Biotechnology and Economic Development:

The Economic Benefits of Maize Streak Virus Tolerant Maize in Kenya

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Abstract

For countries that could not benefit from the Green Revolution due to heterogeneous and unfavorable biophysical environments, agricultural biotechnology potentially provides a means of improving the quality and quantity of agricultural production. This paper analyses some of the major issues relating to the utilization of biotechnology in Kenya. A partial equilibrium trade model is applied to Kenya's corn market to study the potential of genetically modified maize that is tolerant to the Maize Streak Virus. The model accounts for home production and consumption; the positive results of the welfare estimation are disaggregated between consumers, large and small Kenyan corn farms.

Key Words: welfare, biotechnology, corn, Kenya

JEL Classifications: O33, O13, D61

Introduction

Evidence that a productive agricultural sector enhances rural development and economic growth and reduces poverty in both rural and urban areas is twofold (Binswanger, 1998). There are examples of countries such as Taiwan, and China, where agricultural growth as a result of Green Revolution, helped alleviate poverty through lowering consumer food prices, raising rural wages, and generating employment in rural areas. A productive agricultural sector can also benefit the economy indirectly through positive spillovers to the urban informal labor market and non-agricultural sectors (Binswanger, 1998).

However, in Sub-Saharan Africa the Green Revolution has not occurred to any great extent. Kenya, for example, has a predominantly agricultural economy. Although the country was self-sufficient in food production at independence from Great Britain in 1963, factors such as the oil crisis in the 1970s, poor macroeconomic policies, decreasing public investment in agricultural infrastructure during the 1980s and 1990s, and the absence of a Green Revolution has made it difficult for Kenya to feed itself from domestic sources (Karanja et al., 1998). With an estimated 80 percent of the population earning their living in the agricultural sector, a decline in both food production and in exports has increased unemployment and poverty in rural areas. The situation has been exacerbated by a rapid population growth rate of 2.9 percent, well below the 1.9 percent growth rate in food production (Karanja et al., 1998).

Agricultural biotechnology is a potentially powerful means of improving the performance of African agriculture through boosting productivity in heterogeneous and less favorable production environments. Its potential benefit is largest for places like Kenya, which relies mainly on rain-fed agriculture. In addition to increases in yield or reductions in crop losses, biotechnology may also improve the quality and value of crops, raise rural incomes, stimulate employment in agricultural areas, thereby reducing food expenditure and boosting the demand for more agricultural and non-agricultural products and services (Mellor, 1998; Eicher and Kupfuma, 1998)

This paper examines the application of agricultural biotechnology in low income countries (LICs), and specifically, conducts an ex-ante economic evaluation of the benefits of introducing genetically modified (GM) maize in Kenya. The evaluation uses the partial equilibrium displacement model of Hayami and Herdt (1977), which regards home consumption as part of producer economic surplus and disaggregates welfare effects accruing to small and large farmers. A collaborative project between public institutions, private corporations and a non-profit organization has involved developing varieties of maize tolerant to maize streak virus (MSV). The performance of these GM varieties of maize is currently being examined.

Background

Biotechnology and Risks in Agricultural Production in LICs[1]

Agriculture is the key sector of the economies of most LICs, and agricultural development is critical in fostering economic growth. In LICs many poor people live in rural areas and increasing agricultural productivity is a critical step in alleviating poverty. Furthermore, increasing their incomes and assets (i.e. economic rights) of farmers and their families allows them to have greater access to better health and more education so they can increase their economic potential and reduce their vulnerability.

Biotechnology refers to the science "that alters biological processes of microbes, of plants or animal cells (in a laboratory setting) for the benefit of humans" (ERS, USDA). Biotechnology has the potential of increasing food production through increases of yield or

[1] See Norman (2003) for a more detailed exposition on the background.

reducing losses, especially in poor environmental areas; generally it improves returns to costly resources used by poor farmers. In agriculture, this broad definition ranges from traditional plant breeding to more modern methods of crop improvement based on research into genetic mechanisms behind economically important traits. The most outstanding achievement of breeding improved varieties of crops was achieved with the Green Revolution in Asia where classical breeding methods dramatically increased yields of rice and wheat (Chrispeels and Sadava, 2003).

The relatively new discipline of genomics has provided information on the identity, location, function and impact of genes affecting relevant traits for crop production (Chrispeels and Sadava, 2003). The application of genomics has given rise to three main types of biotechnology: micro-propagation (also known as tissue culture), molecular markers and genetic engineering. Micro-propagation has been successfully applied in the production of disease free bananas in Kenya (Wambugu and Kiome, 2001; Qaim, 1999). Molecular markers have helped researchers in South Africa identify maize genes that are resistant to MSV and drought (Thomson, 2004). Genetic engineering (GE) created vitamin A-rich "golden rice," and GM maize, soy, and cotton resistant to insects (e.g., Bt cotton) and herbicides. Since 1996 such crops have increasingly been planted worldwide.

Out of the three techniques described, GE has the highest potential to make a difference since it modifies plants to fit the environment (Norman, 2003). There are numerous studies that document the potential direct and indirect economic benefits that transgenic crops can bring to small-scale farmers in LICs (e.g., James, 2001; Wambubu and Kiome, 2001; Qaim 1999). However, GE is also the most expensive and controversial, and its application in smaller and more impoverished countries has been limited. Yet, partnerships between private (i.e. they provide the technology) and public (i.e. they are in charge of distribution) organizations have successfully made GE available for LICs. In terms of LICs China has been most dominant in introducing transgenic crops with major emphasis on Bt cotton. The economic gain for China from the introduction of transgenic crops has been estimated at $330 million in 1999 for smallholders alone (Leisinger, 1998 and 2002).

However, GE involves some risks. Leisinger (2002) differentiates between risks that are inherent to the technology and those transcending the technology. The first refers to the "potential hazards that might occur during research, development or implementation of the technology" such as bio-safety where unintended changes may result from GMOs competing with wild species. The latter risks refer to the potentially harmful effects resulting from its application in terms of political and social impacts, such as unfavorable distributional impacts of GE technology adoption between high-income and low-income countries, private- sector dominance of research and development, and violation of intellectual property rights. Moreover, the social acceptability of GM crops in some high income countries remains low. In the European Union (EU) and other parts of the world, consumers have demanded their rights should include being able to choose non-GM foods. In many countries, labeling systems for foods containing GM ingredients have therefore been mandated.

Agriculture and Maize in Kenya

With nearly 80 percent of the population deriving their living from agriculture, agriculture plays a critical role in the Kenyan economy (World Bank-Kenya, Webpage), although agriculture's contribution to gross domestic product has decreased from 38.4 percent in 1963 to 24 percent at the present time, and three-fifths of the land is non-productive. Agricultural activities account for 50 percent of foreign exchange earnings mainly in the form of coffee and tea. The urban population accounts for 31 percent of the total population of 30 million and the rural population is dependant mainly on agriculture, concentrated in the west, the richest and most fertile part of the country.

Kenya's agricultural sector is comprised of two sub groups: commercial (i.e., ex–colonial) farms (large) and indigenous or subsistence farms (small). A few thousand large-scale farms vary in size from 50 acres up to many thousands of acres, and are generally focused on the production of coffee, tea and tobacco. There are about 16 million small farms, typically with less than 20 acres, which traditionally grow maize, sorghum and fruits. However, in recent years there is evidence that small-scale farmers are shifting to crops such as coffee and horticultural products (i.e., banana and tomato) to achieve higher returns (Jayne et al., 2001).[2]

Maize has become the most important staple food crop in Kenya and in most countries in sub-Saharan Africa since its introduction from Latin America in the 16th century. Maize accounts for a larger cultivated area than any other crop in Kenya and is produced almost everywhere including in the arid and semiarid agro ecological zones. Average annual production during 1990s was 2.2 million tons, compared with 2.7 million that are domestically required for

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[2] Based on a 1997 and 1998 survey of 1,540 randomly selected households in eight provinces of the country, Jayne et al. (2001) found that over half of the households in the sample (i.e., the sample including only households with less than 20 acres of land) owned less than 0.20 acres of land per capita, and that over 25 percent of the same sample have land holdings of less than 0.05 acres per capita. The authors explain that expenses such as school fees, farm inputs, health, transportation fees and social obligations, exert pressure on the farm households to earn cash.

consumption.[3] Yields vary according to agro-ecological zone, but during favorable weather conditions range from about 2.0 to 5.4 tons per hectare (Nyoro et al. 2001). This is nearly half of the yield estimates attained in the US (James, 2001).

Two out of every three farms raise maize (Karanja et al., 1998). Production levels differ between the large and the small production systems. Large-scale production systems achieve as much as 43 percent higher yield than small ones, although this is somewhat dependent on the ecological zone. Large farms use 39 percent more intermediate inputs—fertilizer and agrochemical—and have higher levels of mechanization than small-scale systems. Yet, because small-scale farmers depend more on manual labor, their labor costs are higher. As a result in both systems the costs of producing a 90-kilogram bag of maize is about the same, namely Ksh780, although there are some regional differences (Nyoro et al., 2001). The majority of the small farm households who raise maize for home consumption are net purchasers an annual basis, not only because they can not produce enough to feed themselves for the entire year, but also because maize production competes in the use of resources with other crops in order to maximize use of available resources and to maximize farm "income" (Jayne et al. 2001).

As part of the Structural Adjustment Program (SAP) and food market reforms encouraged by the World Bank, the International Monetary Fund (IMF) and donors, the government of Kenya implemented a program of economic liberalization and reform in 1993 that included the removal of import licensing, price controls, and foreign exchange controls. As a

[3] Quantity demanded and produced in Kenya varies according to the source. For example, in ISAAA (2000) they cite 2.7 million tons and 3 million tons of quantity produced and demanded respectively. The figures reported by the FAO also differ slightly from the ones given in Jayne et al. (2001).

result, the Maize Marketing Board (MMB) no longer had monopolistic control of the maize markets; storage and distribution, and price supports were eliminated. This allowed the private sector to become more active in the marketing of maize. The import tariff on maize of 15 to 20 percent was removed, consequently, allowing maize prices to drop 15 to 25 percent in the period 1994-1998 compared with prices in the 1980-1988 periods. The result of the liberalization process and its effect on producers and consumers welfare has been the subject of controversy. Jayne et al. (2001) used information collected from rural households in 18 districts during 1997 and 1998 to determine the effect of support policies of maize on rural smallholders. Their findings indicate that 32 percent of rural households were net sellers of maize, compared to 50 percent that were net buyers. Small and large farms accounted for 10 and 90 percent of the maize marketed domestically.

The majority of the poor people in Kenya is located in rural areas and grows maize. The strategy of increasing maize productivity through technological change that is cost-reducing, coupled with investment in agricultural infrastructure and appropriate support systems is likely to facilitate sustained economic development. It can potentially create of surplus of food that can benefit consumers. It can also help raise the real incomes of both small-farm producers and rural consumers thereby helping to stimulate demand and employment growth both in the agriculture and non-agricultural sectors of the economy. Since maize would be more affordable and available, small farmers could potentially shift from a subsistence farming system to a more commercialized one by choosing crops whose returns are higher than traditional crops. This could potentially create opportunities for farmers to engage in other activities where they can get a higher return for land which is their most limiting input. In general, such a strategy would contribute to a food security strategy in preference to the inferior one of food self-sufficiency.

Maize streak virus (MSV) is one of the major diseases affecting maize in Africa (Wambugu and Wafula, 2000). With the help of biotechnological techniques, a collaborative research program funded by the Rockefeller Foundation and Novartis, and led by the International Center for Insect Physiology and Ecology ICIPE), the International Service for the Acquisition of Agri-Biotech Applications (ISAAA), the Kenyan Agriculture Research Institute (KARI), and others, are working for 6 years to develop maize varieties resistant/tolerant, and ultimately immune, to MSV.

Welfare Analysis and Issues

Since the 1960s an increasing number of studies have been devoted to evaluating the returns to agriculture from R&D (research and development) investments. Most of these studies focus on the productivity payoffs of agricultural R&D projects as well as the optimal amounts and allocation of R&D funds. Alston et al. (2000) grouped articles and studies dealing with returns to agricultural research into two categories. The first category were those that evaluated benefits from research estimating an average rate of return derived from changes in consumer and producer benefits (i.e., the difference in changes between producer and consumer surpluses) using a demand and supply model for a commodity. The second category treated research as a production function variable and estimated a marginal rate of return either from the increase in output (for given inputs) or the saving in inputs (for a given output).

Similarly, Norton and Davis (1981) categorized studies as ex ante versus ex post. Ex ante analyses use experimental estimates on the impact of the new technology to calculate the magnitude of the supply shift. The ex post approach estimates the input savings or output growth once the technology has been implemented and become widespread.

While a common conclusion of these studies is that the benefits of agricultural research are high, a review of the literature on returns to agricultural research illustrates a variety of approaches used. Major differences are seen in the specification of the supply and demand functions, the nature and measurement of the supply shift; and other assumptions such as an open versus a closed economy, inclusion of a demand shift, rate of adoption of new technology, aggregate versus disaggregated models, and partial versus general equilibrium models.

For staple food products in LICs, the distinction between consumer and producer is blurred because of crops raised for home consumption. As noted by Alston et al. (1995), technology shifting models based on a semi-subsistence crop should be treated in a different way from products that are more commercial. Alston et al. (1995) recommend a model proposed by Hayami and Herdt (1977) where home-consumption is considered, and the commodity being analyzed not only refers to marketed quantities.

The Partial Equilibrium Displacement Model

A partial equilibrium displacement model proposed by Hayami and Herdt (1977) incorporates a demand curve for home consumption and is appropriate for maize in Kenya, where most small-scale farmers eat up to 80 percent of their production. Models that are specially designed to account for technological shifts in supply in LICs are discussed in Qaim and von Braun (1998). Qaim (1999) applies it to the special case of bananas in Kenya.

An objective in this paper is to consider the welfare and equity implications of such technology changes. This paper adopts the approach of Alston et al. (1995) and uses linear specifications for demand and supply, as well as a parallel shift in the supply curve. Clearly, results obtained from assuming the technological change as a parallel shift could differ in magnitude and in distribution if other types of shifts (e.g., pivotal and proportional) were used.

However, we feel that this decision is justifiable since there are no data available that could indicate how the technology introduced would impact marginal costs in the maize sector. Indeed, Rose (1980) explains that for most cost-saving innovations, given the best information available, the most realistic alternative is to assume a parallel shift. The adoption of such an assumption also simplifies calculations and evaluations of welfare estimations. Alston et al. (1995, p. 65) also point out that adoption of such an assumption provides some consistency and hence comparability in the evaluation of different research projects.

According to Hayami and Herdt (1977), the market for a subsistence crop such as maize in Kenya is graphically depicted in Figure 1. Producers' demand for consumption at home is logically more price inelastic than the market demand. In Figure 1, the demand curve for home consumption is for convenience depicted vertically by line D_h, but it need not be completely price inelastic. The market demand curve is depicted by D_m above the quantity consumed of Q_h and by D_h below Q_h. The horizontal difference between the D_m segment and D_h represents the quantities consumed by non-farmers.

The initial maize supply curve S_0 shifts to S_1 as a result of lower cost per unit as a result of biotechnological improvement in maize. The initial equilibrium price for maize is P_0 and it is determined by the intersection of S_0 and D_m. The new equilibrium price with the technological shift in supply is P_1. Consequently, the change in consumer surplus for the quantity of maize marketed is area gabf (depicted in grey in Figure 1). The change in producer surplus is given by the difference between area ebcd, that represents the reduction in production costs, and area gaef, which reflects the change in commodity price. The only difference between a model for a wholly commercialized commodity and this one is that this model incorporates the amount of home consumption, area P_0gfP_1, which is captured by consumers in the first model, also accrues to producers in this model.

The supply curve can be disaggregated into multiple supply curves, corresponding to various groups of farmers with different price elasticities of supply. Here, two groups—large-scale and small-scale farmers—are considered. If the aggregate price elasticity of supply is assumed to be the weighted average of the price elasticities of supply of the two farmer groups, where the weights are groups' shares of total output, then the supply shift can be disaggregated as the weighted average of the shifts experienced by the farmer groups, weighted by the groups' output share.

Following Qaim (1999), the percentage change in the commodity price, i.e. p_0-p_1/p_0, can be calculated as follows:

$$\frac{dp}{p} = \frac{\sum_{i=1}^{N}(ss_i \cdot E_{s,i} \cdot K_i)}{E_d - \sum_{i=1}^{N}(ss_i \cdot E_{s,i})}$$

where:

ss_i is the production share of each group i,

$E_{s,i}$ is the price elasticity of supply for each group,

K_i is the downward shift factor of producer group i and is given by c_i the per-unit cost reduction for each group times a_i the rate of adoption of the technology by each group, $K_i = c_i * a_i$,

E_d is the price elasticity of demand.

The changes in consumer and producer surplus are given by:

$$\Delta CS = -p \cdot q_d \cdot {dp}/{p} \cdot (1 + 0.5 \cdot E_d \cdot {dp}/{p}) - (-dp \cdot q_d \cdot \sum_{i=1}^{N}(h_i \cdot ss_i)$$

and

$$\Delta PS_i = p \cdot q_{s,i} \cdot (\frac{dp}{p} + K_i) \cdot (1 + 0.5 \cdot E_{s,i} \cdot (\frac{dp}{p} + K_i)) + (-dp \cdot q_{s,i} \cdot h_i),$$

where:

p is the average annual market price for maize in Kenya from 1995 to 1999

q_d is total quantity of maize demanded (marketed and home consumed),

$q_{s,i}$ is the quantity of maize produced by each group,

h_i is the proportional home consumption by each group.

Ex- Ante Estimation of Economic Impact of Maize Biotechnology

The Assumptions

The above framework is applied to evaluate the economic benefits of adopting an MSV-tolerant variety of maize in Kenya after a year of adoption. Because of a great deal of uncertainty regarding the actual impact on costs of adopting the new technology, ex-ante studies are based on several assumptions and predictions. Below, we discuss each assumption in turn:

Potential benefits of the MSV tolerant varieties. The expected technology-induced change in maize yield was elicited by estimating the current incidence of the disease in Kenya. Before 1980, losses due to MSV in Africa were around 10 percent. In the 1990s, the trend worsened and MSV yield losses currently average between 30 and 50 percent (Wambubu and Wafula, 2000). The situation is analogous for Kenya, although MSV incidence in southwest Kenya in 1998 was in the range of 80 to 100 percent. The strength and the losses due to the virus depend on the season, kind of vector, and other conditions.

Given the current estimates of the loss in yield due to the disease, it is reasonable to assume that the introduction of MSV resistant maize could increase maize yield by 30 to 50 percent, which is within the range of outcomes of field experiments (Wambugu and Wafula, 2000). We used the first figure as a low-yield increase scenario and the second one as a high yield increase scenario. To translate the use of the MSV tolerant maize variety to an upward shift in the maize production function, yield increases are converted into per unit cost reductions. That is, in monetary terms, holding all else constant, this shift can be measured as the average cost reduction per unit of output as a result of adopting MSV resistant variety.

Average estimates of costs for large and small scale maize production systems are taken from Nyoro et al. (2001). Though the authors point out that maize is grown nearly everywhere in Kenya, they list costs and returns for large and small farmers in two districts that produce the largest quantities of maize (the Trans Nzonia and Uasin Gishu Districts), which collectively we will refer to as Region 1. We take an arithmetic average of both districts for costs of growing maize for the two groups of farmers (Table 1).

Nyoro et al. (2001) report a wholesale average annual price for metric ton in Kenya in 1999 of $US221 for all regions; whereas Jayne et al. (2001) lists farm gate average annual prices in Region 1 of around $US180. This price is well above neighboring countries, thus reflecting the influence of the Maize Marketing Board on maize prices in Kenya (Jayne et al. 2005). For the purpose of this paper, we use a farm gate price for maize of $US200 per metric ton as a representation of the mean price of the above sources.

Currently, there are no data relating to the implementation of the new technology and its impact on production input mixes and costs. In this study it is assumed that cost of producing maize for each production system (i.e., large-scale and small-scale farms), increases by 20 percent due to the higher price of MSV maize seed, and other costs such as additional labor.

The resulting potential saving in average costs after implementing the MSV biotechnology as a result of the assumptions we have discussed above are summarized in Table

2. The high-yield increase scenario is at least three times higher than the low-yield increase scenario for both small and large farmers.

Market data. In general, production quantities reported by the FAO are a little larger than the ones reported in Jayne et al. (2001). The latter estimated 2.2 million tons per year over the 1995-1999 period, whereas the FAO for the same period estimated 2.4 million tons per year. For this paper the Jayne et al. estimate is used.

Cost estimates are also collected from Jayne et al. (2001) and Nyoro et al. (2001) (Table 1). The initial price for maize used in these calculations consists of average farm gate national price from 1995 to 1999 -- not including the support price implemented at the end of the 1999 year.

Elasticities. Estimates on maize price elasticity for Kenya could not be found in the literature. In the absence of better information, supply response parameters for agricultural crops in LICs are often approximated with a value near to one (Alston et. al., 1995). Since large-scale farmers are more commercialized than small-scale farmers, it is expected that their production is more price responsive, and thus, we assume maize supply elasticities of 0.8 and 1.2 for small and large-scale farmers respectively. The average price demand elasticity for maize in the US is -0.4; in LICs the price responsiveness of demand is much higher than in high-income countries. Therefore price demand elasticity is -0.8 was assumed for maize in Kenya.

Technology adoption. Most studies assume a cumulative rate of adoption for new technologies. Technology adoption tends to increase in the years following its introduction as dissemination becomes more effective and positive results become more apparent. In this study we look at welfare calculations after only one year[4] as a result of the introduction of the new technology. Consequently we are concerned only with the adoption rate after one year following its introduction. Some studies indicate that large farmers usually have a higher adoption rate for new technologies while others report a higher intensity of adoption by small-scale farmers, especially when the technology has low investment costs (Karanja et al. 1998). In other cases it has been found that smallholders initially lag behind large farmers in adopting new technologies but eventually catch up. In the case of adoption of hybrid maize in Kenya small farmers initially lagged in their adoption of the technology (Karanja et al. 1998). For the purposes of this paper we assume large-scale farmers will initially have a higher adoption rate than small-scale farmers, because of greater financial resources, better ability to take risks, and easier access to the new technology than in the case of many small-scale farmers. Therefore we assume the adoption rates of MSV resistant maize in the first year is 40 percent of the total quantity of maize grown by large-scale farmers versus 25 percent for the total quantity of maize grown by small-scale farmers.

Production shares and estimates of home consumption. According to Jayne et al. (2000), 90 percent of the total maize production in Kenya is grown by small-scale farmers. However, only 20 percent of the smallholders' maize production is marketed, with the remaining crop used for home consumption. Large-scale farmers maize sales are estimated at 80 percent of their production. We assumed these figures in our calculations.

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[4] More periods could easily be calculated and incorporated in our model. In such a case, we would assume a rate of adoption which increases from year to year after the technology adoption as the innovation spreads and farmers become better at using it.

Other assumptions. Maize is assumed to be a homogenous commodity, thus no differences in quality are taken into account. Table 3 summarizes the variables and assumptions made in order to calculate economic benefits of adoption of MSV tolerant maize varieties one year (i.e., 1999) after their introduction using a partial equilibrium displacement model.

The Results

Results of the estimated economic evaluation of MSV tolerant maize one year after its introduction in Kenya are given in Table 4. The results are divided according to a low and high-yield estimate scenario:

The distributional effects after a one year adoption of a MSV tolerant maize variety indicates that consumers benefit the most. In both scenarios, consumers capture around 54 to 60 percent of the total welfare changes. The larger share of the producers' surplus accrues to small-scale farmers under both in the low and high yield increase scenarios. They gain an estimated 33 percent of the total change in surplus under the low-yield scenario and 44 percent of the total change in surplus in the high-yield scenario. Large-scale farmers gain an estimated 7 to 2 percent of the total surplus change – depending on the yield change scenario.

The results of the distribution of benefits after a one year adoption of the new technology in maize in Kenya are not at all surprising. Consumers benefit from the reduction of price, raising the quantity demanded. Small-scale farmers gain from the lower costs achieved by the technology and from the reduction in price, since as much as 80 percent of their production is consumed at home. Large-scale farmers, though their adoption rate is greater than small-scale farmers, gain less because they produce only a 10 percent of the total quantity produced in Kenya.

The approach that we have followed in this model permits small-scale farmers to gain from the maize that is consumed at home whereas with other models, this gain will accrue only to consumers in the market place. In the latter type situation, the final share of small-scale farmers, since they commercialize only 20 percent of their production, would decrease by as much as 30 percent.

The total difference in benefits between the low and the high yield increase scenarios is more than 300 percent. The reason is that in the high yield increase scenario the per-unit cost reduction in maize (C_i) is at least three times greater than the reduction in the low yield increase scenario. The difference is justified because in both scenarios it is assumed that the variable production costs increase by 30 percent. In the low yield increase scenario most of the yield increase resulting from the adoption of the MSV tolerant maize varieties is to a great extent offset by the increase in the costs associated with producing them. However, in the high yield increase scenario, the increase in yield is much greater than the increase in production costs and hence the benefits triple.

In the low yield increase scenario the price of maize is reduced by less than 1 percent of the initial price that existed without the MSV resistant technology. Although this differential in price may not appear very large, given the importance of maize in Kenya in everyday diets, the lower price raises the total annual quantity of maize demanded, saving consumers as much as $ 6.3 million. In the high yield increase scenario, the price reduction amounts to 2.3 percent of the initial commodity price, and as a result of this, the quantity demanded rises and the gains accrued to consumers are four times greater than in the low yield increase scenario. Similarly, the small-scale and large-scale farmers' gains in the high yield increase scenario are five times greater than in the low yield increase case.

Conclusion

The magnitude of the results is quite impressive. Despite some overstatement that might arise from the assumptions regarding rates of adoption, it is reasonable to argue that developing maize varieties resistant to MSV disease will certainly bring major benefits to small-scale farmers in Kenya. The distributional effects of the adoption of the technology show that, the use of biotechnology to develop MSV resistant maize will benefit both consumers and small-scale farmers. Similarly, the potential impact of such a technology could be even greater given the fact that an MSV epidemic appears to be occurring throughout Africa (i.e., Southern, Eastern and Western). Since the technology can potentially be adopted in at least 20 other African nations, the MSV project could provide a very good example of a unique, well-coordinated collaborative effort, involving public and private sector institutional support that is so often needed to solve problems that affect many African countries. The application of biotechnology in creating MSV tolerant maize varieties has the potential for greatly improving the living standards of rural families and poor urban populations. In addition by reducing the risks of producing maize through eliminating the MSV it has the potential for reducing some of the maize price variability and periodic shortages associated with growing this important staple food crop.

Another study (Qaim (2000)) relating to using tissue culture on bananas to produce disease free plantlets reports an average annual gain in economic surplus of $US12.8 million in Kenya. One point seven percent of the arable land is devoted to bananas in Kenya. His figures are smaller than ours but his estimates refer to a different crop. He used a model similar to ours, where home consumption is also accounted as part of producers' welfare gains.

In terms of further research, we would like to conduct an ex-post study of the introduction of MSV tolerant maize in Kenya. Indeed, the same technology is also being developed in South Africa (Thomson, 2004). A comparative study of the implementation and distribution of MSV tolerant maize varieties in Kenya and South Africa would be a significant challenge, but possibly, a very rewarding one.

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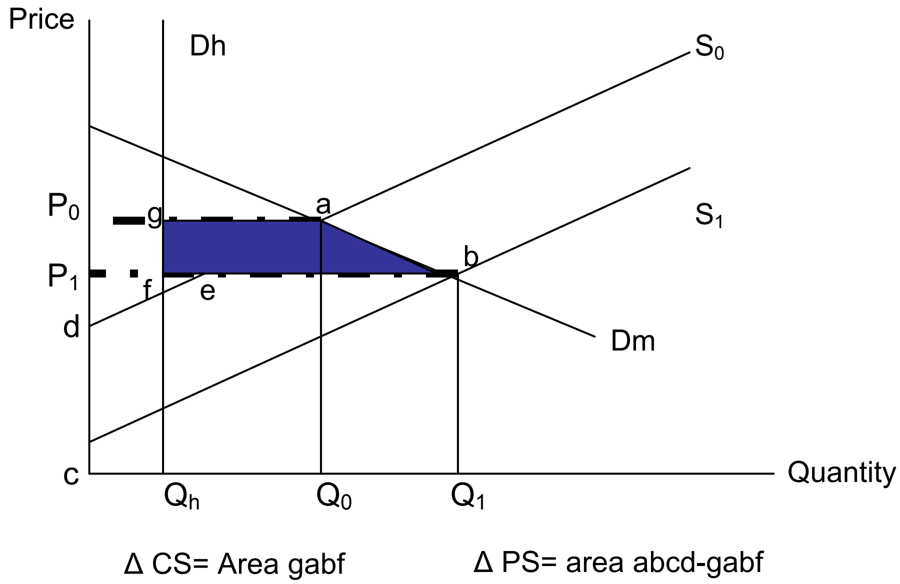
Figure 1. Biotechnological Progress in the Kenyan Maize Market



Source: Adopted from Qaim, 1999.

Table 1. Price and Cost of Maize in Kenya (Region 1) in 1999

Average Actual	Small Farmers	Large Farmers
Total costs of producing maize ($US/metric ton	$125	$120
Yield	15	21
Price ($US/metric ton)	$175	$ 171

Notes: 1KSH= $US0.0137 Dec. 2005; 1 metric ton =1,000 kilos.
Source: Jayne et al.(2001)

Table 2. Estimated Per Unit Cost Reduction After Adopting MSV Tolerant Maize Variety

Scenario	Small Farmers	Large Farmers
Low yield increase scenario	4.28%	5.399%
High yield increase scenario	17%	18%

Table 3. Assumptions Used in Estimating Economic Benefits of MSV Tolerant Maize Varieties

	Small Farmers	Large Farmers
Price elasticity of supply ($e_{s,i}$)	0.8	1.2
Price elasticity of demand (e_d)	-0.8	
Adoption rate (percent area)	25%	40%
maize production in 1999	2.1 million tons	
Production share	90% of total	10% of total
Home-consumed share of production	80% of 90% total	20% of 10% total
Price per ton ($US)	200	
Estimated increase in maize's annual production under MSV tolerant maize (c_i)		
Low yield increase scenario	4.28%	5.399%
High yield increase scenario.	17%	18%

Table 4. Estimated Changes in Consumer (CS) and Producer (PS) Surplus as a Result of Adopting MSV Tolerant Maize Variety

Scenario	Small-Scale Farmers	Large Scale Farmers
Low Yield Increase Scenario (30% increase in yield)		
dp/p	-0.00677	
Δ CS ($US)	6,371,487.97	
Δ PS ($US)	3,535,082.85	683,542.27
High Yield Increase Scenario (50% increase in yield)		
dp/p	-0.02582	
Δ CS ($US)	16,789,982.91	
Δ PS ($US)	14,155,414.78	647,203.17

Note that $US are nominal $US