

4. Results and discussion

The empirical analysis on factors determining yield are explained under two sets of specifications and derived from equation (1) using both OLS and 2SLS as presented in Table 5. The only coefficient that is significant (at the 10% level) in the OLS regressions that directly accounts for yield is the lagged maize price. As one would expect, higher prices give rise to the intensification of external inputs use or through expansion of acreage. More specifically, yields increase by 1.9–2.1 kg/ha from a 1% increase in producer maize prices. Intensification can occur through the higher use of inputs such as fertilizer, high yielding seeds, pesticides, or labor. Since the coefficients on fertilizer and share of maize to improved

18

varieties are not significant (and negative for IV_MAIZE_t), it would appear that intensification is occurring through higher labor use or some other input not accounted for here (such as manure) and not due to the use of improved varieities. Maize area ($AREA_t$) is found to be negative and insignificant (Table 5). This would suggest that although maize acreage has been increasing over time, the expansion includes maize that is being grown in less productive regions with less productive cultivars resulting in increased yield variability across different agro-climatic zones (Abate et al., 2015).

[Insert Table 4]

For two sets of 2SLS estimates, yields are positively impacted by a lagged maize price variable.[5] Also, the number of maize varietal releases and fertilizer consumption are significant at the 1% and 10% level, respectively. Although there is a change in the signage of the share of improved varieties from the OLS estimates, the results still remain insignificant with high standard errors. Inclusion of area cultivated slightly improves the overall model estimation. As discussed above, all of the selected instruments (public R&D expenditures, presence of private firms, and plant breeder's rights that affect VAR_MAIZE_t directly) are also expected to impact yield (Y_t) besides the number of varities released. From the results of the first stage estimation of on varietal releases only the coefficient on the plant breeder's rights variable is found to be significant (see Appendix Table A1). This suggests that PBRs are incentivizing breeders to release more varieties, as evidenced in the literature. The insignificance of the $RESEARCH_t$ coefficient is surprising, but one should note that it is measuring total public R&D and that the dependent variable is the total number of varietal releases (both private and public). Because all the variables in the dataset by type (i.e., public

---

[5] Note the inclusion of maize area growth has further strengthened the validity of maize prices on yield increases.

and private) cannot be differentiated, public R&D may be an inefficient predictor of total releases.

To justify the appropriateness of the use of 2SLS over OLS, a series of post-estimation tests are performed for both specifications. First, endogeneity tests for VAR_MAIZE_t with the null hypothesis that it can be treated as exogenous is rejected (Durbin (score) χ^2=11.3 (p=0.008; Wu-Hausmann F = 12.6 (p=0.0010)). Second, using F statistic for the joint significance on the coefficients of the additional instruments F(2,41)=12.1 with p=0.000, the null hypothesis that the instruments are weakly identified can be rejected. Finally, in the test for over-identifying restriction, under the null hypothesis that the instrument set is valid and the model is correctly specified, the p values for both the Sargan (score) (χ^2=3.83 p=0.1470) and Basmann (χ^2=3.48 p=0.1755) are greater than 10%, suggesting that the model is indeed valid. Similar post-estimation results are obtained when maize area ($AREA_t$) is used instead of IV_MAIZE_t.

The key question to answer here is what is one to make of the negative but significant coefficient on the number of maize varieties released over years VAR_MAIZE_t and the relationship to yield levels of maize? Taken at face value, an additional varietal release decreases yields by 15-17 kg/ha; which suggests a disconnect between yield gains and new cultivar releases. As has been suggested previously, this could be because newer varieties offer small yield advantages over the previously released improved varieties (Ariga and Jayne, 2011), and tht not many varieties were developed to address the agro-ecological concerns, including not issues related to varieties suitable for maize-based intercropping resulting in poor genetic gains. Furthermore, since not all released varieties are adopted and the negative coefficient is likely to account for the non-adoption of new varieties. Note that that the share of maize area due to improved varieties while positive is insignificant. Since the share has not changed much over the last 20 years and already is above 70%, the yield

gains from increasing improved varietal share are not going to be large if the same (older) varieties are going to be adopted.

5. Conclusions

Since the early 1990s, Kenya has undertaken a number of reforms to liberalize its agricultural markets with a view of improving productivity. Agricultural input markets that were previously heavily regulated with little private sector participation have undergone dramatic changes, especially the maize seed market. Since 1999, for example, 333 improved varieties have been released, compared to 21 in all the years prior. Nearly half of the varieties released since 1999 have been due to private firms.

While policy reforms have been largely focused on improving the supply of new varieties and varietal development, it is unclear whether it has had the desired productivity impact. In this paper, this question is addressed directly by relating Kenya's national maize yields with a number of exogenous factors, including those that are influenced by policy changes. The results of the 2SLS regression--where the first stage relates how different policies impact the development of new varieties and second stage on how those varieties influence yields--suggest that the release of new varieties does not affect yields. The lack of an increase in yield due to new varietal releases is surprising, considering newer releases are often regarded as being productive than the older ones they replace.

However the results are plausible when one considers that the adoption of the released varieties has not been widespread and that the yield advantage for many of the released varieties (over existing varieties) has been marginal. This suggests greater R&D investments to improve the productivity of new varieties and better traits for managing biotic and abiotic stresses. Policy needs to be directed toward encouraging the adoption of new varieties, specifically targeted to replace older or 'tired' varieties of maize. This requires concerted

extension and dissemination efforts supported by the Ministry of Agriculture, the private sector, and local administrative officials.

Although Kenya has reformed its seed sector through liberalization, the government parastatal (Kenya Seed Company) still controls nearly 70% of the seed market, distributing seeds at subsidized prices. Under these circumstances, private firms are unable to compete effectively and are discouraged from making investments that would allow them to introduce new varieties. Further policy reforms are therefore needed to enable more private firm entry and to make the market more competitive.

References.

Abate, T., Fisher, M., Abdoulaye, T., Kassie, G. T., Lunduka, R., Marenya, P., and Asnake, W. (2017), "Characteristics of maize cultivars in Africa: How modern are they and how many do smallholder farmers grow?," *Agriculture and Food Security,* Vol. 5, No. 1, pp. 30.

Abate, T., Mugo, S., Groote, H. D., and Ragasa, C. (2015), "Maize in Kenya: Chance for Getting Back to Former Glory?," *DT Maize: A Quarterly Bulletin of the Drought Tolerant Maize for Africa Project (DTMA),* 4.

Alila, P. O., and Atieno, R. (2006), "Agricultural policy in Kenya: Issues and processes," paper presented at the Future Agricultures Consortium Workshop, Nairobi, Kenya.

Alston, J. M., and Venner, R.J. (2002), "The effects of the U.S. Plant Variety Protection Act on wheat genetic improvement," *Research Policy,* Vol. 31, No. 4, pp. 527-542.

Ariga, J., and Jayne, T.S. (2009), "Private sector responses to public investments and policy reforms: The case of fertilizer and maize market development in Kenya, IFPRI, Washington, DC.

Ariga, J., and Jayne, T.S. (2011), "Fertilizer in Kenya: Factors driving the increase in usage by smallholder farmers," in Chuhan-Pole, P. and Angwafo, M. (Eds.), *Yes Africa Can: Success Stories from a Dynamic Continent*, World Bank, Washington, DC.

Aylward, C., Biscaye, P., Harris, K. P., LaFayetter, M., True, Z., Anderson, C. L., and Reynolds, T. (2015), "Maize yield trends and agricultural policy in East Africa: Macro-level literature review for six countries," EPAR, University of Washington, Seattle, WA.

Carew, R., and Devadoss, S. (2003), "Quantifying the contribution of plant breeders' rights and transgenic varieties to canola yields: Evidence from Manitoba," *Canadian Journal of Agricultural Economics,* Vol. 51, No, 3, pp. 371-395.

CGIAR. (2015). "CGIAR's DIIVA Project: A consolidated database of crop varietal releases, adoption, and research capacity in Africa south of the Sahara," ASTI/IFPRI/CGIAR, Washington, DC.

Chemonics, International. (2010), "Staple foods value chain analysis: Country report, Kenya. USAID, Washington, DC.

Doss, C., Mwangi, W., Verkuijl, H., and De Groote, H. (2003), "Adoption of maize and wheat technologies in East Africa: Synthesis of East African adoption studies" working paper 03-02, CIMMYT, Mexico City.

Evenson, R.E., and Gollin, D. (2003), "Assessing the impact of the Green Revolution, 1960 to 2000," *Science,* Vol. 300, No. 5620, pp. 758-762.

FAO. (2016). *FAOSTAT*, FAO, Rome.

Fuglie, K., and Marder, J. (2015), "The diffusion and impact of improved food crop varieties in Sub-Saharan Africa," in Walker T. and Alwang, J. (Eds.), *Crop Improvement, Adoption and Impact of Improved Varieties in Food Crops*., CABI, Wallingford, UK.

Gerhart, J. (1975), "The diffusion of hybrid maize in Western Kenya," CIMMYT, Mexico City.

Gisselquist, D., Pray, C., Nagarajan, L., and Spielman, D. (2013), *"*An obstacle to Africa's Green Revolution: Too few new varieties," available online at SSRN website.

Gitau, R., Kimenju, S., Kibaara, B., Nyoro, J., Bruntrup, M., and Zimmermann, R. (2009), "Agricultural policy-making in Sub Saharan Africa: Kenya's past policies," Tegemeo Institute of Agricultural Policy and Development, Nairobi, Kenya.

Gitonga, Z. M., and De Groote, H. (2016), "Role of hybrid maize adoption on food security in Kenya: An application of two-step generalized method of moments," paper presented at the International Conference of the African Association of Agricultural Economists, Addis Ababa, Ethiopia.

Hassan, R.M., and Karanja, D.D. (1997), "Increasing maize production in Kenya: Technology, institutions, and policy," in Byerlee, D. and Eicher, C. (Eds.), *Africa's Emerging Mziae Revolution*, Lynne Reinner Publishers, Boulder, Colorado.

Jayne, T.S., Mather, D., Mason, N., and Ricker-Gilbert, J. (2013), "How do fertilizer subsidy programs affect total fertilizer use in sub-Saharan Africa? Crowding out, diversion, and benefit/cost assessments," *Agricultural Economics,* Vol. 44, No. 6, pp. 687-703.

Jayne, T.S., Myers, R.J., and Nyoro, J. (2008), "The effects of NCPB marketing policies on maize market prices in Kenya," *Agricultural Economics,* Vol. 38, No. 3, pp. 313-325.

Karanja, D.D. (1996), "*An economic and institutional analysis of maize research in Kenya,"* Michigan State University, East Lansing, Michigan.

Karanja, D.D. (2007), "The impact of public investment in maize research in Kenya," in P. Anandajayasekeram, P., Rukani, M., Babu, S., Liebenberg, F., and Keswani, C. (Eds.), *Impact of Science on African Agriculture and Food Security*. CABI, Wallingford, UK.

Kolady, D.E. and Lesser, W. (2009), "But are they meritorious? Genetic productivity gains under plant intellectual property rights," *Journal of Agricultural Economics,* Vol. 60, No.l 1, pp. 62-79.

MAFAP. (2013), "Review of food and agricultural policies in Kenya, 2005-2011," FAO, Rome.

Mathenge, M. K., Smale, M., and Olwande, J. (2014), "The impacts of hybrid maize seed on the welfare of farming households in Kenya," *Food Policy,* Vol. 44, pp. 262-271.

Munyi, P. and Jonge, B.D. (2015), "Seed system support in Kenya: Consideration for an integrated seed sector development approach," *Journal of Sustainable Development,* Vol. 8, No. 2, pp. 161-173.

Muraoka, R., Matsumoto, T., Jin, S., and Otsuka, K. (2016), "On the possibility of a maize Green Revolution in the Highlands of Kenya: An assessment of emerging intensive farming systems," in Otsuka, K. and Larson, D. (Eds.), *Pursuit of an African Green Revolution*, Springer, Amsterdam, pp. 145-164.

Naseem, A., Oehmke, J.F., and Schimmelpfennig, D.E. (2005), "Does plant variety intellectual property protection improve farm productivity? Evidence from cotton varieties," *AgBioforum,* Vol. 8, No. 2/3, pp. 100-107.

Nyangena, W. and Juma, O.M. (2014), "Impact of improved farm technologies on yields: The case of improved maize varieties and inorganic fertilizer in Kenya," SIDA, Stockholm, Sweden.

Nyangito, H.O. and Karugia, J.T. (2002), :The impact of recent policy changes on the agricultural sector and public agricultural research in Kenya," in Bigman. D. (Ed.), *Globalization and the Developing Countries: Emerging Strategies for Rural Development and Poverty Alleviation*, CABI, Wallingford, UK.

Oseko, E. and Dienya, T. (2015), "Fertilizer consumption and fertilizer use by crop (FUBC) in Kenya," Africafertilizer.org.

Perrin, R.K., Hunnings, K.A., and Ilhnen, L.A. (1983), "Some effects of the U.S. plant variety protection act of 1970," North Carolina State University, Raleigh, North Carolina.

Poulton, C. and Kanyinga, K. (2014), "The politics of revitalising agriculture in Kenya," *Development Policy Review,* Vol. 32, No. s2, pp. s151-s172.

Pray, C., Gisselquist, D., and Nagarajan, L. (2011), "Private investment in agricultural research and technology transfer in Africa," paper presented at the ASTI/IFPRI-FARA Conference, Accra, Ghana.

Renkow, M. and Byerlee, D. (2010), "The impacts of CGIAR research: A review of recent evidence," *Food Policy,* Vol 35, No. 5, pp. 391-402.

Sheahan, M., Ariga, J., and Jayne, T.S. (2016), "Modeling the effects of input market reforms on fertiliser demand and maize production: A case study from Kenya," *Journal of Agricultural Economics,* Vol. 67, No. 2, pp. 420-447.

Sheahan, M. and Barrett, C. B. (2017), "Ten striking facts about agricultural input use in Sub-Saharan Africa," *Food Policy,* Vol. 67, Supplement C, pp. 12-25.

Smale, M., Byerlee, D., and Jayne, T. (2013), "Maize revolutions in Sub-Saharan Africa," in Otsuka K. and Larson, D. (Eds.), *An African Green Revolution: Finding Ways to Boost Productivity on Small Farms* (pp. 165-195). Springer, Amsterdam, pp. 165-196.

Smale, M., and Olwande, J. (2014), "Demand for maize hybrids and hybrid change on smallholder farms in Kenya," *Agricultural Economics,* Vol. 45, No. 4, pp. 409-420.

Spielman, D. and Ma, X. (2014), "Intellectual property rights, technology diffusion, and agricultural development: Cross-country evidence, IFPRI, Washington, DC.

Spielman, D. and Smale, M. (2017), "Policy options to accelerate variety change among smallholder farmers in South Asia and Africa south of the Sahara," IFPRI, Washington, DC.

Swanckaert, J. (2012), "Effects of the liberalization on maize production system in Kenya: 1990-2010," University of Ghent, Ghent, Belgium.

The African Seed Access Index [TASAI]. (2016), TASAI-Kenya brief," TASAI, Nairobi, Kenya.

Walker, T.S., and Alwang, J., Eds. (2015), *Crop Improvement, Adoption, and Impact of Improved Varieties in Food Crops in Sub-Saharan Africa,* CABI, Oxfordshire, UK.

World Bank. (2017), "Enabling the business of agriculture," World Bank, Washington, DC.

Appendix

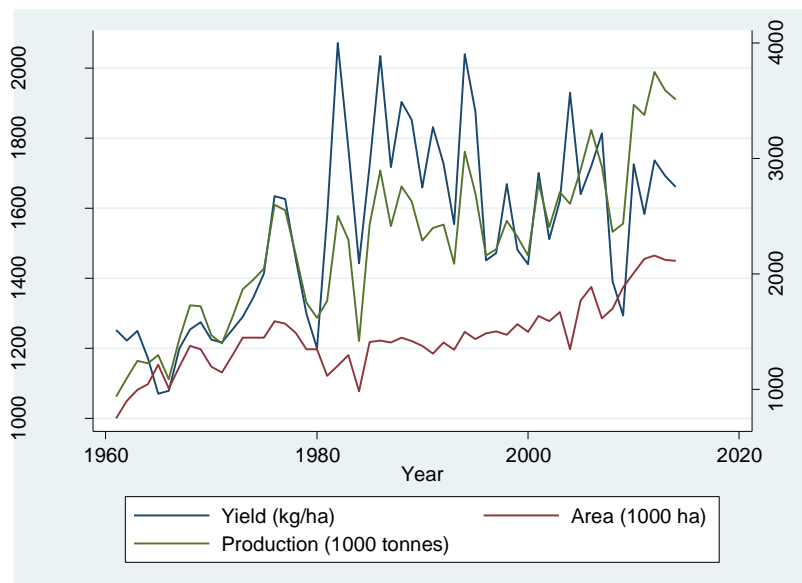**[Insert Appendix Table A1]**

FIGURES

Figure 1. Trends in maize yields, production and area for Kenya (1961-2015)

Source: FAO (2016).
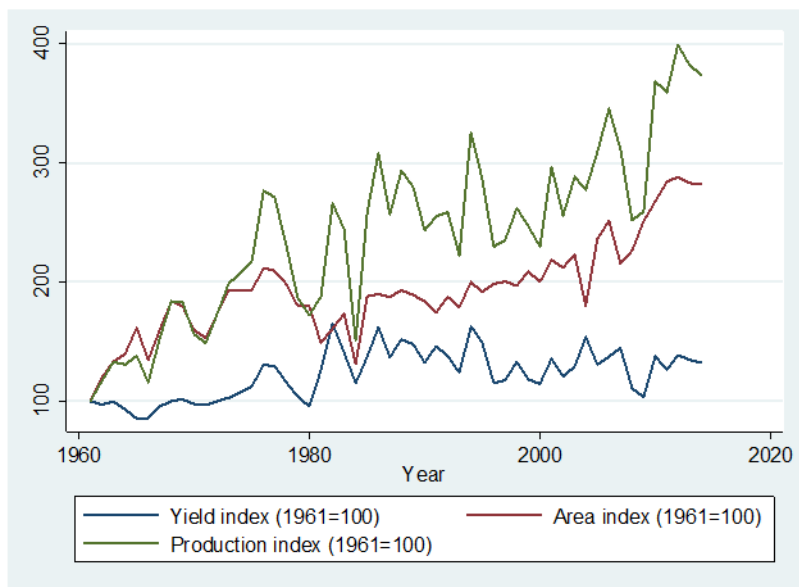
Figure 2: Trends in maize yield, production and area indices for Kenya (1961=100; 1961-2015)

Source: FAO (2016).
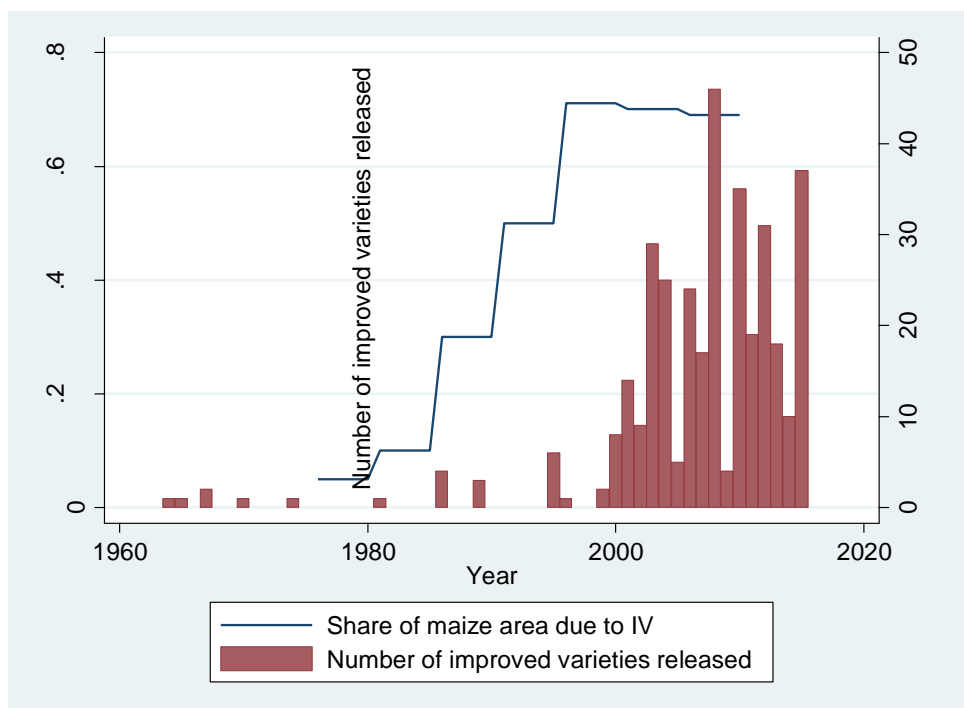
Figure 3. Adoption of IV of maize and release of new maize varieties (1961-2014)

Source: Authors based on data from DIIVA (2015) and KEPHIS (2016).
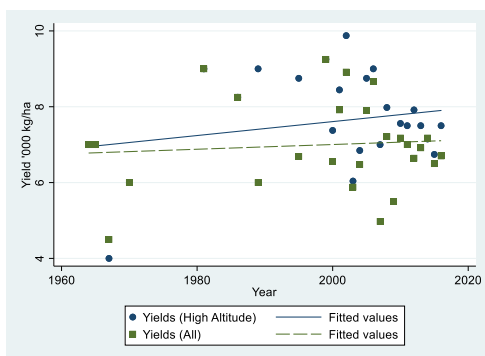
Figure 4. Average experimental yields of released varieties (1960-2015)

Source: Generated using KEPHIS (2009)

Note: Each scatter point represents the average experimental yield of varieties released that year. We differentiate between all released varieties and varieties intended for the high altitude (high potential) areas.
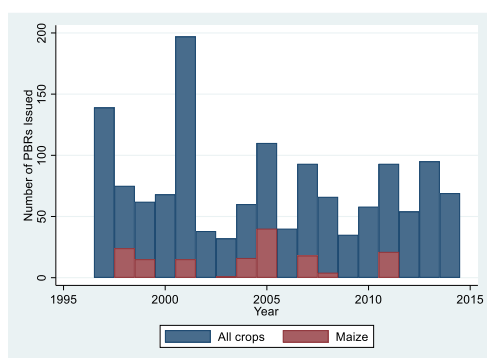
Figure 5. Number of plant breeders' rights issued in Kenya (1997-2014)

Source: Generated using UPOV (2016).

TABLES

35

Table 1. Maize yields by key regions (2010-2014)

Region / Country	Average Yields (kg/ha) 2010-2014
Asia	4896
Sub-Saharan Africa	2188
East Africa	1772
Kenya	1680
West Africa	1631
Southern Africa	4238
Latin America	3912
North America	9444
Europe	6249
World	5268

Source: FAO (2016)

Table 2. Maize varietal adoption in Kenya (1993 and 2009)

	1993		2009	
	Variety	% Area	Variety	% Area
By Variety				
	H614D	41.8	H614D	22.6
	H625	22.9	SC DUMA 411	7.2
	H626	12.8	H624	4.7
	H511	7.2	Katumani	3.8
	Katumani	5.3	H6210	3.1
	Rest (5 var)	7.6	Rest (60 var)	35.5
	Total	97.6	Total	76.9
By Type (Public vs. Private)				
Public				
(KARI/KSC)	100		74.8	
Private			25.2	
Seedco			9.8	
Pannar Seed			7.3	
Pioneer			3.9	
Western Seed Company			3.8	
Monsanto			3.7	
By Age				
< 10 years	55.4		42.7	
10-20 years			14.2	
> 20 years	42.8		43.1	
Weighted Age	23		19	

Source: Hassan and Karanja (1997) for 1993 and CGIAR (2015) for 2009

Table 3. Growth rates (%/yr) of Maize yield, area and production (1962-2014)

	1962-1982	1983-1999	2000-2014	1962-2014
Yield	2.99%	-0.86%	1.72%	1.40%
Area	2.89%	2.28%	2.62%	2.62%
Production	5.97%	2.27%	3.91%	4.20%
Varieties Released	7	16	294	317

Source: Yield, area and production growth rates calculated from FAO (2016). Varietal release data from KEPHIS.

Table 4: List of variables used in regression analysis

Variable	Definition	Data Source	Mean	Std. Dev.
Y_t	Maize yield (kg/ha)	FAO	1555.47	258.60
$FERTILIZER_t$	(Log) Fertilizer consumption (kg/ha)	FAO	3.04	0.56
$RAINFALL_t$	Rainfall amount (mm)	World Bank	54.87	8.85
P_MAIZE_{t-1}	(Log) Maize price (US\$/tonne)	FAO	4.80	0.61
IV_MAIZE_t	Share of maize area under improved varieties (IV)	DIIVA	0.36	0.31
$AREA_t$	Maize area ('000 ha)	FAO	1487.23	282.30
VAR_MAIZE_t	Number of maize varieties releases in year t	KEHPIS	6.22	10.87
$RESEARCH_t$	Public agricultural R&D expenditures (2011 US\$ millions)	ASTI	190.78	60.89
PBR_t	Number of released maize varieties protected by PBRs	UPOV & KEPHIS	13.73	20.05
$PRIVATE_t$	Dummy variable to indicate private varieties (1 if >1996, 0 otherwise)	KEPHIS	0.33	0.48

Number of observation for all variables is 51, except maize price (50 observations) which was lagged by 1 year.

Table 5. Results of the yield function; dependent variable Y_t

VARIABLES	(1) OLS	(2) 2SLS	(3) OLS	(4) 2SLS
VAR_MAIZE_t	-4.53	-17.11***	-3.13	-15.54**
	(3.863)	(6.018)	(4.0071)	(6.715)
$FERTILIZER_t$	157.19	248.83*	140.98	237.08*
	(113.966)	(133.658)	(102.858)	(122.877)
$RAINFALL_t$	3.67	4.644	3.85	4.53
	(3.670)	(3.954)	(3.616)	(3.849)
P_MAIZE_{t-1}	186.40*	194.51*	214.97**	200.51**
	(103.409)	(109.248)	(95.550)	(100.073)
IV_MAIZE_t	-105.47	12.55		
	(225.963)	(242.693)		
$AREA_t$			-0.27	-0.03
			(0.186)	(0.210)
Constant	53.30	-281.8	247.53	-234.43
	(499.295)	(576.301)	(340.096)	(438.878)
Observations	50	49	50	49
R-squared	0.306	0.069	0.326	0.1124

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

Table A1. Reduced form (first stage) estimates; dependent variable VAR_MAIZE_t

VARIABLES	(1)	(2)
$FERTILIZER_t$	4.839	4.169
	(3.479)	(3.464)
$RAINFALL_t$	0.0701	0.073
	(0.114)	(0.115)
P_MAIZE_{t-1}	-3.111	-3.604
	(3.115)	(3.206)
IV_MAIZE_t	-10.79	
	(10.83)	
AREA		-0.0012
		(0.006)
$RESEARCH_t$	0.0142	-0.017
	(0.0413)	(0.0278)
PBR_t	0.379***	0.334**
	(0.131)	(0.130)
$PRIVATE_t$	6.935	7.216
	(4.438)	(4.481)
Constant	-3.857	4.602
	(16.42)	(15.422)
Observations	49	49
R-squared	0.702	0.695

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