IMPACT OF SEED INNOVATION AND POLICES ON MAIZE YIELDS IN KENYA

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A thesis submitted to the

Graduate School-New Brunswick

Rutgers, the State University of New Jersey

In partial fulfillment of the requirements

For the degree of

Master of Science

Graduate Program in Food and Business Economics

Written under the direction of

Dr. Carl E. Pray

And approved by

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New Brunswick, New Jersey

October, 2016

ABSTRACT OF THE THESIS

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The technical innovation in agriculture inputs, in particular with regard to seed related- innovations has resulted in enhanced crop yields in several parts of the developing world. In Kenya maize is a major staple food crop for over 80 % of the population. The Kenyan maize story has been often quoted as one of the success cases in Sub-Saharan Africa (SSA). The major reasons have been partly due to the focused investments in R&D of developing new varieties – exploiting hybrid vigor in maize to attain higher yields, and enabling agricultural policies encouraging the use of agri-inputs in general. The adoption of improved varieties in Kenya also have increased over years and the recent studies indicate nearly 72 % of the maize area is under improved maize cultivars. In this research study, we have examined if the maize research system outputs have had any effect on maize productivity levels in Kenya since 1964. Though number of maize seed based innovation - in terms of new releases (currently 354 released varieties) have significantly increased in the last decade, the yields have been relatively 'stagnant' in Kenya. There are several factors that affect the yield, ranging from weather patterns, to use of external inputs (apart from seeds) and also policies regarding maize development in Kenya. In this research paper the relationship between 'maize productivity levels' and 'seed related innovations' in

Kenya has been examined through a two-stage least squares regression model, where 'the seed innovations (# of cultivar releases since 1964) has been endogenously determined through the seed market size, the level of plant variety protection, fertilizer imports and maize producer prices. In general, the maize yields in Kenya are significantly influenced by the increased number of cultivars available for use (seed-innovations); increased levels of investment in public sector R&D; and rainfall received. Though private sector presence is a significant factor in Kenyan seed industry, the impact is over-shadowed by the presence of para-statal (Kenya seed company), occupying more than 70 % of maize seed market share. These results have varied policy implications; ranging from the role of R&D investments in agriculture in general and policy reforms needed to liberalize Kenyan seed industry to improve the stagnating yields.

Acknowledgements

I would like to express my great appreciation to Dr. Carl E Pray for his constructive advice and technical critiques of this thesis. I would also like to express my deep gratitude to Dr. Latha Nagarajan for her patient guidance, valuable technical support and great encouragement during planning and developing this thesis work. I would like to thank Dr. Latha Nagarajan for her great assistance in doing data analysis and in keeping my thesis on schedule.

Special thanks should be also given to my thesis committee members for their professional suggestions and useful recommendations on this project.

Table of Contents

List of tables

Chapter 1 Introduction

1.1 Kenya Agriculture status

As the largest economy in East Africa, Kenya, after 50 years of independence, has been transforming in both political and economic performances (EARC, 2014). With a sustained GDP growth rate of 5.6% in 2014-15, Kenya has made some significant structural and economic reforms that contribute to the national development (WorldBank, 2015). However, Kenyan economy still faces lot of challenges in terms of maintaining such economic growth due increasing population growth levels (2 % per annum); with more people below poverty line (45.6 % of total population) with enhanced malnutrition levels (WorldBank, 2005).

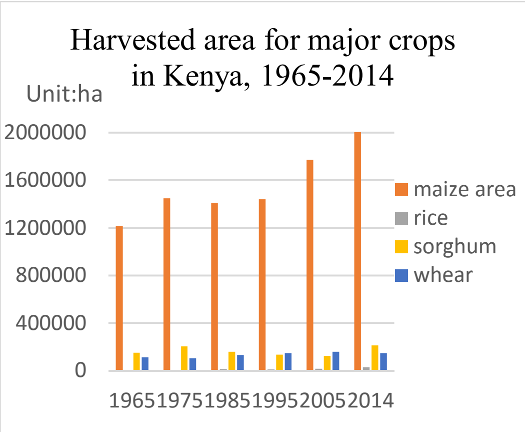
Agriculture sector plays a vital role in Kenyan economic development. Agriculture is recognized as one of the key sectors to contribute the 10% annual economic growth rate in the strategy of Kenya's long term development blue print Vision 2030 (O'Connor, Anna, & Wamache, 2012). As a large agrarian country with the feature of small-scale farming, the share of value added in agriculture in GDP accounts for 32.9% in 2015 (WorldBank, 2015). The proportion of workforce – population engaged in an agricultural-related activities is around 75% (ContextNetwork, 2016).

Under these circumstances, it implies that the Kenyan economies rely heavily on the success of the agricultural sector. Nonetheless, the agricultural productivity of crops remains far below potential agricultural productivity (O'Connor et al., 2012). Current yield levels of maize in Kenya is about 1.66 tones/ha, which is equivalent to the average global maize yields of 1960s. In addition, the yields for other major crops in Kenya are also similarly low as well (O'Connor et al., 2012)

1.2 Status of maize

Past literature often correlates crop productivity levels with adoption of improved crop technologies such as improved seeds, fertilizers, irrigation and other crop management technologies. Therefore, it is necessary to increase agriculture productivity and further accelerate economic growth and reduce poverty in Kenya. Among all the major crops in Kenya, maize has its dominant role in agriculture sector. As a significant staple food, maize is for over 80% of Kenya's population and of vital importance in both nutrition and economy. Maize is Kenya's most important crop. Current FAOSTAT show that more than 2.1 million ha of Kenya's 5.3 million ha of all crops harvested area was occupied by maize. Maize accounts for 40% of all crop area in Kenya. Other major crops include common bean, sorghum, cowpea, wheat, pigeon pea, potato, tea, millet, coffee, and other pulses. Kenya's per capita maize consumption is estimated at 103 kg/person/year, compared to 73 kg for Tanzania, 52 kg for Ethiopia, and 31 kg for Uganda.

In spite of maize's importance for food security and economic wellbeing of the country, the productivity and production have not shown significant improvements over the years. The current yield is estimated at 1660.2 kg/ha, with average production of nearly 3.5 million tons. Increases in maize production in Kenya resulted from area expansion rather than from increases in productivity. More than 75% of maize area is cultivated by small-scale farmers – who produce more than 65% of the maize consumed in the country (Compete USAID Report, 2010). Maize is produced for both home consumption and market – with small-scale farmers only selling an estimated 20% of their production (DTMA-Maize Kenya 2015). An analysis of yield gains between 1980 and 2013 indicates that Kenya's average yield has shown a slight decline of about 1kg/ha/year, compared to growth figures of 146 kg for South Africa, 121 kg for Mali, 120 kg for Ethiopia, 97 kg for Zambia, and 93 kg for Malawi; the SSA average was 31 kg/ha/year (DTMA, 2015). Kenya's maize trade balance has been sporadic during the four decades between 1961 and 1990, where it was mostly a net exporter. Since the late 1990s, however, Kenya has remained a net importer of maize.



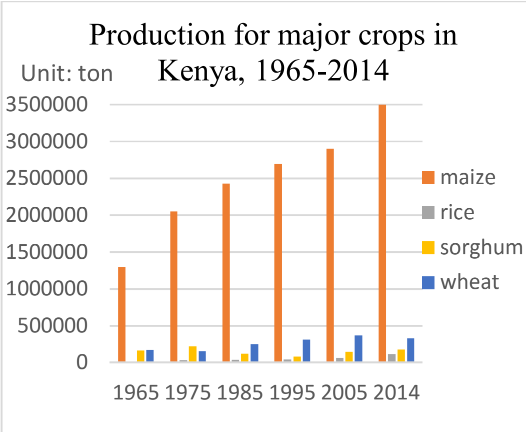


Figure 1: Major crops of Harvested area and production for major crops in Kenya from 1965-2014

Source: FAO Stat 2015

Since Kenyan independence in 1964, there is a significant expansion in terms of area under maize, with improvements in production and crop yields. However, the yields of maize have shown lot of variations responding to weather and other technology/policy related interventions in Kenya. As a result, along with a low yield rate, Kenya is now a net maize importer. FAOSTAT shows that Kenya imported 87,981 tons of maize in 1965 and 236,000 tons in 2012 (93,473 tone in 2013). It imports maize primarily from the East African Community (EAC) through formal market channels. Whereas, by seeing an expected increasing demand for maize, it is highly possible for Kenyan government to import maize from outside EAC to satisfied the need in the future.

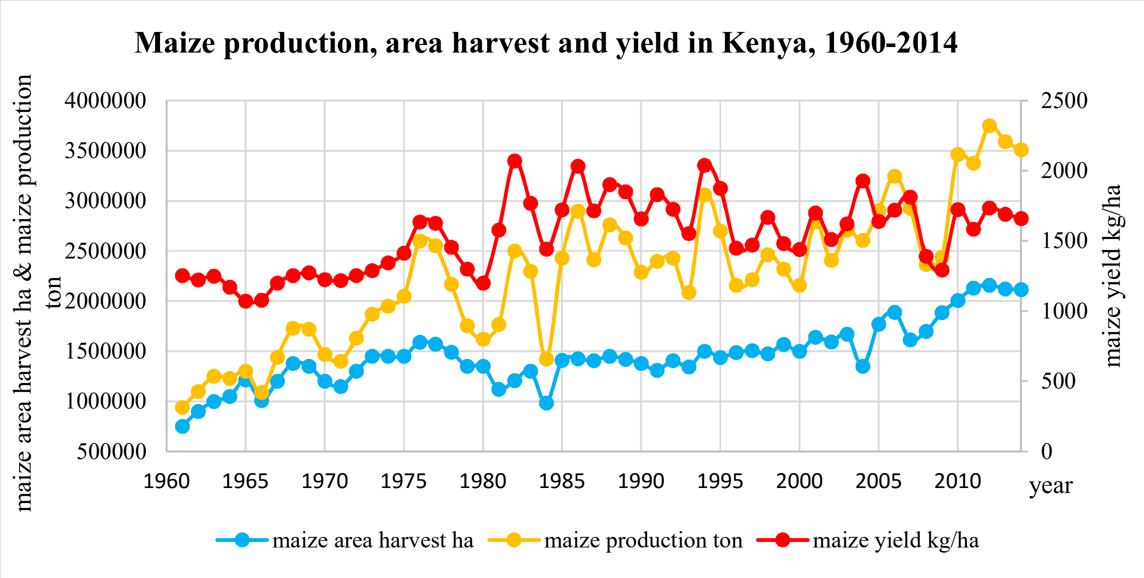


Figure 2: Maize Production, Area Harvest and Yield in Kenya 1960-2014

Source: FAO stat 2014

Maize production evolution in Kenya has undergone transformation since its independence, has gone through several phases starting with a growth phase from 1963-74; followed by improved adoption by small farmers between 1975-1984 due to adoption of improved seed in high potential areas, input use and extension services. However, this phase also saw some unfavorable policy changes (procurement through national board) and severe drought impacted heavily on yield levels. The slow growth phase from 1985 to 91 may be due to the reduction in R&D investment levels, with old varieties still dominating the market, along with structural adjustment policies weighing the economy; the years between 1992-95 showed improved the yields of maize, with significant adoption of improved seed in high potential area farmers with hybrids and increased fertilizer use; and also opening up of markets to private sector. The yield varied differently among different ecological area.

Important events happened in the seed industry from mid-1980s to 1990s further changed the maize adoption and yields in Kenya. The government de-regulation of maize prices, liberalization of seed sector, and deregulation of seed pricing and enacted regulation in protecting breeders' rights all paved way to maize seed growth and adoption in Kenya. Since the beginning of 21st century, most farms incorporated improved hybrid maize seed in Kenya.

Kenya has been modeled as "success story" for decades (Byerlee & Eicher, 1997; Smale & Jayne, 2003) . However, there are emerging concerns mainly looking at the data on 'stagnating yields' (FAO), though farm level longitudinal studies conducted by Tagemeo institute since 1997 provide a more positive trend on yields, however with a caution on the age of the hybrids grown by farmers along with other factors that lead to such yield concerns.

From the historical trends in maize yields it appears that Kenyan maize sector growth is primarily influenced by increased public investment in R&D; policies related to maize input (seed, fertilizers etc.), and output (pricing, protection) and also by agro-ecological factors such as drought etc. Hence the primary focus of this paper is to examine the factors that influences maize productivity levels in Kenya, in particular attributable to the 'innovations' in seed sector, measured through number of maize releases in Kenya since independence. The Kenyan maize research system and seed industry is considered to be one of the dynamic compared to other countries in the region.

1.3 Objectives

The specific objectives include;

1. Providing an historical review of maize development in Kenya and the growth of maize seed industry.
2. Relating various policies that impact the growth of maize in Kenya.
3. Empirically determine the factors influencing productivity levels of maize since Kenyan independence in 1964.
4. Determine the role of 'seed innovations' i.e, the impact of maize varietal releases on the maize productivity levels in Kenya.

1.4 Outline of the thesis

In the following chapter 2, a brief literature describing the phases of maize productivity growth in Kenya; and a description of Kenyan seed system, with particular reference to maize has been presented. This chapter also provides a brief review on Kenyan agricultural R&D investment, and policies and institutions affecting maize development. Chapter 3 provides the analytical description of the empirical model relating productivity levels to innovation in maize in Kenya; followed by a short description of data used for the research along with description of variables. Results from the empirical analysis along with data summary are described in Chapter 4. Suitable conclusions are derived based on empirical results in Chapter 5.

Chapter 2 Literature Review

2.1 Phases of maize productivity growth in Kenya

In 1964, the first Kenyan maize hybrid H611 was developed and released. Nearly half of large-scale farmers in the high-potential place adopted improved varieties and also widely use inorganic fertilizer. As a result, it stimulated a dramatic growth in maize yield. In addition, in 1963, Kenyan government made an agreement with Kenya Seed Company (KSC), enabling KSC to have the right distributing new hybrid and contracting more maize growers. High-quality of public research program during this period is also a contribution to this successful maize story and government chose to be active in multiplying maize production through providing an enabling policy environment, with extension services and road infrastructure (Byerlee & Eicher, 1997) .

The second phase is during 1975 to 1984. In this time period, there was a smaller gain in maize yield; wider diffusion of technology reached to the smallholder famers and there was a surge in small farmers' adoption of improved maize seed, which positively influenced the maize yield. Yet, due to the limited access of fertilizer to smallholders, the yields of maize during that time were not so productive. Furthermore, there was an unfavorable policy environment and severe drought in 1979-1980 and 1983-1984. Therefore, yields eventually went down from 1977 to 1980 and 1982 to 1984. However, overall maize yield went up during that period in a small amount (Byerlee & Eicher, 1997) .

The third phase is from 1985 to 1991. In this phase, the maize yield gained slowly and there was an unstable trend of maize yield. Several attributions accounted for this situation. First, according to the survey data gathered by the Kenya Maize Data Base Project, the small farmers who adopted improved varieties were in low-potential area and still with a lower fertilizer use. Besides, drastic cut in funding for maize research is another major reason that slowed down the progress of developing new varieties and hybrid maize. More importantly, major varieties released at that time were variants of breeding materials used in the 1960s, which reflected a less impressive advantage of maize yield with improved varieties. Also inadequate funding source on the Kenya Agriculture & Livestock Research Organization (KALRO) research program constrain the development of improved varieties and indirectly influence negatively on maize yield (Byerlee & Eicher, 1997).

The fourth phase is from 1992 to 1995. Byerlee & Eicher, (1997) show the results of a national survey that reflected maize yield growth during that time. Overall, there was a general slight increase in maize yield and it is mainly due to that maize farmers adopted newly improved maize seed and fertilizer over the country. The survey implied that farmers in the high-potential area had more maize yield than that in the low-potential area. Improved varieties also had a better performance and efficient fertilizer-response in the high-potential area. In the lowland, due to a lack of appropriate improved seed and unawareness of seed potential, farmers used more OPVs (both improved and unimproved) (Byerlee & Eicher, 1997). Therefore, the yield varied differently among different ecological area.

Several policy and regulatory changes influenced the structure of the seed industry from mid 1980s to 1990s. Along with experiencing severe economic pressure and mounting losses in maize trade as well as continuing complaints from maize growers, Kenyan government was under a huge pressure to liberalize seed industry. Before, government controlled over maize marketing and pricing. The National Cereals and

Produce Board (NCPB) is the monopoly in maize trading (Byerlee & Eicher, 1997). Gradually, marketing network turned out to be financially unsustainable where there was a growing demand for food and adverse macroeconomic conditions. The board generated financial losses continuously. Government's overregulation in the economy and the weak public financial support in research also hindered the growth of maize yield. Therefore, a Cereal Sector Reform Program was established in 1988 to foster competitive marketing and pricing (Byerlee & Eicher, 1997). Deregulation of seed pricing and enacted regulation in protecting breeders' rights started at this time also. Moreover, private seed companies started coming to the market. Eventually, due to increased pressure such as complaints about low seed quality from farmers, high cost of improved seed, and contract problems with farmers, the Kenyan government decided to liberalized Kenyan seed market in the mid-1980s to 1996 (Makelo & Ndege). During that time, the state gave up more control and several private seed companies were set up in Kenya.

Currently, most farms incorporate improved hybrid maize seed in Kenya. From the World Bank report, it states that it is profitable and risky to operate a hybrid maize seed business based on observing a price ratio of certified/hybrid seed to grain, which is 5:1. The report illustrates that this ratio reflects a viable hybrid seed market in the development stage.

From the historical maize yield trend, it can be concluded that total varieties of released improved seed, fertilizer use, type of the varieties, producer price, public R&D expenses, policy environment, and weather conditions are all critical factors that can influence maize yield in an important way.

2.2 Kenya seed system with particular reference to maize

2.2.1 Seed industry in Kenya

Seed industry in Kenya comprises of two sectors: formal and informal sector. There are five major seed systems under these two sectors, which are farm-saved, NGO/cooperatives, parastatal, private international companies, and private local companies (Munyi & Jonge, 2015). NGO and cooperatives are considered as intermediary between the formal seed sector and informal seed sector. Informal sector including intermediary owns a large market share, accounting for 75~80% of total seed transaction while formal sector has only 20~25% market share. However, the source of certificated seeds varies by different crops (ContextNetwork, 2016). Formal sector is responsible for breeding, producing and sale of certified seeds. It is the dominant source of improved seeds and maize holds the largest share of improved seeds. Kenya Plant Health Inspectorate Service (KEPHIS) is in charge of registering seeds and more than half of these certified seeds are maize (ContextNetwork, 2016). In the formal seed sector, there are both public and private entities. Major players belonging to the public sector include Ministry of Agricultural, Livestock and Fisheries, KALRO, and KEPHIS, and Consultative Group on International Agricultural Research (CGIAR); donor funded initiatives by NGOs such as Alliance for a Green Revolution in Africa (AGRA), and One Acre Fund. In the private seed sector, there are multinational (regional and international) private seed companies such as PANNAR, SEEDCO Kenya, Monsanto, Pioneer, East African Seed and Western Seed Company. Kenya Seed Company is a para-statal company that has both public and private shares. It can be recognized as a big monopoly in the certified seed market with a market share of 77% (Mbata, 2013). The chart below describes how many market share that each companies have in the Kenyan seed market.

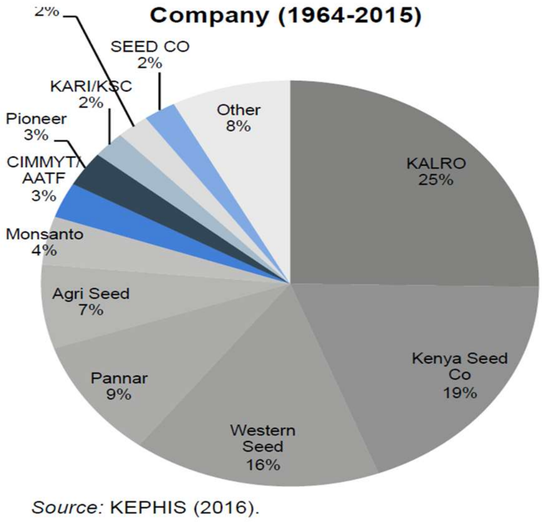


Figure 3: Registered improved varieties of maize by company

Source: ContextNetwork. Kenya Early Generation Seed Study 2016

2.2.2 Maize seed industry in Kenya

The origin of maize research in Kenya started in 1955 when Kenyan government initiated a comprehensive maize research program (Byerlee & Eicher, 1997). More than 20 high-yielding maize hybrids and varieties were developed and released from this program (Byerlee & Eicher, 1997). The first hybrid maize was introduced in Kenya in the mid-1960. Nowadays, around 80% of maize area in Kenya are planted with a combination of both hybrid and OPV. Sources of these improved seed are public sector organizations, local seed companies and international seed companies. Within the maize seed value chain, according to KEPHIS, KALRO accounts for the vast majority of released seeds (ContextNetwork, 2016). Hybrid seed has a larger market share than OPV. According to the Kenya seed study done by USAID, it reports that public institutions such as KALRO, regional and local seed companies such as KSC, and international seed companies such as Monsanto are all involved substantially in developing hybrid maize seed research and having released lots of hybrid. They have breeder and develop parent seed and hybrid. Then, some NGOs and agro-dealers will be responsible for marketing and distributing them to farmers. Within the whole process, KEPHIS plays the role of all inspection, certification and verification. Maize production cannot go into the next step if it does not pass the KEPHIS inspection. Based on the same study, the market share of OPVs is declining throughout the years. According to the survey involved in this study, it indicates that formal sector is highly possible to convert to pure hybrid development.

Research activities are the key to seed industry development since it is responsible for creating improved seeds that is able to generate higher yield. Breeding program is the major research activity. Breeding crosses and evaluates materials from a wide range of sources and then narrows down the genetic pool until it obtains the desired variety. Research activities are carried out purely by formal sector while all informal sector seed is non-hybrid (O'Connor et al., 2012). In Kenya, KALRO is responsible for breeding research and most new varieties are developed by it. Multinational seed companies as well as some local seed companies also have their own research center, but they only account for a small amount. The products in the seed sector can be divided into four different crop categories: grains, pulses, roots and tubers, and horticultural crop. Also, the products are also labeled according to the different ways that they are produced. They are listed as open pollinated varieties (OPV), hybrid, vegetatively propagated, and tissue cultured (O'Connor et al., 2012). OPV seed can be replanted for numerous seasons without a significant loss of yield while hybrid seed are normally planted only in one season since it will have a much lower yield if they are saved and replanted. However, hybrids have a significantly higher yield than OPV (O'Connor, 2012)

In terms of the marketing activities, private sector plays a major role in marketing and distribution activities. After the liberalization when private sector came into the market, it becomes more accessible for farmers to receive hybrid seed and fertilizer due to the greatly improved distribution system.

Overall Kenya seed industry performance stronger than many other SSA countries but still lags behind the regions outside Africa. As one of the measure for industry performance, product innovation in Kenya such as hybrid maize seed still takes long time to be produced and the total number of released varieties is far behind South Africa. According to Kenya Seed Industry Study, it concluded that Kenya seed industry is characterized as a dominant role of KSC controlling the market as well as a large share of seed supply from informal sector. Moreover, a weak linkage between research and extension as well as a high financial cost for private seed sector jointly slows down the progress of developing seed industry and further impedes the development of seed industry.

Maize variety release in Kenya started in 1964, with H632, a hybrid; the most popular OPV (KCB) was released in 1967. The National Crop Variety List of MOA indicates that a total of 354 maize varieties were registered between 1964 and 2015. The frequency of maize variety releases showed substantial increases starting in the mid- 1990s. Hybrids dominated maize varieties in Kenya. For example, about 91% of all varieties released between 1964 and 2012 were hybrids (DTMA, 2015). Variety releases by private companies in Kenya accounted for about 48% of the total releases.

Of the total varieties released between 1964 and 2012 most were by KALRO (27%) and by the parastatal, Kenya Seed Company (25%). Private companies also are involved in maize breeding, hybrid introduction, seed production and marketing in Kenya. The major private companies in maize variety release in Kenya are Western Seed Company and Pannar. Agri-Seed Company Ltd, Monsanto, Pioneer, Lagrotech, FICA Seeds and Faida Seeds had smaller contribution.

In order to address the importance of private sector and its performance on releasing improved seed, Figure 4 illustrates how much hybrids and OPVs were released by public and private sector since 1964 till now. From the figures, it is obvious to see that before liberalization, public sector was in charge of producing and releasing all kinds of improved seed. With liberalization, private companies gradually came into the seed market and played an increasingly important role in the seed industry. According to the figures, since 2000, private sector released a large share of hybrids yearly, almost as many as public hybrid share. In the recent three years, private sector released more hybrids than that by public. However, private sector is not interested in releasing OPVs mainly because there is less profit in selling them.

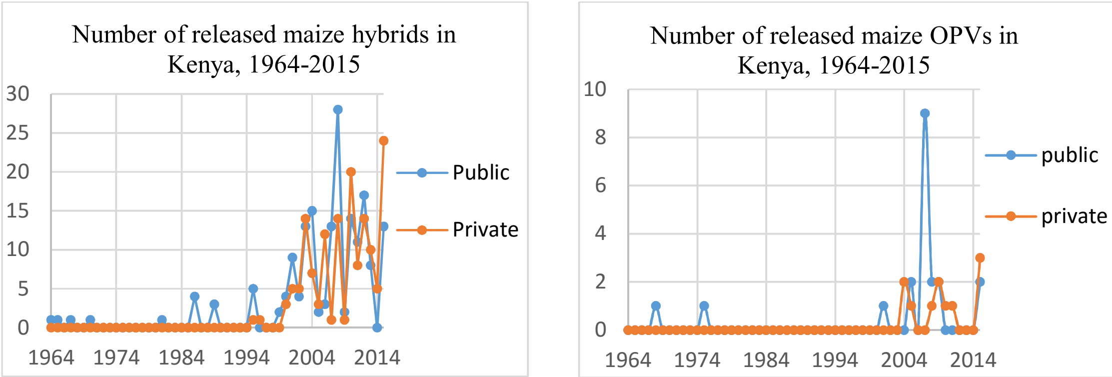


Figure 4: Number of maize hybrid and OPVs released by public and private in Kenya, 1964-2015

Source: KEPHIS. Seed Sector Platform Kenya 2015

2.3 R&D and innovation in seed industry

Over the last two decades, global trade in agricultural input has grown rapidly and R&D is one of the major factors contributing to it. Based on a research conducted by Fuglie et al (2011) that the productivity growth of the global food and agricultural system will largely depends on R&D investment. That study further found that the private sector R&D expanded considerably over the last decade due to several reasons such as strengthening intellectual property rights (IPR) over agricultural innovation, new regulatory requirements and expansion of agricultural input market. Public agricultural R&D investment in low- and middle-income countries has a rapid growth rate than it in high-income countries from 2000 to 2008 with a more focus on narrowing yield gap and adapting new technology well (Beinteme, Stads, Fuglie, & Heisey, 2012).

2.3.1 Kenya agricultural R&D investment

From 2000 to 2008, agricultural R&D investment in low-income countries grew slowly at a rate of 2.1% annually and larger eastern African countries such as Kenya are the main drivers contributing to this growth. However, when considering only low-income countries, it is obvious to see a negative yearly growth in public agricultural R&D in nearly half of African countries. The reason is mainly due to completion of large donor-funded project. This phenomenon implies a low investment and capacity level of agricultural R&D in Africa. Worse, it causes more agricultural R&D spending volatility in SSA countries (Beinteme et al., 2012). Thus, it is noteworthy to examine the degree of agricultural R&D investment in Kenya in more detail.

In 2011, the African Seed Access Indicator was formalized by The Africa Seed Access Index (TASAI) formalized the African Seed Access Indicator to monitor and evaluate the economic performance and structure of seed sector in Africa countries and Kenya is included. They measured R&D sector in the seed industry in three aspects: number of active breeders, varieties released in the last 3 years and availability of foundation seed to seed companies ("TASAI-Kenya Brief ", 2015). The number of active breeders influences the seed industry development on the breeding capacity of this country. More active breeders will provide a wider range of crop varieties that will put a positive impact on the seed industry development. The varieties released in the last 3 years reflect the outcome of R&D to some degree. More varietal releases imply more progress that has been achieved by R&D sector. TASAI also found that Kenyan farmers relative to other countries in the region have higher access to foundation/ certified seeds, which is a significant measure of more investment in R&D. i.e, having more access to foundation seed reflects a stronger research capacity. According to the report, some companies, particularly multinational companies have their own research team to produce foundation seed in Kenya. However, most small- and medium-companies in Kenya still do not have their own research team and they rely on public research institution for their foundation seed.

Many African countries attained their independence from colonies since mid 1960s. Since then through several donor initiatives and realizing the importance of agriculture, many African governments have begun expanding their investment in agricultural research in order to improve the efficiency of African farming. Maredia et al (1998) and the recent studies relating African agricultural productivity growth since independence (Block, 2010; Block and Bates, 2013) provide evidence of agricultural transformation in Africa due to continued investment in agricultural research and technological innovation. There are many factors that can contribute to innovation and research is one of the major ones. It is of great importance and necessary to address the significance of invocation since it is at the heart of sustainable intensification which increases the agricultural production with less environment damage effects by utilizing existing knowledge (Juma, Tabo, Wilson, & Conway, 2013). It further improves the resilience of African agricultural system and ensures a growing productivity to finally eliminate hunger, malnutrition and poverty in Africa.

2.4 Policies and regulations influencing seed system in Kenya

Seed policies and regulations play a critical role in directing seed development and shaping seed industry. In Kenya, the development of seed industry can be divided into three eras, which are pre-independence period (up to 1963), post-independence I (1964-2004) and post-independence II (2004-present) (Munyi & Jonge, 2015). Overall, Kenya agriculture grew from a traditional tribal farming that caters for subsistence need in the pre-independence period to a government centralized-control traditional farming in the first period after independence and now Kenya agriculture is on the way of transformation, becoming more and more open to the market. In terms of seed industry, for each era, policies and regulations are the vital drivers to promote seed industry focusing on different aspects. Among those aspects, seed quality management and plant variety protection are of great importance since both of them determine agricultural yield directly.

Before the independence, Kenya was rule by the British Government. It established the centralized-control system in the seed industry from plant breeding to multiplication and distribution. Therefore, it is the government at that time that was responsible for releasing new seed varieties and protecting breeder's right. Besides that, the government also set up policies proposed to increase agricultural productivity and self-sufficiency. In the early 1990s, Kenya was on a way of liberalizing seed market. Several policies were also established to promote the process. In the third era, regulations are more related to R&D perspective with emphasis on promoting high-quality seed. For example, in 2004, the Strategy for Revitalization of Agricultural (SRA) was adopted to improve delivery of research. In 2010, the National Seed Policy also addressed the importance of raising agricultural productivity through improving quality of farm-saved seed. Moreover, according to the 2013 Crop Act which classified the scheduled and non-scheduled varieties, the government intended to increase the number of scheduled varieties by using the government authority on the development and market promotion of these crops (Munyi & Jonge, 2015).

All of these policies and regulations strengthening Kenya seed system gradually and make it more adaptable to the current economic development. All the policy changes have intensifying the support for developing formal seed sector through managing seed quality and protecting breeders' right (Munyi & Jonge, 2015).

Enabling Agricultural Trade (EAT), a project funded by USAID, identified and the regulatory and legal framework of agricultural practices using the Agribusiness Regulation and Institutions (AGRI) index. Kenya is one of the countries in its pilot research(Mbata, 2013) The EAT project found that Kenya has a strong legal framework in regulating seed sector. However, it does not mean there exists an efficient seed system since most small- and median-scale farmers can still hardly afford all the procedures to receive high quality seeds.

Regulations in the seed industry are related to variety release and seed certification. The Seed and Plant Variety Act, cap 326 of the Laws of Kenya regulates releasing new varieties. And KEPHIS is responsible for field inspection in the seed certification. According to the Kenya Seed Industry Study, KSC is dominant in releasing varieties while private sector has no success in it exception of maize varieties (O'Connor et al., 2012).

TASAI measured Kenya seed policies and regulations in five aspects: the length of varieties release process, quality of seed policy framework, quality of seed regulation and enforcement, adequacy of seed inspectors and efforts to stamp out fake seed ("TASAI-Kenya Brief ", 2015). The Kenya National Seed Policy came into force in 2010 and this new seed policy framework increases seed sector players' optimism on the matter of self-regulation by allowing more private players to participate in the regulatory field. The Plant Varieties Act has its most recent amendment published in 2013 with authorizing some private persons to deal with some functions that are initially confined to the regulator. According to this regulation, with involving in private section part, this study claim that it intends to improve efficiency in the seed industry. Besides these new policy or regulations, there are still some seed policies needed to be improved. None of the regulators inspected agro-dealers regularly and it may result in fake seed and illegal repackaging ("TASAI-Kenya Brief ", 2015). Besides Kenya is also a signatory of International Union for the Protection of the New Varieties of Plants (UPOV) system since 1992.

2.4.1 Impact of liberalization on Kenya maize yield

In the 1990s, many African countries have experienced liberalization in the agriculture market, which stimulates a transformation in agricultural development. A large number of studies have been conducted to analyze the impact of this liberalization on agricultural productivity for difference African countries and Kenya is not an exception. In Kenya, there was a maize green revolution that once increased maize yield through adoption of improved varieties and fertilizer. However, it has been stalled since in the middle of 1980s. Along with the liberalization in Kenya the government also implemented few other policies. A study named “The Maize Green Revolution in Kenya Revisited” analyzed whether these policies were active and efficient in increasing maize yield again. In this analysis, a farm-level survey from 1992 to 2002 was conducted in doing so (De Groote et al., 2005).

In this study, three major inputs: seed, fertilizer and labor have been taken into consideration as key factors for maize yield. It reflected that the success in implementing policies to deregulate input market was only moderate in Kenya. Several challenges have emerged when government attempted to liberalize the market. In the seed sector, due to the liberalization policies, although there was an increasing number of companies entering into the market and the mechanism for releasing new varieties have been opened up to private seed companies, it is still costly to develop new varieties through research activities. Most research costs were compensated by yearly seed sales. In the fertilizer industry, liberalization polices ensure an increased distribution and availability of it but government still played a central role in fertilizer market.

Based on the survey, it concluded that maize yield has increased only slightly and it is fertilizer that has significant influence on yield. It seems that adoption of improved varieties has little effect of increasing yield and it is possibly due to that those improved varieties were not adapted well in those survey areas (De Groote et al., 2005).

Therefore, there is an urgent need for policy makers to enact new policies to regulate the liberalized market more efficiently. First, it recommends that public extension service should have a stronger collaboration with NGOs by seeing that there is a reduction in accessibility in agricultural extension and public service employment. Second, it is necessary and important for R&D institutions to develop new improved varieties that are able to adapt to the local environment well (De Groote et al., 2005).

Other studies have also started with the assumption that more new varieties will lead to higher yields. Unfortunately, these new varieties have not yet inspired widespread smallholder market participation (Olwande et al., 2015); and farmers tend to replace ‘newer; varieties with ‘older’ varieties very slowly due to several factors, ranging from agro-ecological suitability, genetic gains of new varieties, and other policy related interventions. Since 1995, at least 50 new maize hybrid or open pollinating varieties are released in Kenya, but newer varieties offer small yield advantages over the previously released improved varieties (Ariga & Jayne, 2009; de Groot et al, 2006; Olwande and Smale, 2012). In 2010, the adoption rate of hybrid maize seed increased to 82% from 68% in 2000, while yield increased by only 16%. (Olwande et al., 2015; Ogada et al., 2011). This suggests that there is disconnect between yield gains and new cultivars.

In the aspect of agricultural research system development in SSA, there is a trend of transforming public-oriented research landscape to a public-private-partnerships (PPPs) research landscape. This means private sector has placed an important role in this area. According to a research paper by African Center for Biodiversity in 2015, prior to the independence of most sub-Saharan countries, the largest share of crop research benefited large-scale farmers of European descent. Not until the late 1970s, the Consultative Group on International Agricultural Research (CGIAR) established several research centers in SSA. The Bill and Melinda Gates Foundation (BMGF) became important in agricultural research since 2006 and further became one of the largest donors of CGIAR. More recently, with an amount of multinational seed companies involved in the research body in SSA, the role of private sector in agriculture research contributed more to the release of new varieties. More or less, many major public research bodies have entered into PPPs. The Water Efficient Maize for Africa (WEMA) project also has Monsanto, the International Maize and Wheat Improvement Centre (CIMMYT) involved collaboratively (Rumball et al., 2015). In the wave of investment seed industry in SSA, there is emergence of many organizations contributing to the growth of seed industry. The Africa Seed Trade Association (AFSTA) was founded in 2002. In 2006, there was another key organization named as the Alliance for a Green Revolution in Africa (AGRA) established and it promoted Program for Africa’s Seed Systems (PASS) program in 2007, supporting around 80 seed companies across 16 countries in SSA. According to the PASS report, all those 80 seed companies were combined as the largest seed producer in SSA (AGRA, 2015). In the recent year, those organizations tend to focus more on private sector seed production in

SSA. Therefore, a trend of transforming farmer managed seed system with public supports for seed breeding to private sector starts.

In order to increase agricultural productivity and reduce national poverty, Kenyan government invested heavily on hybrid seed research since seed quality, thus Kenya has one of the most advanced regulations or seed laws to regulate and manage certified seed among African countries. The KSC has a dominant role in regulating certified seed. It can be recognized as a big monopoly in the certified seed market with a market share of 77% From 2000 to 2010, on average 67.2% of maize area plants certified maize seed and 54.2% of wheat area plants certified wheat seed (World Bank, Agri-Business Indicators, 2012). Of this, private companies and farmers multiplied 20% of certified seed while public seed sector still control the majority. In the recent years, there are more private seed companies coming into the market from a number of 67 in 2008 to 90 in 2012. All of these facts illustrate that the government still largely controls the seed sector in Kenya even though there are more and more private seed companies that come into the market.

2.4.2 PVP scheme in Kenya

In Kenya, plant varieties were protected according to the Seed and Plant Varieties Act of 1972 in the first place. This Act protected proprietary rights to breeders or people who discovered new varieties. In 1994, the regulations for implementation of PVP were introduced and in 1997, PVP scheme started to operate in Kenya (Declaration, 2005).

Table 1. Number of PVP application for different crops in Kenya since 1999

Crop	No. of pvp application since 1999
irish potato	30
beans	24
sorghum	9
finger millet	6
pearl millet	4
maize	156
wheat	33
barley	13
rice	1
cassava	8
pigeon peas	4
cow peas	4
sweet potato	1
french beans	33
peas	9
cabbage	1
pumpkin	1
tomato	1

Source: Peter Munyi. PVP experience in Kenya, ISSD 2016

Since the introduction of PVPs in Kenya it is evident that the number of varieties released after establishing PVP system is more than tripled than before. Those registered varieties are on the Kenyan official list, which means farmers can produce and market these seeds legally in Kenya. Among those varieties, the staple crop maize seed accounts for almost half of the total improved varieties Between 1997 and 2003, 60 maize varieties were registered while 136 seed varieties were registered in total (Declaration, 2005) Thirdly, PVP system also contributes to breeding program in Kenya for numerous crops. In terms of domestic breeding, the numbers of breeding entities and PVP applications for agricultural crops have increased dramatically after introduction of PVP system. Public breeding institutions play an important role in breeding program. However, there is also a number of new varieties that have been bred jointly by private and public breeding institutions. Obviously, PVP system helps promoting public-private cooperation including partnerships between international institute and Kenya seed companies.

2.4.3 Farm input subsidy programs in Kenya

Before market reforms in Kenya, agricultural input was subsidized mainly through state-owned enterprises. From 1960s to 1980s, many African countries including Kenya, Malawi, Tanzania, Zimbabwe and Zambia had lager scale “universal” subsidy programs. These subsidy programs depended heavily on government control. In Kenya, there is a Farm Input Subsidy Program which is operated since 2007. It targets at resource-poor smallholder farmer by subsidizing them fertilizer and improved seeds. Kenyan input subsidy scheme (NAAIP) primarily works with private sector, at all levels of input distribution, thus offering competitive environment for fertilizer products and services (Ariga and Jayne, 2010).

In Kenya, the National Cereal and Produce Board (NCPB) is another mechanism that can provide subsidy program to Kenyan farmers and the subsidy program was prior to NAAIAP subsidy program. The government controls the distribution of inputs through NCPB. Around 30-40% subsidy of fertilizers is available at NCPB depots and the quantities have been scaled up in 2008 (Mather, 2008). Subsidies through NCPB lack clear targeting criteria. All of these implied that although NCPB have the potential to improve access to fertilizer use for smallholders, it targeted slightly to larger farmers. All of these indicate that the effectiveness of fertilizer subsidy program still needs to be improved.

Chapter 3 Conceptual Framework

As a dominant staple crop with both nutritional and economic values, maize has been planted widely all over Kenya. Hence, it is crucial to increase maize yield especially through adopting improved maize seeds and other crop technologies efficiently. Though adoption of improved varieties of maize in Kenya is as high as 70%, with significant increases in number of new varieties released over years, the maize yield levels have not significantly improved over years. This study has attempted to understand the empirical relationship between maize productivity levels in Kenya since independence, and the 'maize-seed innovations (# of improved cultivars)'. Our hypothesis is based on the fact that 'crop yields are determined by the embodied technological factors, namely 'innovations' (i.e, number of new varieties); i.e increased innovations will result in improved agricultural productivity.

3.1Empirical model specification:

In order to examine the relationship between "maize productivity levels" and "seed related innovation" in Kenya seed industry, a two-stage regression model has been (2SLS) derived.

$$1. \boldsymbol{Maize\ Innovation\ (IV) = f(X_1) +\ \varepsilon_1}$$

$$2\ . \boldsymbol{Yield = g(Innovation\ (IV),\ X_2) + \varepsilon_2}$$

Where the total number of improved maize cultivars released since 1964 measures 'maize innovation'. National average productivity levels i.e., yields of maize as reported in FAOSTAT from the year 1964 to 2015 are used for this estimation. X_1 and X_2 are sets of exogenous variables affecting both innovation and yield respectively. Since there are unobserved factors that affect both innovation and yield, we have used two stage least squares to account for endogeneity posed by the innovations on maize yield levels.

In order to control the endogeneity, we set up a recursive system of equations: two-stage least squares regression model and introduce instrumental variables that influence seed innovation. Instrumental variables are strongly correlated with the endogenous variable and also cut correlation between the error term and the endogenous variable. In the first stage, we use this estimation to predict a rate of innovation. In the second stage, we conduct yield as a function of innovation and X_2. Since innovation indicator should display less correlation with ε_2 , the coefficient on innovation will give an unbiased estimate and further the result of this estimation should be unbiased.

In this study, we use number of maize varieties to measure seed innovation denoted as “IV” and maize yield to measure maize productivity denoted as “yield”. The independent variables that affect maize yield include number of maize varieties, denoted as “IV”, private varieties share, denoted as “private” public R&D investment, denoted as “research”, and annual rainfall, denoted as “rainfall”. The instrumental variables affecting seed innovation are maize producer price, denoted as “PPI”, fertilizer imports, denoted as “fertilizer”, and the level of plant protection which is PVPs issued, denoted as “pvps”. Thus, the set X_1 includes the variables listed as: market, fertilizer, and pvps while the set of X_2 involves independent variables such as: total, private, research and rainfall.

$$3.\ \boldsymbol{IV = f(PPI, fertilizer, pvps) + \varepsilon_1}$$

$$4.\ \boldsymbol{Yield = g(IV, private, research, rainfall) + \varepsilon_2}$$

Based on the empirical framework derived above as well supported by literature review, the following empirical model is estimated with the support of relevant data.

$$5. \boldsymbol{IV = \alpha_0 + PPI + \alpha_2 fertilizer + \alpha_3 pvps + \varepsilon_1}$$

$$6. \boldsymbol{Yield = \beta_0 + \beta_1 IV + \beta_2 private + \beta_3 research + \beta_4 rainfall + \varepsilon_2}$$

The first-stage regression is a linear regression for innovation equation, which controls the endogeneity of seed innovation. The second-stage regression is linear regression model, which examines the impact of each factor on maize yield. Using STATA 12.0 software package, data from both governmental and international database mentioned above were used to first estimate the determinants of seed innovation, control the endogeneity of innovation, and analyze the influence of each factor on maize yield. The following table shows expected signs for each of these variables, showing my hypothesis of impacts of each variable on maize yield.

Table 2. Expected signs of coefficients for each independent variable of yield

Independent Variables	Expected signs
Number of total released varieties (in #) since 1964	+/-
Private variety share (% to total)	+/-
R&D expenses (in Mill US$)	+/-
Maize producer price (annual USD/tonne)	+/-
Rainfall (MM/year)	+/-
Imported quantity of fertilizer (Tonnes)	+/-
Market size (Tonnes of seeds)	+/-
PVPs issued (in # per year)	+/-

Source: Author

Crop yields are significantly influenced by the ‘genetic gain’ associated with cultivar in use. The evidence from green revolution in Asia and elsewhere have proven the ability of improved varieties and hybrids in attaining higher yields apart from use of other complementary inputs. In Kenya of all the crops, maize research has been productive, in terms of significant number of new improved cultivars releases as well in use of such cultivars suitable for different agro-ecology. Kenya released its first maize hybrid in 1964 and since then 270+ new improved cultivars of maize have been released The increasing maize yields witnessed in the 1960s to 1970s was primarily associated with development and release of new varieties (Ouma, De Groote, & Owuor, 2006). Farmers in Kenya have high demand for improved varieties that is suited to their agro ecologies in order to increase their productivity (O'connor et al, 2012). However, one should note that Kenyan maize phase also has undergone a period of 'stagnation' in terms of varietal releases as well as 'improved maize yields'. Hence the varietal releases may or may not be the only significant factor in improving yields of maize in Kenya. Of the maize cultivar types, exploiting the heterosis of maize will have a huge potential to enhance maize productivity. The area share of planting hybrids to total area planted by improved varieties increased from 83% in 1992 to 92% in 2010 (Swanckaert, 2012). Of the total maize cultivars, as discussed in previous chapter, 80 % of them are hybrids, signifying the Kenyan research in exploiting the 'heterotic vigor' towards improved yields' in maize. We assume that Kenya seed industry is a hybrid seed industry. The better development in maize hybrids will be expected to generate a positive influence on yield. The advent of hybrids also encouraged more private firms to participate in the seed market in Kenya and elsewhere due to inherent property rights attached to hybrids over open-pollinated varieties.

Along with liberalization in 1980s, an increased number of private companies came into the seed market in many African countries. In Kenya after liberalization in mid 1990s, public breeding was complemented with private breeding. The share of area which is planted by privately owned varieties increased from 14% to 34% by 2010 (Swanckaert, 2012). However, with Kenya Seed Company, a para-statal still holds a major share of around 70-75% of seed market in Kenya, might offset the private sector efforts in Kenya, which is still developing its market share. Investing in R&D efforts in agriculture complemented by a good dissemination mechanism is a critical factor that would impact crop productivity. Based on the historical development of maize productivity growth in Kenya, it can be concluded that R&D investment affects maize yield indirectly through affecting the progress of developing new varieties and hybrid maize. Lack of R&D investment will slow down the progress of developing improved maize seed and further possibly results in a stagnated maize yield.

Apart from these factors, the output price of any commodity also impacts the farm level decisions, i.e, and allocation of land for the crop. Better producer prices always provide incentives for the farm household to invest in better crop technologies such as improved seeds, fertilizers etc. However in Kenya there are several distortions surrounding the maize producer prices; maize is the food security crop and is often protected by the government. According to FAO-MAFAP analysis of incentives and disincentives of maize development in Kenya (2013), maize prices were set by the government before liberalization, with the policy objective of maintaining maize prices at a stable and affordable level for Kenyan consumers. National cereal and produce board (NCPB) was in charge of the trade before liberalization. However, since liberalization, though NCPB plays a minimum role in terms of setting prices, still dominates the market with direct procurement from medium to large sized farm holders (30-40 %) at pre-fixed prices.

Along with improved seed use, other agri-inputs technologies such as use of fertilizers will have a positive impact on crop yields. In Kenya, with input subsidies in place, the amount of fertilizers imported over years has significantly risen due to demand for fertilizers at farm level. There are positive evidence showing the uptake of fertilizers and yield impacts in Kenya, due to efficient distribution of subsidized fertilizers with private sector participation (Jayne and Ariga, 2010).

Plant variety protection is another key indicator relating to innovation capability of a country's research system. Kenya has been the member of UPOV system from 1993 onwards and started to operate its PVP system of registering plant varieties and providing breeder's rights since 1998. So far 158 maize varieties have been registered in Kenya. For breeders, the Kenyan PVP expects to offer greater access to improved cultivars, thus provide motivation to develop new varieties and pay more attention to the benefits of their varieties. The PVP strategy also ensures "farmers privilege". According to this strategy, farmers have the right to save the seed of a protected variety (Swanckaert, 2012). By being more accessible to improved varieties, famers are able to plant more improved seed and therefore increase maize yield. Hence, PVP is expected to have a positive impact on maize yield.

Apart from the above factors, agro-ecological factors such as rainfall and temperature may have sizeable impacts of crop yields. In Kenya maize is grown in two seasons, depending on the rainfall received in long and short rains season. Kenyan agriculture is periodically affected by droughts, with recurrence of every 3 to 5 years. Hence it is important the research efforts should also address the 'weather concerns' and 'its impact on yield levels' during maize breeding.

Chapter 4 Data and Analysis

4.1 Data source and variables

For empirical estimation, the data has been extracted primarily from secondary sources of information, available through government and international organizations. The time period of the data collected on variable used in the analysis is from 1964 to 2014. The dependent variable in the model is national maize yields, collected from the FAOSTAT website and measured in Kilogram/hectare from the year 1964 to 2014. The endogenous or innovation variable indicated here as the number of improved maize varieties released by the Kenyan agricultural system (public and private), is extracted from the national varieties list reported by KEPHIS since the year of independence, 1964 to 2014. Further from this data on releases, it was classified as hybrid and open pollinated maize cultivar based on the type of breeding. The varieties are also categorized in to cultivars released through private and public sector research. Therefore, the variable 'private variety share' was calculated as the number of hybrid maize cultivars released by private sector each year; this data was partly extracted from both Seed Sector Platform Kenya and KEPHIS national varieties list. Maize producer price, in the unit of USD/ton, is a producer price index and reported on the FAOSTAT website from 1966 to 2014. The public R&D investment is the total spending of Kenya public R&D. This data source is from Agricultural Science and Technology Indicator (ASTI) database. The values is in the unit of million constant 2011 US$ ranging from the year 1971 to 2011. Annual rainfall indicates the weather pattern that influence maize yield. This data is from the World Bank ranging from 1964 to 2012 in the unit of millimeter, extracted from World Bank. Fertilizer imports was used to proxy for the demand for fertilizers, and the data was extracted from COMTRADE/FAOSTAT data base from 1964 to 2013. This indirectly measures the amount of input subsidies involved in Kenyan agriculture system, as most of the fertilizers are distributed through existing subsidy programs. The PVPs issued for a crop, represents the level of plant protection. It is the total number of varieties released that has been approved by PVP from 1964 to 2013 according to the PLUTO-UPOV database. The following table describes the definition of variables along with its source.

Table 3. Summary information of variables

Variables	Definition	Source	Year
Yield	Harvested production per unit of harvested area for crop products. Unit: kg/ha	FAOSTAT	1964-2014
Number of maize varieties	Total number of released improved varieties for each year	Seed Sector Platform Kenya/KEPHIS	1964-2015
Private variety share	number of improved varieties released by private sector to total number of released varieties	Seed Sector Platform Kenya/KEPHIS	1964-2015
Public R&D	Agriculture research spending. Unit: million constant 2011 PPP dollars	FAOSTAT ASTI database/IFPRI	1971-2011
Maize produce price	Maize producers annually price.	FAOSTAT	1966-2014
Annual rainfall	Average annual rainfall (mm)	The World Bank	1964-2012
Size of seed market	Maize seed production tones	FAOSTAT	1964-2013
Fertilizer imports	Import fertilizer quantity in tones	FAOSTAT/COMTRADE	1964-2013
PVPs issued	Total number of varieties released that has been approved by PVP in each year	PLUTO-UPOV database	1964-2013

Source: Author

4.2 Descriptive statistics

Table 4. Summary statistics

Variable name	Obs	Mean	Std. Dev.	Min	Max
yield--Yield	51	1555.47	258.60	1071.3	2071.2
IV--Maize innovations	52	6.81	11.58	0	46
rainfall--Rainfall	49	54.69	8.86	39.9	83.8
research--Public R&D expenses	41	78.13	21.79	47.3	144.1
private--Private sector share	52	0.17	0.27	0	1
PPI--Maize producer price	49	153.15	91.72	38.5	401.8
fertilizer--Fertilizer imports	50	157168.10	153102.90	19270	594408
pvps--PVPs issued	51	0.96	1.79	0	9

Source: Author

From Table 4, it could be seen that the average maize yield is around 1555 kg/ha since 1964 to 2014; with a maximum yield of 2071 kg/ha achieved in the year 1982. The yield of maize shows variation from year to year, since independence. On an average 6 varieties were released per year since 1964, with a maximum number of improved varieties released in the year 2008. With regards to rainfall, the average rainfall received is around 54mm/ year. Kenya receives rainfall in 2 seasons – short rains (October –December) and long rains during May – July. However long rains are more beneficial to maize growers than short rains. As discussed above, Kenyan agriculture has been affected by frequent droughts, once in 3 to 5 years, ranging from moderate to severe drought conditions. The private variety share for maize in Kenya accounts for about 17%. Though Kenya has liberalized seed industry since mid 1990s, very few domestic firms (4 of them) have R&D investments in maize; but their research outputs are dependent on CIMMYT and KALRO still. Kenya seed company, the parastatal and KALRO are the major sources of improved maize cultivars still. The public R&D research investment is about US $78 million since independence. The maize producer prices in Kenya are volatile to some degree, with an average price of maize around US $153/ton and a maximum price was around US$401/ton in 2012 and minimum price at US $38.5/ton in 1970. In terms of fertilizer use, the average use of fertilizer is around 160000 tones annually with an impressive increasing use of it in the recent 15 years. In terms of PVP, in 2003, there are the most varieties that have been approved by plant varieties protection, nine in total. There were 36 maize varieties approved by plant variety protection from 1995 to 2008, comparing with a total number of 49 pvp varieties from 1964 to 2015.

Chapter 5 Results and Discussion

As discussed in previous sections, the model formulated for this research follows a two stage regressions, to determine maize yields, which is influenced by the rate of innovations and factors associated with Kenyan maize sector. The following reduced form equations were estimated to determine yields and innovations.

5. $$Maize\ Innovations = \alpha_0 + \alpha_1 Maize\ Producer\ Prices + \alpha_2 Fertilizer\ Imports + \alpha_3\ PVPs\ issued + \varepsilon_1$$

6. $$Yield = \beta_0 + \beta_1 Maize\ innovations + \beta_2 Private\ sector\ share + \beta_3 Public\ R\&D\ expenses + \beta_4 Rainfall + \varepsilon_2$$

The first-stage regression is a linear regression for innovation equation, which controls the endogeneity of factors affecting innovation and yields. The second-stage regression is linear regression model, which examines the determinants of maize yields, through innovations (which was determined endogenously) and other exogenous factors affecting maize yields in Kenya. Using STATA 12.0 software package, data from both governmental and international databases as discussed in previous chapters were used to first estimate the equations.

5.1 Empirical results of the model

The results from the two stage regressions are presented below.

Table 5. Maize yield regression using instrumental variables (2SLS) regression

Variable name	Coef.	Std. Err.	t-value
IV--Maize innovations	2.98	5.39	0.55
private--Private sector share	-325.14	195.25	-1.67
research--Public R&D expenses	4.76	1.81	2.64*
rainfall--Rainfall	5.61	4.19	1.34
_cons	967.17	243.07	3.98**

*--P≤0.05 **--P≤0.01

Source: Author

From the results it is evident that, maize yields in Kenya since independence though influenced by 'seed innovations' the impact of such innovations is not as significant one could expect. There are several reasons for such phenomena; the Kenya's government has invested in seed variety development and multiplication, especially for the maize subsector since independence. This has not yet inspired widespread smallholder market participation (Olwande and Smale, 2012); and farmers tend to replace 'newer; varieties with 'older' varieties very slowly due to several factors, ranging from agro-ecological suitability, genetic gains of new varieties, and other policy related interventions. Since 1995, at least 50 new maize hybrid or open pollinating varieties are released in Kenya, but newer varieties offer small yield advantages over the previously released improved varieties (Ariga & Jayne, 2009; de Groot et al, 2006; Oluwande and Smale, 2012). In 2010, the adoption rate of hybrid maize seed increased to 82% from 68% in 2000, while yield increased by only 16%. The adoption of improved seed for other crops remains below 6% (Olwande et al., 2015; Ogada et al., 2011). This shows clearly there is disconnect between yield gains and new cultivars.

Though innovation as such may not be a major factor affecting yields, but one cannot ignore the fact, that innovation is endogenously determined through other factors such as availability of complementary inputs such as fertilizer – which is significantly increasing over years due to input subsidies primarily focusing on fertilizers than seeds; the maize output prices –

which is significant (at 10 %), especially after liberalization in mid to late 1990s where prices were de-regulated and private sector could participate in competitive markets. However, still NCPB plays a key role in surplus maize procurement, especially generated by medium and large sized maize farms in the country.

Table 6. Maize innovation regression

Variable name	Coef.	Std. Err.	t-value
rainfall-Rainfall	0.03	0.14	0.23
research--Public R&D expenses	-0.09	0.07	-1.27
private--Private sector share	5.00	6.28	0.8
fertilizer--Fertilizer imports	0.00	0.00	2.19*
PPI--Maize producer price	0.05	0.03	1.92
pvps--PVPs issued	1.64	0.62	2.63*
_cons	-4.79	8.09	-0.59

*--P≤0.05 **--P≤0.01
Source: Author

The maize seed innovations further are positively impacted by the presence of plant variety protection and in Kenya. Since the PVP act was implemented in 1996, the number of crop cultivars registered have increased, especially for maize cultivars among the cereal crops. It is mainly because Kenya seed market has been liberalized as well as pvp scheme has operated during that time. Based the previous literature review, all the policies changes focused more on managing seed quality as well as protecting breeder’s right after liberalization in order to adapt to the current economic development. Therefore, the increasing number of released varieties that have been approved by pvp is consistent with this trend. The level of protection offered by the Kenya also has attracted many multi-national and regional seed firms to begin their operations, in the country since then.

Another major factor influencing maize productivity levels in Kenya is the amount of public R&D expenses towards agriculture and allied activities. Since independence maize has been the priority crop in terms of food and livelihood security in Kenya. The Kenyan government has invested in production and dissemination of high-yielding varieties and inorganic fertilizers since independence. This has resulted in increased adoption of improved varieties, especially among maize-growers, yet productivity is stagnating or declining (Ogada et al., 2014). In the 1990s, policy reform focused on seed research by the Kenya Agriculture Research Institute and private firms, contributing to improved maize productivity and smallholder farm income (Ariga & Jayne, 2009). Our estimates show a positive and a significant relationship with the amount of public R&D expenses on maize yields in Kenya. One should note that still public sector share in maize seed markets is around 75 % vs. private sector, implying the presence of parastatal in terms of research and seed market presence; with a very small share for private sector operations, though the seed industry has been liberalized since mid 90s. This is reflected in our regression estimates also, with private sector share in cultivars have had a negative, but a significant impact on Kenyan maize yields. The existing private sector in Kenya, primarily depends on national and international research R&D for germplasm, parental line requirements. Though more than 20 private seed firms are involved in maize seed production in Kenya, the amount of R&D invested by domestic private firms is less than 1 % of annual expenditure; MNCs and regional companies who are operating in Kenya, at the moment bring their finished lines from South Africa or elsewhere.

The maize yields in Kenya are further influenced by agro-ecological factors such as rainfall; the major being the drought occurrence in Kenya and its impact on maize productivity levels. In the last 50 years, Kenya has been affected by drought for about 20 times, indicating 40% drought probability of occurrence of drought during the cropping season. This has significant impact on the maize yields, as maize is cultivated as 'rainfed' in Kenya in two seasons.

Thus to sum up, our results indicate that though the innovation variable, which is reflected by the number of released varieties, indicates a positive but no significant relationship with maize yield. It means releasing a new improved variety will generate as low as 2.95 kg/ha maize yield; implies increases in maize production in Kenya resulted from area expansion rather than from increases in productivity. As discussed earlier the analysis of yield gains in Kenya since 1980s shows that Kenya's average yield has shown a slight decline of about 1 kg/ha/year, compared to other growth figures exhibited in other countries such as south Africa (146 kg/ha/year; Malawi 93kg/ha/year). Public R&D investment shows positive and significant relationship to maize yield, which consistent with our expectations. It states that for every US $1 million (constant 2011 PPP dollars) invested in public R&D, about 5 kg/ha more yield will be generated. Private sector share reflects a negative relationship to maize yield, implying a weak contribution to seed innovation from private firms. It is mainly due to a lack of private seed companies in Kenya and Kenya Seed Company is still the most important source of supplying improved seed. Rainfall received though has a positive impact on maize yield, but not as significant as one would expect, because most of the maize in Kenya is grown as rain fed.

Chapter 6 Conclusions and Policy Implication

In conclusion, based on the results, seed innovation does not contribute significantly to maize yield in Kenya as expected. It has a positive but less important impact on the yield. Therefore, we can conclude that it is the expansion of maize area that resulted increased maize production other than increased maize yield. In addition, it proves that there is a higher adoption of improved maize seed with a rate of 72%. However, the replacement of new cultivars is still poor and slower, which also accounts for a less impressive impact of seed innovation on maize yield. What's more, public R&D investment still plays a major role in producing improved seeds. From the history of Kenya seed industry development, it is always the public seed sector that controls the operation of Kenyan seed industry. Even now, after liberalization. Kenya Seed Companies can be still considered as the most powerful authority source of supplying improved seed. And with strong supports from public seed sector, maize yield has increased due to it. Moreover, in terms of private seed sector, it has less contribution to maize yield. Hence, there is still potential for private sector participation towards improving maize yields across agro-ecologies. Last but not least, rainfall is crucial to maize growth while drought is a major phenomenon affecting Kenyan agriculture. Since 1964, the agriculture has faced more 8 major droughts, which also impacted yields.

Several policy implications can be therefore concluded. First, it is necessary and urgent to set up policies that providing a favorable environment of establishing more private seed companies in Kenya and further develop private sector R&D. As described in Chapter 2, private sector R&D expanded rapidly in the recent years in the global. Therefore, there is a trend of increasing power of private sector in contributing agriculture development all over the world. Compared to public sector, private sector has more flexibility in building cooperation among themselves and even collaborate with international organizations, getting technology or funding supports from some international organizations. Policies related to strengthening IPR can have positive impact of establishing more private firms. Secondly, policies should encourage public sector giving more power of controlling seed industry to private seed sector. From literature review, public sector still holds the majority share of improved maize seed in Kenya, which hinder the development of private seed companies. It is still weak of private seed sector to develop improved seed. Therefore, policies such as limiting the power of public seed sector and encouraging improving the structure of Kenya seed industry are also necessary. Last but not least, rainfall affects maize yield in a significantly positive way. Hence, it is also important to set up policies that are good for protecting environment such as maintain soil fertility. Having enough and regular rainfall is a major factor of having a sound maize harvest. Thus, it is obvious that policy framework plays an irreplaceable of improving maize yield. Even with a large area of planting improved seed as well as adopting new technology, there will not be an expected increasing in maize yield where there is an unfavorable policy environment. Further, seed policy also affects the structure of seed industry in Kenya. It is believed that with more adjusted policies implemented, Kenyan seed market will become more efficient and accordingly, maize yield therefore grew along with increased fertilizer use.

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