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AGRICULTURAL BIOTECHNOLOGY, INTERNATIONAL TRADE, GENERAL EQUILIBRIUM AND EFFICIENCY

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AGRICULTURAL BIOTECHNOLOGY, INTERNATIONAL TRADE, GENERAL EQUILIBRIUM AND EFFICIENCY

by

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Advisor: Hendrik Van Den Berg

Ongoing debates about the adoption of the agricultural biotechnology in the developing countries and EU have dominated the literature in development economics and biosciences. This dissertation considers some environmental, economic and social consequences of the technology from three perspectives: 1) the impact of the ongoing pest density on the performance of the agricultural biotechnology in India; 2) trade consequences of EU restrictive trade policies towards biotech products; and 3) the adoption decision of the technology in the EU and the developing economies. Agricultural biotechnology appears to be successful in increasing yield and reducing the use of pesticides. However, most studies fail to consider the dynamic effect of the pest population. Pests are getting more resistant to the biotech seeds. I use a stochastic production function to capture the impacts of inputs on the mean of the output and the effect of pest density on the variability of the output. The results show that, due to the presence of new pests, the productivity of the damage control inputs such as biotech seeds and the insecticides decreases.

The ban on the agricultural biotechnology products by the European countries has affected trade flows between EU and its trading partners. I use the international-trade-gravity-model to assess the trade impacts of EU policies towards agricultural biotechnology products. The results show trade creation in the Food and Live Animals category**.** However trade diversion was found in the Beverages and Tobacco and Animal and Vegetable Oils and Fats categories.

Using a general equilibrium and comparative statics analyses, I determine the impact of the enforcement of the Intellectual Property Rights, consumers' preferences and externalities on the production of biotech crops. The results show that efficient production of biotech crops under the influence of these three factors is contingent upon the output elasticity of capital in both biotech and non-biotech productions, total factor productivity in biotech production, and the ratio of the proportions of the biotech and non-biotech products consumed by each consumer

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Praise the LORD, my soul; all my inmost being, praise his holy name. Ps 103-1

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CHAPTER 1

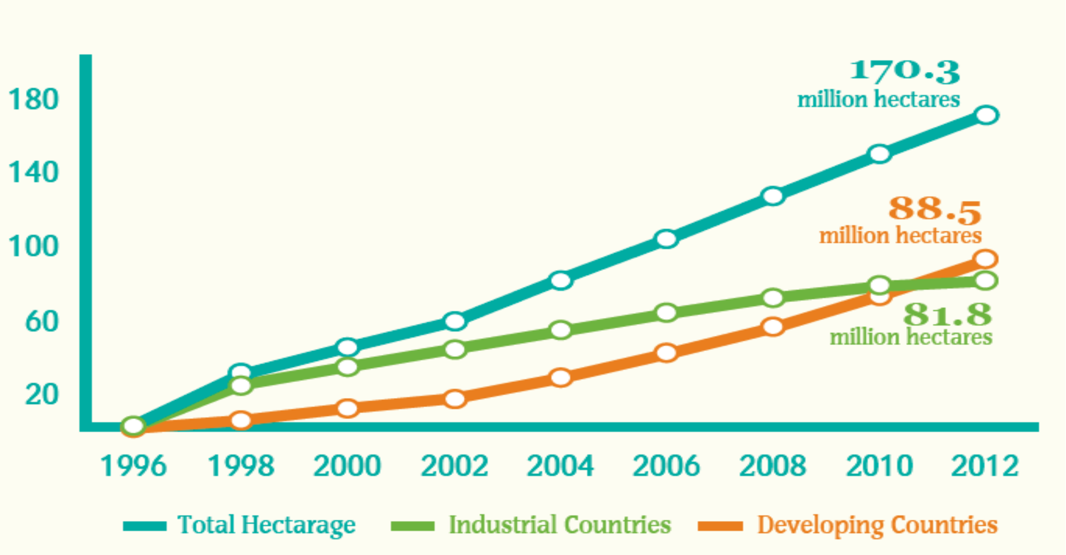
INTRODUCTION AND ISSUES OF AGRICULTURAL BIOTECHNOLOGY

Modern biotechnology encompasses a variety of methods for modifying living organisms according to the purposes of the scientists. The technology’s application across medical, pharmaceutical, chemical, environmental and agricultural uses is spreading quickly across the globe. While biotechnology is accepted in other sectors, agricultural biotechnology, which is known as GMOs, is encountering some obstacles in various countries. Agricultural biotechnology can be put into three categories: production-trait applications, output-trait applications and bioengineered products applications (Brenner, 1998). The most common production-trait applications are herbicide tolerance and insect resistance which have been developed for extensive use in crops cultivation. Moschini et al., 1999, described herbicide tolerance crops as being modified with a gene found in a oil bacterium that allows plants to metabolize herbicides. Insect resistant varieties of maize, cotton, soybean and wheat, have been genetically modified to generate pesticidal property of Bacillus thuringiensis (Bt) that produces a protein toxic to certain insects (Harlander, 1993).

Agricultural production has always been risky, and characterized by large annual variations in crop yield. The risks to the yield can originate from weather (drought, floods, hail and frost), from soil conditions (salinity, nitrogen depletion and erosion), from disease (rot, fungal and rust), and from pests (bacteria, viruses, nematodes, insects and animals). North America scientists made the breakthrough by developing GM-crop varieties to reduce production risks. For instance, new GM varieties of conventional crops have been created with higher degree of stress tolerance to ecological conditions and with a higher degree of resistance to pests and disease (Isaac, 2002).

The adoption and the commercialization of biotech crops have reached several countries around the World. Biotech crops were first commercialized in 1996. Biotech crop hectares increased by an unprecedented 100–fold from 1.7 million hectares in 1996, to over 170 million hectares in 2012 (Clives, 2012). In 2012, the number of hectare of biotech crops grew at an annual growth rate of 6%, up 10.3 million from 160 hectares in 2011. Figure 1.1 shows that the growth rate of biotech crops increase faster in developing countries than industrial countries from the year 2010. In 2012, growth rate for biotech crops was at least three times as fast, and five times as large in developing countries, at 11% or 8.7 million hectares, versus 3% or 1.6 hectares in industrial countries (Clive, 2012).

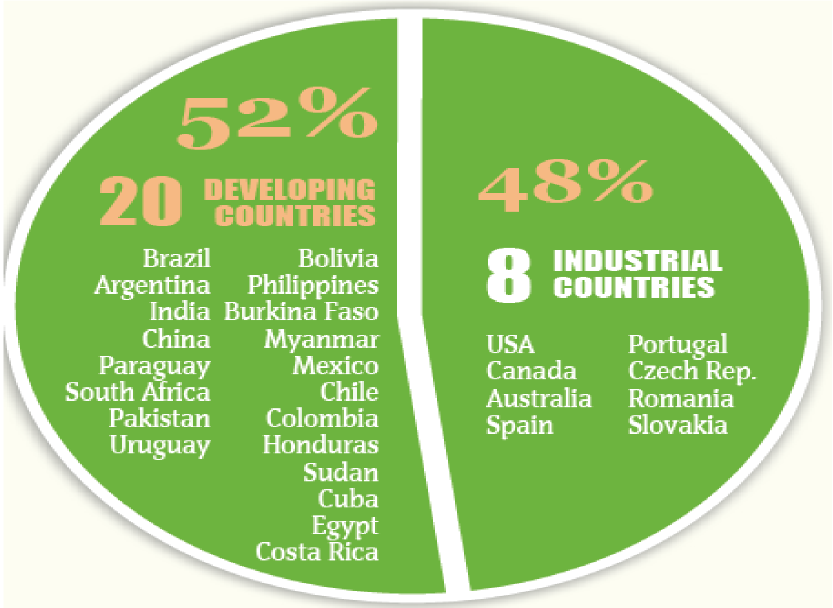
Figure 1.1: Trend of biotech hectarage of developing and industrial countries



Source: James, Clive. 2012. Global Status of Commercialized Biotech/GM Crops: 2012. *ISAAA Brief No. 44*

According to 2012 report of ISAAA, developing countries grew more, 52%, of global biotech crops in 2012 than industrial countries at 48%. Of the 28 countries which planted biotech crops in 2012, 20 were developing countries and 8 were industrial countries. In 2012, Sudan and Cuba have adopted Bt cotton and Bt maize, respectively. The number of farmers growing biotech crops was 17.3 million farmers in 2012, up 0.6 million from 2011(See Figure 1.2 below).

Figure 1.2: Developing versus Industrial Biotech Countries



Source: James, Clive. 2012. Global Status of Commercialized Biotech/GM Crops: 2012. *ISAAA Brief No. 44*

The technology is widely used in the US with 69.5 million hectares and an average of 90% adoption across all crops. Brazil takes the second place for the fourth consecutive year with a record increase of 21% from 2011 (from 6.3 million to 36.6 million). With 23.9 million hectares, Argentina kept its third place, followed by Canada with 11.8 million hectares. India with its 10.8 million of hectares of Bt cotton took the fifth place. In Africa, only Sudan, South Africa, Burkina Faso and Egypt are currently planting biotech crops.

Figure 1.3: Non-Biotech and Biotech adopting Countries

Biotech: Green/ Non-Biotech: Yellow

Source: James, Clive. 2012. Global Status of Commercialized Biotech/GM Crops: 2012. *ISAAA Brief No. 44*

As shown in Figure 1.3 above, the agricultural biotechnology is widely used in the North America than any other parts of the world. Since the technology is highly embedded with economic implications (Isaac, 2002), its substantial use in the North America where the enforcement of the IPRs is very effective, makes more sense. A place like Africa where the enforcement of the IPRs does not exists; the adoption rate of the technology is very low. In other words, the lack of effective regulatory system in small and poor countries continues to be the major constraint to adoption (Clives, 2012). Despite the increasing adoption rate of the agricultural biotechnology, consumers still express some reluctance regarding the products. Some consumers express economic, human safety and health, biodiversity, moral, ethical and religious concerns about biotech products. Consumer acceptance is critical for the future of biotech agriculture. For example, Monsanto's shares dropped from US$ 51 in May to US$ 38 October 1999, because shareholders are concerned about consumers'attitudes towards GM crops (Public Ledger 1999a).Consumer acceptance has been a key issue for various groups active in the development of biotech crops.

According to economic theory, if the use of GM crops reduces the relative price of agricultural goods, consumers will purchase more, so long as agricultural goods are normal. The economic concerns of the consumer regarding biotech crops may be viewed in broader perspectives. For example, a high concentration of research capacity, providing well-paying jobs, may have positive impact on the consumer acceptance. On the other hand, consumers may perceive that most of the benefits go to the large, private, multinational firms commercializing GM crops, with no benefit to them. This kind of perception among consumers may have negative impact on consumer acceptance of the technology.

With respect to human safety and health concerns, consumers are afraid of getting sick in the long- run after the consumption of biotech products. Specifically, the concern is that toxigenic, pathogenic, infective or invasive changes to the plant may affect human health and safety (Isaac, 2002).These concerns will have negative impact on consumer acceptance of GM crops.

Biodiversity concerns are also raised among consumers; the issue is that farmers producing herbicide-resistant GM crops will apply herbicides in a reckless, irresponsible manner in order to control weeds. By doing so, they can harm diversity and contaminate ground water. With that in mind, some consumers will refrain from purchasing GM crops. Moral and ethical concerns of GM technologies are raised by the fact that many private firm scientists advocates for the use of GM crops solely to enhance their own monetary rewards. Indeed, the owners of the technology deserve some compensation, but the compensation must be limited by some moral and ethical boundaries. Private leadership of the GM technology has raised several questions among consumers. For example, Ho (1998) argues that the shift from public leadership in research on biotechnology to private leadership is associated with several substantial problems. The profit- seeking motives behind innovative attitudes towards GM technologies fail to address public interest. The public interest comes into play only when it comes to commercialization. Therefore, given the profit motives, private scientists can no longer be trusted to act in a moral and socially ethical manner.

After exploring current issues surrounding the agricultural biotechnology, I construct this dissertation which comprises three essays. In the first essay, the impact of the proliferation of new pests on biotech crops yield was considered. The performance of the technology was evaluated in India using the stochastic production function in order to capture yield risks caused by the additional applications of pesticides due the presence of the secondary pests such as aphids and jassids.

In order to consider the impact of consumer acceptance of GM technologies, I extend the dissertation to the second essay which deals with the EU preferences and policies towards GM crops. The idea is to determine trade related consequences of such policies which are significantly affected by consumer preferences. I found strong evidence that EU restrictive trade policies have caused trade diversion in the import flows from the Rest of the World. Trade creation was also found.

The third essay is a theoretical exercise. Considering consumer attitudes towards GM products, the enforcement of the IPRs by the private seed companies and the presence of negative externalities of the biotech seeds, I investigate the impact of these three factors on the production of biotech using general equilibrium and comparative statics analyses.

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CHAPTER 2

CROP YIELDS AND ONGOING PEST DENSITY: EVALUATING THE PERFORMANCE OF BIOTECH CROPS IN INDIA

Abstract: Several studies have evaluated the performance of biotechnology crops and found that the technology is successful in increasing yield and reducing the pesticides. In contrast, most studies fail to consider the dynamic aspect of the pest population, even though the pests are getting more resistant to both pesticide-producing crops and the pesticides. The pest density kept growing and different types of new pests kept emerging regardless of the amount of pesticides sprayed. The objective of this paper is to evaluate the performance of biotechnology crops in India, taking into account the pest density. I use the stochastic production function to capture the impacts of the inputs on the mean of the output and the effect of pest density on the variability of the output. Insecticides squared and human-labor squared are used as proxies for the pest density in order to get more accurate econometric estimation. Furthermore, comparative analysis is conducted between biotech and non-biotech crops using the elasticities of the insecticides and human labor with respect to the yield. The results show that the presence of new pests upon the adoption of the biotech seeds has nullified the productivity of the damage control inputs such as biotech seeds and the insecticides.

Keywords: Biotechnology crops, pest density, stochastic production function, India

2.1. Introduction and Background

Biotechnology (BT) crops have been developed to substitute for conventional crops across the globe. They have been commercialized for more than a decade. BT crops were designed by companies like Monsanto, Syngenta, and others to produce natural insecticides that fight against pests. Farmers in some developing countries have embraced the technology, and it seemed to be successful in terms of a reduction in pesticide use and increasing yields. Eighteen developing countries like South Africa, Burkina-Faso, China, and India adopted the technology over the period of 1996-2010 (James, 2010). In particular, India has been cultivating BT crops, mostly cotton and maize, since 2002. Previous studies that evaluated the performance of the technology have undertaken farmer-level analysis using survey data, and their results are quite similar. More detailed results of some studies that have been done are provided in Table 2.1. below.

However, these studies did not take into consideration the dynamic evolution of pest density. For example, there are some sucking pests like aphids and jassids over which BT crops have no control, and farmers still need to increase the use of insecticides. These secondary pests, which increase in numbers as other more traditional pests targeted by the GM crops, can result in causing significant damage to BT crops. In Australia, pesticide use against bollworms has dropped, but farmers still spray their BT cotton fields with insecticides 4.6 times per year (Qayam et al, 2002). Furthermore, in the state of Andhra Pradesh in India, farmers growing BT crops increase the numbers of sprays against the secondary pest aphids more than farmers growing conventional crops. (Report on production practices, 2002). Even in the US, where the BT crops have been widely used, insecticide applications against bollworms have declined by half due to the introduction of BT crops; however, total insecticide use has remained stable due to the increasing importance of the secondary pests (Benbrook, 2003).

The strategies of the Integrated Pest Management, which include the use of BT crops, were developed with little attention to the dynamics of pests or the role of predators, parasites, and others biological control organisms. As a matter of fact, the combination of insecticide resistance and resurgence of cotton bollworm, cotton aphid, and other pests had become a major threat to cotton production in China (Wu and Guo, 2005). In order to get a more comprehensive idea of the issue of pest proliferation due to the adoption of the BT crops, we would like to make use of the history. For instance, before the 1970s, aphids could easily be controlled by treating seeds with insecticides. In the mid-1970s, aphids became a prominent pest of cotton owing to an insecticide-induced resurgence in mid-and late season (Wuhan, 1980 and Guo, 2003). The increasing aphid damage to cotton was caused by the insecticide sprays against *H.armigera*, which kill most natural enemies of the aphid, such as ladybeetles and lacewings. Therefore, the reduction in predation mingled with a high resistance to insecticides has resulted in major yield losses (Xing et al., 1991). Furthermore, we need to emphasize the roles of target pests, and nontarget pests in the proliferation of the secondary pests. In the cotton field for example, the target pests are cotton bollworm and pink bollworm, and the nontarget pests are mirids and aphids. Cotton field experiments in China show that mirid density is significantly higher on nonsprayed BT cotton than on sprayed non-BT cotton owing to a reduction in the number of insecticide applications against *H. armigera*. (Wu and Guo, 2005). In addition, the substitution of broad spectrum chemical pesticides, with a narrow spectrum toxin such as BT, would result in a higher concentration of secondary pests (Wang et al., 2008)

This suggests that the mirids have become key insect pests in BT cotton fields, and their damage to cotton could increase further with the expansion of BT cotton-growing areas if no additional measures are adopted. Consequently, BT crops are not the ultimate pest management strategy given the dynamic proliferation of the secondary pests. Considering the resistance management of target insects, the greatest threat to the continued efficacy of BT cotton against *H.armigera* is evolution of resistance (Burd et al., 2003 and Wu et al., 2002).

In sum, the reduction in chemical pesticide use associated with BT crops production is increasing the abundance of some insects and improving the natural control of specific pests such as cotton aphids. In contrast, chemical control, especially the use of more specific, less disruptive compounds, remains important for controlling nonlepidotrean pests such as mirids and spider mites (Wu and Guo, 2005).

From the economic perspective, some studies show there is no economic benefit for farmers planting BT crops compared with those who planted conventional crop seeds. Wang et al. (2008) in their survey, suggest that the main reason for the eroding advantage of BT cotton was the increasing prevalence of the secondary pests for which BT was never designed to control and the higher cost of BT-cotton seeds. For example, from 1999 to 2004, the quantity of pesticide used to control secondary pests increased several fold in the four provinces which were subject to the studies conducted in China. Similarly, the pesticide used to control secondary pests in 2004 dominates that for 2001 at all levels of use, thus suggesting that pesticide expenditures due to secondary pests has increased the cost of production (Wang et al., 2008).

The goal of this paper is to consider the presence of the secondary pests in order to provide more accurate evaluation. Using a *Just-Pope production function*, we consider risky elements that affect yield variability. In general, farmers cannot accurately predict either the population growth of the pests that could attack their crops in the next generations or the rainfall that could favor the presence of pests. In many agricultural situations, both pest density and rainfall are very important variables (Shankar et al., 2008).

2.2.Theoretical Approach

Following Qaim et al (2005) and Shankar et al (2008), we use a Just-Pope production function in which Y accounts for yield, X is an input vector, and Z represents pest density. The production function is:

$$Y_{ijt} = Q(X_{ijt}, BT, \beta) + \varepsilon_{ijt} \qquad (1)$$

$$Q(X_{ijt}) = \beta_0 + \sum_k \beta_k X_{ijt} + \sum_l \beta_l X_{ijt}^2 \qquad (2)$$

$$\varepsilon_{ijt} = e_{ijt}[h(Z_{ijt})]^{1/2}, \; h_{ijt} = \alpha_0 \prod_m z_{ijt}^{\alpha_m} = \exp\{log(\alpha_0) + \alpha_m \sum_m \log(z_{ijt})\} \qquad (3)$$

Inserting equations (2) and (3) into (1), the model becomes:

$$Y_{ijt} \quad = \quad \beta_0 + \sum_k \beta_k X_{ijt} + \sum_l \beta_l X_{ijt}^2 + \exp\{log(\alpha_0) + \alpha_m \sum_m \log(z_{ijt})\} \quad (4)$$

The subscripts i, j and t stand for state, crops, and the time period, respectively. The coefficients β and α are related to the inputs and the pest density, respectively. The effects of the inputs on the mean of the output are given by $E(Y_{ijt}) = Q(X_{ijt}, \beta)$ and the effects of the pest density on the output variance are portrayed by $V(Y_{ijt}) = h(Z_{ijt}) = \exp\{log(\alpha_0) + \alpha_m \sum_m \log(z_{ijt})\}$, under the assumption that e_{ijt} is normally distributed with mean 0 and variance 1. Therefore, the error term ε_{ijt} is normally distributed with mean 0 and variance

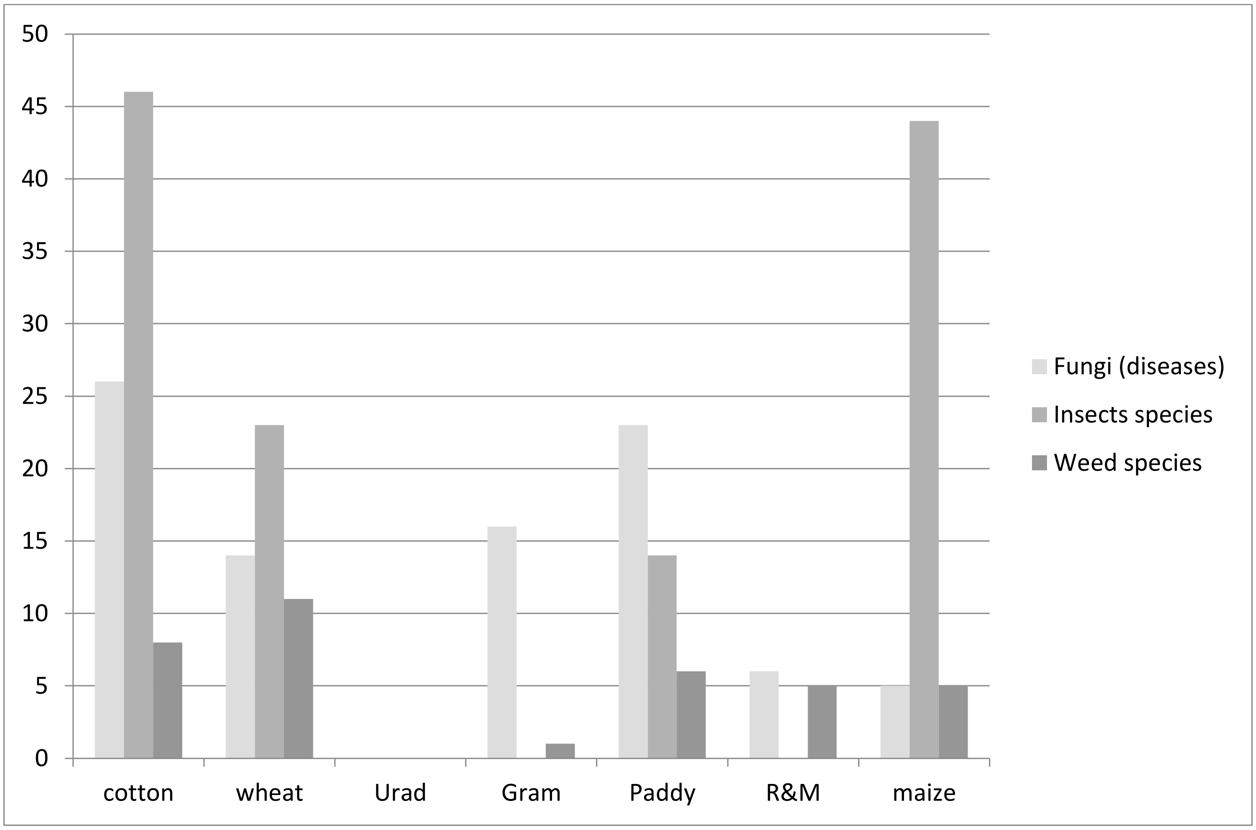
$$h_{ijt} \quad = \quad \exp\{log(\alpha_0) + \alpha_m \sum_m \log(z_{ijt})\}$$

Q (X_{ijt}) follows quadratic spline specification, and $h(Z_{ijt})$ follows Cobb-Douglas specification, assuming the constant returns to scale. Equation (4) is estimated using the Maximum Likelihood method. Saha et al., (1997) use Monte Carlo experiments to show that the Maximum Likelihood method for a stochastic production functions provides unbiased and more efficient estimates than FGLS.

2.3. Data Description

This study is conducted using the data from India Agricultural Department between 1996 and 2009. The data covers 19 states in India and 7 crops which are cotton, maize, wheat, paddy, urad, gram, and rapeseed &mustard. We encountered some difficulties because some states do not produce all the 7 crops, and some crops were not produced during the entire period selected. For example, the state of Assam did not produce cotton, gram, maize, or wheat, only produced urad between 2008 and 2009, and produced paddy and rapeseed and mustard (R&M) between 1996 and 2009. Similarly, the state of Andhra Pradesh produces gram (from 2005-2006), cotton, maize, paddy, and urad for the entire period; but did not produce wheat and R&M. Another difficulty is that only the costs of insecticides are available, but for the production function we need the physical quantity of insecticide inputs. We thus use the cost share of insecticides relative to the total costs of cultivation instead. For lack of data on capital, interest paid on working capital is used as proxy for inputs of capital. In the context of this paper, we use the yield (Qtl/hect) as output of 7 crops such as cotton, maize, paddy, gram, urad, gram, R&M, and wheat. Cotton, wheat, and maize are considered the major biotech crops in India (James, 2010).The inputs are seed (Kg.), fertilizer (Kg. Nutrients), manure (Qtl.), human labor (Man Hrs.), animal labor (Pair Hrs.), insecticides and capital. The pest density is captured by counting the number of the species of insects, weeds, and fungi that attacked the crops considered in this study. Figure 2.1 provides an idea of the different types of pests. It shows that BT crops (cotton, wheat and maize) endure a strong pressure from insects, while non- BT crops are usually attacked by fungi and weeds.

Figure 2.1: Different types of pests per crops



Source: Indian Agricultural Department

Table 2.2 describes the data used for biotech crops (cotton, wheat and maize) and table 2.3 provides the description of the data used for non-biotech crops (paddy, gram, urad and rape& mustard). After deletion of the missing observations and the removal of the outliers, the number of observations came down to 111, 101, and 59 for cotton, wheat and maize, respectively. Among the biotech crops, cotton is extensively cultivated in India and as it is described in table 2.2, it is human labor, insecticides and capital intensive crop. In other words, the cultivation of cotton cost more for farmers than that of

wheat and maize. For example, on average the cultivation of cotton requires 763.69 manual hours of
human labor, 79% of the total the cost goes into the purchase of insecticides and 325.90 R.S. interests are paid on the working capital. Similarly, the cultivation of wheat on average requires 428.71 manual hours of human labor, 40% of the total cost spent on insecticides, and 245.53 R.S. interests paid on the working capital. In the same way, maize necessitates 579.80 manual hours, 20% on the total costs for insecticides and 227.94 R.S. interests paid on the working capital, on average. Table 2.3 describes the data used for the non-biotech crops (paddy, urad, and gram and rape &mustard). The number of observations are 171, 66, 74 and 86 for paddy, urad, gram and rape&mustard, respectively.

On average, human labor is heavily used in the cultivation of paddy than on any other non-biotech crops. For example, 823.19 manual hours is dedicated to paddy compared to 327.85 manual hours devoted to the cultivation of gram. 70 % of the total cost is used on insecticides and 326.46 R.S. interests are paid on the working capital for the cultivation of paddy. As for urad, gram and rape&mustard, the cost share of insecticides are 0.9%, 11% and 0.61% respectively. The amount of manual hours used in the cultivation of urad and gram are relatively the same and that of rape&mustard is 438.17 manual hours on average.

In sum, the cultivation of cotton is more expensive in India than that of other biotech crops and the cultivation of paddy is also more expensive than that of other non-biotech crops.

2.4.Estimation Methods

Equation (4) is estimated with the Maximum Likelihood under heteroscedasticity following the three -step process described by Just and Pope (1979). Specifically, Harvey's multiplicative heteroscedasticity is considered to estimate the model parameters. We have defined i =1… n inputs, j = regions and the time periods. In the procedure, we define V_{ijt}^{T} = [1,q_{ijt}^{T}], where we consider q_{ijt}^{T} the suspected variables causing heteroscedascity. In the context of this paper, the pest density is specified as the main factor causing heteroscedasticity because it may affect the variability of the yield under the adoption of the agricultural biotechnology. Some other factors such as rainfall, agroecological factors and farmers' education level could affect the variability of the yield, but they are not considered in this paper due to lack of data. Furthermore, we believe that the emergence of the new pests is followed by additional applications of pesticides or insecticides which require additional human labor. In other words, additional human labor is devoted to spraying activities to combat new pests. As a result, the quadratic forms of insecticides and that of human labor are considered as proxies of pest density which is not easy to measure. Despite the fact that different types of pest that attacked each crop are known, this information is not sufficient for an econometric estimation. Therefore, in our model q_{ijt}^{T} is defined as follow:

$$q_{ijt}^{T} = [\text{insecticides squared, human labor squared}]$$

2.5.Estimation Results

The estimation of the equation (4) was conducted for each of the 7 crops separately because the contribution of the inputs to the yield and the agroecological conditions for the crops are not identical across India. The estimation results of each crop are presented from table 2.4 through table 2.10 presented below. Since the goal of this study is to evaluate the performance of biotech crops taking into account the presence of new pests, we are only interested in the estimates of insecticides, insecticides squared, human labor and human labor squared. In the mean equation, their coefficients are interpreted as the expected value of yield with respect to the variable inputs. For example, the estimates with positive coefficients lead to an increase in the excepted value of yield and the estimates with negative values trigger a decrease in the expected value of yield. As for cotton, the expected value of the yield increases by 5.0425 kg with an additional 1% of the total cost spent on insecticides. The negative coefficient of the insecticides squared could be explained by the emergence of new pest that has nullified the yield increasing characteristics of the insecticides. In other words, cotton yield experiences diminishing returns at the presence of the new pest despite the damage control characteristics of the insecticides. Similarly, the negative coefficient of human labor squared also shows diminishing returns effect of the additional manual hours spent on spraying insecticides. In the mean equation, unlike the coefficient of human labor, the coefficient of insecticides is highly significant. Turning to the variability of the yield, human labor squared and insecticides squared which are considered as proxies of the pest density exhibit negative and significant impact on the variance of the yield. That is, additional applications of the insecticides and extra manual hours of work due to the presence of the new pests reduce the risk on yield. The yield risk reducing effect could be coupled with the fact that biotech cotton seeds generate natural insecticides. Wheat which is also biotech crop experiences similar impact of insecticides, insectides squared, human labor and human labor squared on the yield in both the mean and the variance equations.

Unlike, cotton and wheat, maize has a different pattern in terms of yield effect of the inputs. For example in the mean equation, the insecticides have negative impact on the yield but not significant. Human labor has positive and significant impact on the yield. In the variance equation both exhibit risk reducing impact on the yield and this is due again on the fact that maize is a biotech crop. Furthermore, the R^2 from the estimation of the equation (4) for cotton, wheat and maize are 0.6339, 0.8393 and 0.8466, respectively.

Considering the estimation results from the mean equation for non-biotech crops (paddy, gram and urad), insecticides and insecticides squared have positive impact on the yield as opposed to biotech crops. The explanation for this is that these crops are not targeted by the secondary pests and once the primary pests are killed by the insecticides, additional applications of the insecticides can only contribute to an increase of the yield.

However, these additional applications of the insecticides can also be harmful to the crops at the certain points and they may even impede productivity (Lichtenberg et al., 1986). As a result, the coefficients of the insecticides squared and human labor squared in the variance equation are positive for paddy and it means that additional use of the inputs can be risky for the yield. As for the human labor, it exhibits diminishing returns to scale in the mean equation for paddy. The applications of the insecticides on urad increase yield by 5.00018 kg and the coefficient on the insecticides squared in the mean equation is positive. Similarly, the coefficients of human labor and human labor squared are positive in the mean equation. In the variance equation, insecticides squared have risk reducing effect but not significant and human labor squared has risk increasing effect. The results on urad are not surprising because it is not targeted by any major pests. In case of rape &mustard, both insecticides and human labor experience diminishing return effect on yield in the mean equation and risk increasing effect from the variance equation.

2.6. Comparative Analysis between Biotech and Non-Biotech Crops using the Output Elasticities

Even though the yield of all the crops is measured in kilogram, it would be misleading by comparing the productivity of insecticides in the cotton field to the productivity of insecticides in the field of wheat despite the fact that both are biotech variety. The comparison of the productivity of the inputs will be more misleading when it occurs between biotech and non-biotech crops. In order to overcome this discrepancy, output elasticities of insectides and human labor are used. For biotech crops, we choose cotton and wheat since they are the major biotech crops in India and also are more targeted by the new pests. As for non-biotech crops, we chose Urad which is not targeted at all, and paddy which is relatively targeted by the new pests. Figures 2.2 and 2.3 show the relationship between output elasticities of insecticides and insecticides, and output elasticities of human labor and human labor for cotton. Output elasticities of the insecticides are positive which means that 1% increase in insecticides increase the yield when the cost share of the insecticides is between 0 and 1.7. Output elasticities of insecticides become negative when the cost share of the insecticides is greater than 1.7. Similarly, output elasticity of human labor is zero at 199 manual hours of work and become negative from 200 manual hours of work. In other words, as the applications of the insecticides and the number of manual hours increase, the elasticities of these inputs increase as well but under the pressure of the pest density, they decrease and become negative. Similar trend is found for wheat which is also a major target for the sucking pests (see Figures 2.4 and 2.5).

For paddy which is a non-biotech variety widely cultivated in India, output elasticities of the insecticides increase and are positive as the applications of the insecticides increase but at a decreasing rate (Figure2.6). Output elasticities of human labor increase and are positive when human labor increase up to 1000 manual hours of work and become negative after 1000 manual hours of work (Figure 2.7). For urad which is not targeted by any pests, the output elasticities of the insecticides increase sharply as the applications of the insecticides increase (Figure 2.8). Also, the elasticities of human labor increase at an exponential rate as the human labor increases (Figure 2.9).

2.7.Conclusion

The results from the stochastic production function show that both biotech varieties and insecticides contribute to the increasing yield, while the insecticides experience diminishing returns on yield due to pest density. From the comparative analysis, we found that the yields of the non-biotech crops are almost exempt from the threat of the emerging pests and the use of insecticides was successful in increasing yield. The key point is that the biotech seed increase and reduce the use of pesticides but under the threat of the new pests, these features of the biotech seeds are offset.

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Table 2.1: The Results of Some Studies on BT Crops

Countries	**Year and rate of adoption**	**Author**	**Findings**
Argentina	1995(0.7%) 1998 (3.6%) 2000 (5.4 %) 2001-02 (5%)	De Janvry and Qaim (2002) IV estimates and Quadratic specification of the yield function	Bt technology reduces applications rates of toxic chemicals by 50 %, and increase the yield significantly
India	March 2002 2005 (25%)	Qaim et al.,(2006) Profit function	Insecticides amount on Bt plots were reduced by 50% Lower insecticide expenditures Higher Yield and Profit ($45 revenue per acre for Bt cotton)
Australia	1996-1997(8%) 2001-2002(30%)	James Clives, 2001	The average number of sprays required by Bt cotton is 40 % less than that required y non-BT
		Kristen et al., 2002	Both large-scale and small-scale farmers enjoy financial benefits due to higher yields and despite higher seed costs
USA	1996 (14%) 2001 (34%)	Edge et al.,2001	The findings after 5 yr. of commercial use on >2 × 10^6 ha globally indicate that *Bt* cotton provides an effective method for lepidopteron control that is safer to humans and the environment than conventional broad-spectrum insecticides, making *Bt* cotton a valuable new tool in integrated pest management.
Burkina- Faso	2005	Vitale et al., 2008	The first three years of Bt cotton file trials shows that Bt cotton increased yields by an average of 20% and reduced insecticide applications by two-third

Table 2.2: Descriptive Statistics- Biotech Crops in India

VARIABLES	N	MEAN	STD. DEV	MIN	MAX
COTTON					
Yield	111	12.55	8.00	2.53	46.47
Seed	111	17.18	31.53	0.00	156.49
Fertilizer	111	113.04	53.98	2.69	308.46
Manure	111	13.08	12.78	0.00	61.34
Human labor	111	763.69	273.74	184.87	1617.30
Animal labor	111	52.693	40.75	0 .13	150.80
Capital	111	325.90	142.35	24.28	728.83
Insecticides	111	0.79	0.63	0.02	3.80
WHEAT					
Yield	101	27.87	10.67	5.05	48.34
Seed	101	117.63	37.23	3.53	157.99
Fertilizer	101	128.90	56.18	18.73	236.79
Manure	101	9.76	16.38	0.00	83.58
Human labor	101	428.71	137.14	163.56	802.06
Animal labor	101	36.16	35.68	0.41	179.20
Capital	101	245.53	82.41	71.04	405.94
Insecticides	101	0.40	0.64	0.04	2.37
MAIZE					
Yield	59	22.12	10.68	6.41	45.66
Seed	59	26.38	18.63	1.56	117.32
Fertilizer	59	105.84	57.19	24.39	258.54
Manure	59	18.80	15.56	0.00	50.49
Human labor	59	579.80	163.39	286.23	1267.40
Animal labor	59	63.32	27.34	4.35	111.57
Capital	59	227.94	148.26	49.40	694.83
Insecticides	59	0.20	0.35	0.002	2.33

Table 2.3: Descriptive Statistics Non- Biotech Crops in India

VARIABLES	N	MEAN	ST. DEV	MIN	MAX
PADDY					
Yield	171	34.09	12.58	2.19	70.53
Seed	171	45.01	39.83	0.00	115.92
Fertilizer	171	124.20	68.34	0.68	265.35
Manure	171	19.58	15.61	0.00	80.42
Human labor	171	823.19	253.12	121.71	1327.30
Animal labor	171	79.23	72.753	0.40	259.37
Capital	171	326.46	151.04	76.68	726.40
Insecticides	171	0.70	0.84	0.001	3.62
URAD					
Yield	66	4.93	2.08	2.16	12.94
Seed	66	22.61	7.03	6.75	39.98
Fertilizer	66	16.55	19.33	0.00	82.84
Manure	66	2.15	3.16	0.00	19.80
Human labor	66	346.94	88.86	94.20	578.73
Animal labor	66	43.09	34.64	1.51	109.95
Capital	66	152.97	144.01	49.14	716.84
Insecticides	66	0.09	0.16	0.0006	0.91
GRAM					
Yield	74	9.52	2.91	5.05	19.90
Seed	74	67.65	24.00	1.24	101.19
Fertilizer	74	34.83	31.67	1.70	157.48
Manure	74	1.89	8.95	0.00	73.83
Human labor	74	327.85	128.65	185.18	801.91
Animal labor	74	36.08	19.86	2.49	83.61
Capital	74	177.10	94.13	59.65	555.61
Insecticides	74	0.11	0.18	0.0002	0.95
RAPE&MUSTARD					
Yield	86	14.10	11.25	4.33	68.01
Seed	86	7.71	11.02	0.00	85.17
Fertilizer	86	91.64	42.69	8.17	212.89
Manure	86	6.90	9.18	0.00	45.31
Human labor	86	438.17	151.48	229.47	999.87
Animal labor	86	55.48	71.71	0.36	244.29
Capital	86	203.09	110.10	57.95	593.56
Insecticides	86	0.061	0.07	0.0003	0.36

Table 2.4: Estimation Results: Cotton

COTTON			
Variable	Estimated Coef.	Std. Error	T-Ratio
Mean Equation:			
Seed	-0.29066	0.9359e-01	-3.106
Fertilizer	0.29021e-01	0.2746e-01	1.057
Manure	0.10500	0.6923e-01	1.517
Human labor	0.38707e-02	0.9771e-02	0.3961
Animal labor	-0.69757e-01	0.2905e-01	-2.402
Capital	-0.23211e-01	0.1365e-01	-1.701
Insecticides	5.0425	1.265	3.985
Seed Squared	0.27044e-02	0.6244e-03	4.331
Fertilizer Squared	-0.54806e-04	0.7701e-04	-0.7117
Manure Squared	-0.23080e-02	0.1212e-02	-1.904
Human labor Squared	-0.20611e-05	0.4265e-05	-0.4833
Animal labor Squared	0.14101e-03	0.2202e-03	0.6405
Capital Squared	0.53386e-04	0.1663e-04	3.209
Insecticides Squared	-1.5010	0.3899	-3.850
Constant	10.350	4.692	2.206
Variance Equation:			
Human labor Squared	-1.1558	0.1757	-6.580
Insecticides Squared	-0.21893	0.8068e-01	-2.713
Constant	17.395	2.311	7.529
R-Square			0.6339
Log-likelihood Function			-292.655

Table 2.5: Estimation Results: Wheat

WHEAT			
Variable	Coef.	Std. Error	T-Ratio
Mean Equation:			
Seed	0.17615	0.5345e-01	3.295
Fertilizer	0.17703	0.4904e-01	3.610
Manure	0.34118	0.7422e-01	4.597
Human labor	0.66168e-01	0.2373e-01	2.789
Animal labor	-0.83836e-01	0.3801e-01	-2.206
Capital	-0.12816e-01	0.2271e-01	-0.5642
Insecticides	9.2862	2.544	3.651
Seed Squared	0.32071e-03	-0.3332e-03	-0.9624
Fertilizer Squared	-0.40069e-03	0.2001e-03	-2.002
Manure Squared	-0.35215e-02	0.8967e-03	-3.927
Human labor Squared	-0.64594e-04	0.2102e-04	-3.072
Animal labor Squared	0.20123e-03	0.1826e-03	1.102
Capital Squared	0.27535e-04	0.4497e-04	0.6122
Insecticides Squared	-0.95707	1.264	-0.7570
Constant	-19.355	7.359	-2.630
Variance Equation:			
Human labor Squared	-1.7494	0.2253	-7.763
Insecticides Squared	-0.10943	0.3301e-01	-3.315
Constant	22.861	2.664	8.580
R-Square	0.8393		
Log-likelihood Function	-264.641		

Table 2.6: Estimation Results: Maize

MAIZE			
Variable	Coef.	Std. Error	T-Ratio
Mean Equation:			
Seed	0.12230	0.1520	0.8047
Fertilizer	0.18022	0.5478e-01	3.290
Manure	-0.13023	0.1796	-0.7252
Human labor	0.68475e-01	0.2955e-01	2.317
Animal labor	-0.22665	0.9505e-01	-2.385
Capital	-0.97700e-02	0.2386e-01	-0.4096
Insecticides	-3.2416	5.693	-0.5694
Seed Squared	-0.59176e-03	0.1235e-02	-0.4792
Fertilizer Squared	-0.10903e-03	0.1954e-03	-0.5581
Manure Squared	0.27271e-02	0.3591e-02	0.7594
Human labor Squared	-0.54003e-04	0.2187e-04	-2.470
Animal labor Squared	0.16169e-02	0.8736e-03	1.851
Capital Squared	0.25934e-04	0.3017e-04	0.8596
Insecticides Squared	2.0264	3.015	0.6721
Constant	-9.9866	10.69	-0.9341
Variance Equation:			
Human labor Squared	0.99676	0.3488	2.858
Insecticides Squared	-0.90357e-02	0.4574e-01	-0.1975
Constant	-9.9059	4.392	-2.255
R-Square	0.8466		
Log-likelihood Function	-165.196		

Table 2.7: Estimation Results: Paddy

PADDY			
Variable	Coef.	Std. Error	T-Ratio
Mean Equation:			
Seed	-0.19637e-01	0.5200e-01	-0.3776
Fertilizer	0.10464e-01	0.4657e-01	0.2247
Manure	0.18718	0.8198e-01	2.283
Human labor	0.63727e-01	0.1022e-01	6.238
Animal labor	-0.13911	0.3278e-01	-4.244
Capital	0.58779e-01	0.1705e-01	3.447
Insecticides	4.6177	2.222	2.078
Seed Squared	0.34276e-03	0.5050e-03	0.6788
Fertilizer Squared	0.26452e-03	0.1423e-03	1.859
Manure Squared	-0.91656e-03	0.1267e-02	-0.7234
Human labor Squared	-0.31437e-04	0.5899e-05	-5.329
Animal labor Squared	0.52031e-03	0.1068e-03	4.873
Capital Squared	-0.86614e-04	0.2167e-04	-3.998
Insecticides Squared	0.41329	0.7484	0.5522
Constant	-11.942	4.716	-2.532
Variance Equation:			
Human labor Squared	0.10745	0.1478	0.7271
Insecticides Squared	0.12774	0.2596e-01	4.920
Constant	2.2259	1.968	1.131
R-Square			0.8075
Log-likelihood Function			-522.395

Table 2.8: Estimation Results: Gram

GRAM			
Variable	Coef.	Std. Error	T-Ratio
Mean Equation:			
Seed	-0.42595	0.4852e-01	-8.779
Fertilizer	-0.19779e-01	0.2334e-01	-0.8476
Manure	-0.83036	0.7821e-01	-10.62
Human labor	0.16128e-01	0.8033e-02	2.008
Animal labor	0.52853e-02	0.3806e-01	0.1389
Capital	0.37025e-02	0.7475e-02	0.4953
Insecticides	2.6911	3.400	0.7914
Seed Squared	0.36428e-02	0.3828e-03	9.517
Fertilizer Squared	0.11935e-03	0.1258e-03	0.9489
Manure Squared	0.12306e-01	0.1093e-02	11.25
Human labor Squared	-0.20307e-04	0.8066e-05	-2.518
Animal labor Squared	-0.71215e-04	0.4600e-03	-0.1548
Capital Squared	0.11355e-04	0.1056e-04	1.076
Insecticides Squared	1.9970	3.616	0.5523
Constant	16.244	2.169	7.489
Variance Equation:			
Human labor Squared	-1.3101	0.2639	-4.965
Insecticides Squared	-0.96204e-01	0.4068e-01	-2.365
Constant	15.084	3.039	4.963
R-Square			0.7108
Log-likelihood Function			-132.280

Table 2.9: Estimation Results: Urad

URAD			
Variable	Coef.	Std. Error	T-Ratio
Mean Equation:			
Seed	-0.32444	0.1638	-1.980
Fertilizer	-0.44943e-01	0.3149e-01	-1.427
Manure	-0.18465	0.1269	-1.455
Human labor	0.26941e-02	0.7707e-02	0.3496
Animal labor	-0.40901e-01	0.2324e-01	-1.760
Capital	0.10619e-01	0.5432e-02	1.955
Insecticides	5.0018	2.379	2.103
Seed Squared	0.83973e-02	0.3258e-02	2.577
Fertilizer Squared	0.13992e-02	0.4695e-03	2.980
Manure Squared	0.73911e-02	0.8049e-02	0.9183
Human labor Squared	0.16335e-05	0.1262e-04	0.1294
Animal labor Squared	0.22352e-03	0.2076e-03	1.076
Capital Squared	-0.11661e-04	0.6979e-05	-1.671
Insecticides Squared	0.89312	2.855	0.3128
Constant	6.0029	2.125	2.825
Variance Equation:			
Human labor Squared	0.53898	0.3130	1.722
Insecticides Squared	-0.61026e-02	0.4290e-01	-0.1422
Constant	-6.1227	3.530	-1.734
R-Square	0.7074		
Log-likelihood Function	-99.8746		

Table 2.10: Estimation Results: Rape& Mustard

RAPE&MUSTARD			
Variable	Coef.	Std. Error	T-Ratio
Mean Equation:			
Seed	-0.29410e-01	0.2612	-0.1126
Fertilizer	0.10813	0.2128e-01	5.082
Manure	0.33716	0.7755e-01	4.348
Human labor	0.94445e-01	0.1127e-01	8.380
Animal labor	-0.65112e-01	0.1109e-01	-5.871
Capital	-0.79434e-01	0.9448e-02	-8.407
Insecticides	39.034	12.21	3.196
Seed Squared	0.19066e-02	0.3355e-02	0.5682
Fertilizer Squared	-0.18093e-03	0.1078e-03	-1.678
Manure Squared	-0.89593e-02	0.2134e-02	-4.199
Human labor Squared	-0.11140e-03	0.1442e-04	-7.724
Animal labor Squared	0.18247e-03	0.5412e-04	3.372
Capital Squared	0.24118e-03	0.2781e-04	8.674
Insecticides Squared	-154.06	46.17	-3.336
Constant	-8.3632	2.517	-3.323
Variance Equation:			
Human labor Squared	1.6723	0.2155	7.762
Insecticides Squared	0.49639e-04	0.4109e-05	12.08
Constant	-16.597	2.602	-6.379
R-Square	0.6089		
Log-likelihood Function	-282.400		

Figure 2. 2: Output Elasticities of Insecticides: Cotton

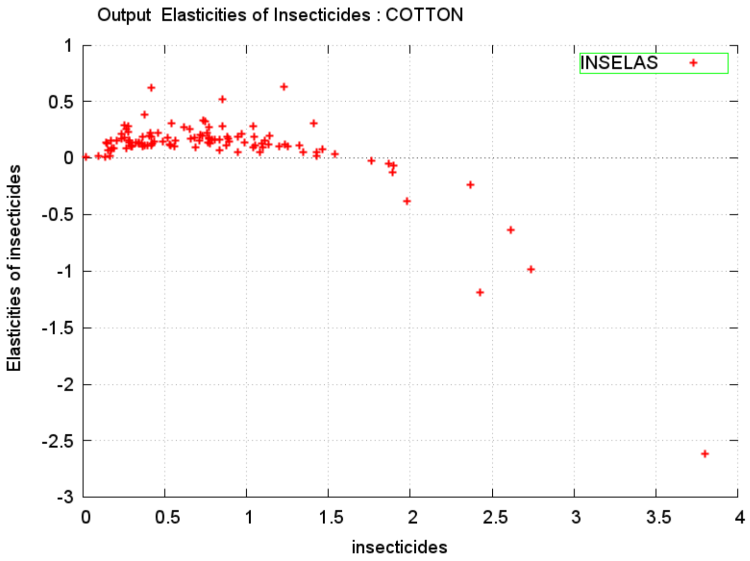


Figure 2.3: Output Elasticities of Human Labor: Cotton

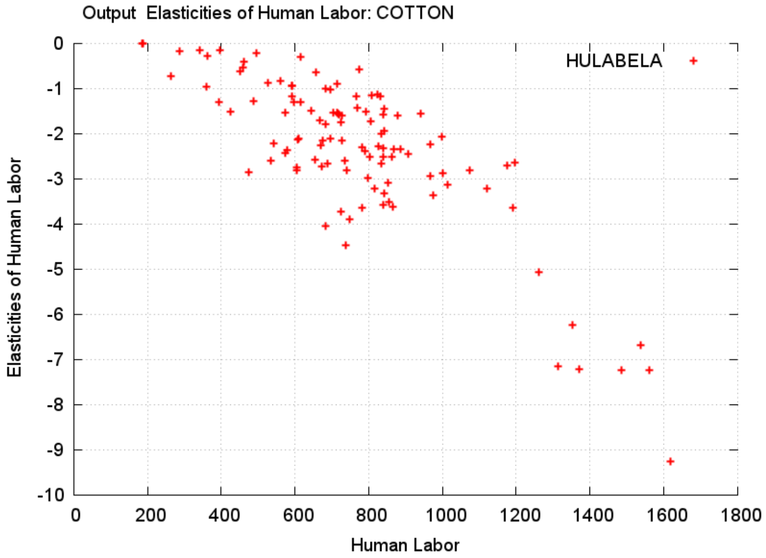


Figure 2.4: Output Elasticities on Insecticides: Wheat

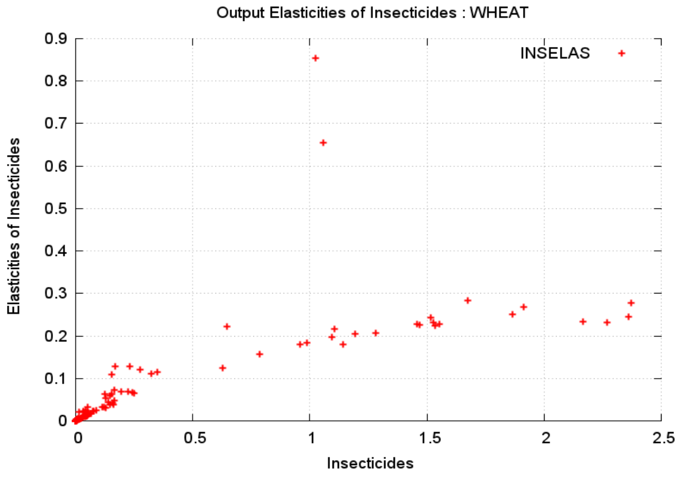


Figure 2.5: Output Elasticities of Human Labor: Wheat

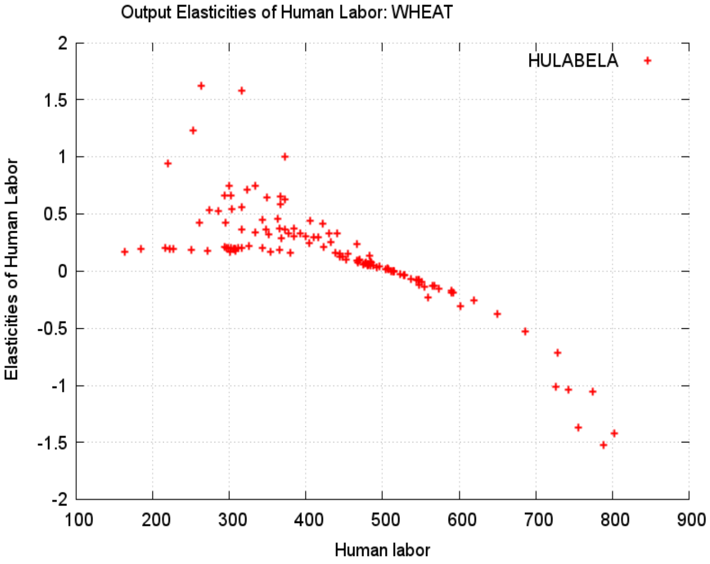


Figure 2.6: Output Elasticities of Insecticides: Paddy

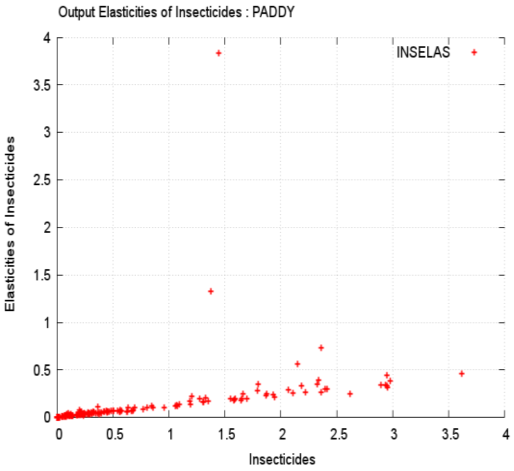


Figure 2.7: Output Elasticities of Human Labor: Paddy

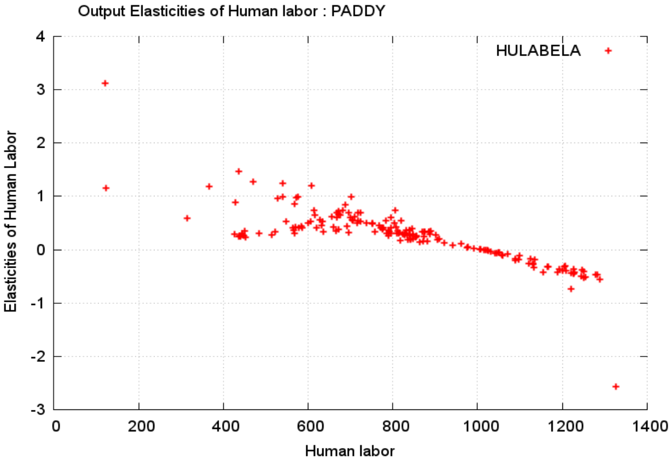


Figure 2.8: Output Elasticities of Insecticides: Urad

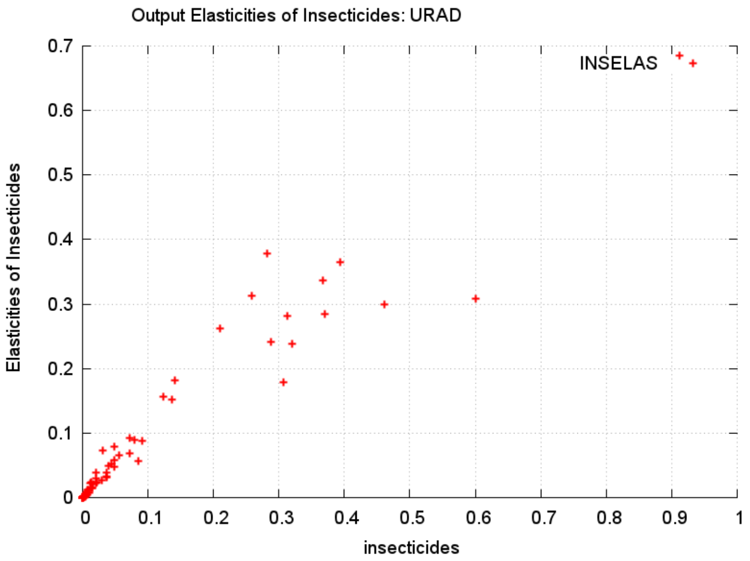
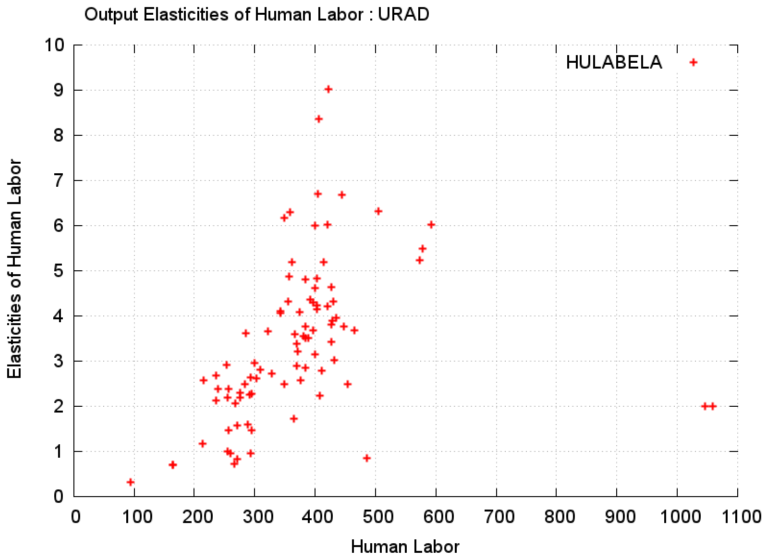


Figure 2.9: Output Elasticities of Human Labor: Urad



CHAPTER 3

EUROPEAN AGRICULTURAL BIOTECHNOLOGY PREFERENCES AND POLICY: TRADE CREATION OR TRADE DIVERSION?

Abstract: One of the current issues in International Trade is the European restrictive trade policies on the agricultural biotechnology products from the rest of the World. The ban on these products by the European countries is likely to have had some impact on the trade flows between EU and its trading partners. I use the gravity model of international trade to assess the trade impacts of the EU trade policies towards the agricultural biotechnology products. The results show trade creation in Food and Live Animals**.** However, trade diversion was found in Beverages and Tobacco, Animal and Vegetable Oils and Fats.

Keywords: Agricultural Biotechnology, Gravity Model, Trade Creation and Diversion, Panel Data

3.1.Introduction and background

The European Union’s restrictive policies towards biotechnology are closely dependent upon the attitudes of European consumers towards the biotech products. In Europe today, public opinion is more influential when it comes to the adoption of a technology. Negative attitudes were developed towards biotechnology since the occurrence of two major health crises: contaminated blood and mad cow disease outbreaks (Joly and Lemarie, 1998). Since these disease crises, European consumers have become very cautious about biotech foods and crops, and they have developed distrust towards their public regulation and expertise. Comparing the regulations of agri-food production of the US to those of the EU, the US focuses on regulating the end product and the EU has the tendency to regulate the whole production process. In general, US policies tend to be more supply-driven, while EU policies are dominated by consumer concerns (Hanitios, 2000). US consumers more often trust the Food and Drug Administration and United State Department of Agriculture scientists and more often accept the consumption of biotech crops and foods approved by these institutions. The difference between US and EU policies towards the agricultural biotechnology is that EU consumers influence the policy decisions and US consumers trust their officials and go for what is approved by food and safety officials. As a result, consumers’ preferences should not be neglected when it comes to EU policies towards biotech crops and food. As in the EU, public opinion actively constrains and influences the course of development of biotechnology (Durant, Bauer and Gaskell, 1998). For example, in the EU, bovine somatotropin was not approved as a result of the resistance of a large amount of consumers who expressed animal health and welfare concerns (Gaskell, 2000).

Growth and trade consequences of EU preferences and policies towards the agricultural biotechnology should not be overlooked. These growth and trade consequences could be addressed within EU countries, between the EU and biotech adopting countries, and between EU and non-biotech adopting countries. This paper discusses only trade effects between the EU and the rest of the World. The ban on both production and consumption of the agricultural biotechnology products has been an issue in European trade relationships with the rest of the World. The technology which is widely used by the North American countries is being transferred to the developing countries. Even though some developing countries are still reluctant to the technology due to the fear of loss of export to Europe, other are adopting it and are investing more in biotechnology research and development. Some authors argue that restrictive European Union policies on biotechnology production and consumption work in a manner similar to that of an export subsidy of capital to the South. That is, the South will become more capital intensive by producing more biotech products. North America will become the dominant producer of biotechnology research and development and biotech products, and the European Union will become dominant producer of traditional agricultural products. Francis et al. (2005) conclude that when factors are measured in efficiency units, the South will become more capital-intensive, EU will become relatively less capital intensive, leading to lower exports of capital intensive goods and smaller overall of trade.

The weakness of these arguments is the lack of empirical evidence. Both trade and growth effects of the restrictive EU biotechnology policies have not been empirically determined in the current literature. The motivation behind this paper is to show empirical evidence of trade effects. In that regard, we use the gravity model on international trade and the difference in difference estimation method to explain the trade effect of the EU policies towards the biotech products. Our results suggest that the policies led to trade creation and trade diversion in some categories of the disaggregated imports data from the rest of the World to EU.

3.2.Theory of Trade Creation and Trade Diversion

The theory of trade creation and trade diversion was developed by Jacob Viner (1950) to describe the static and the dynamic impacts of the economic integration. In the terms of Viner, trade creation arises when the economic integration leads to a shift in product origin from a domestic producer whose resource costs are higher to a member producer whose resource costs are lower. According to the standard neoclassical theory, trade creation always leads to welfare improvement as a result of the economic integration. Trade diversion happens when the economic integration leads to a shift in product of origin from nonmember producer whose resource costs are lower to a member country producer whose resource costs are higher. As a result, there is a welfare reducing consequence of the economic integration through trade diversion since the terms of trade of the importing country decrease by the amount of the tariff revenue forgone in shifting imports to a member country. Also, we should note that the elasticities of demand and supply have some effects on the terms of trade upon economic integration. Using partial equilibrium analysis to illustrate the concepts of trade creation (Figure 3.1) and trade diversion (Figure 3.2), we follow the textbook example (Appleyard et al, 6th edition) where three countries A, B and C are trading partners. Country A is importing the good from country B as well as producing it domestically prior to the formation of the economic integration. Before the economic integration which led to the removal of tariff among members, the price of the good in country A is $1.50 (the $ 1.00 price in country B plus the 50 percent tariff). With the integration between A and B, the tariff is removed, and A now imports 150 units (250units-100 units) rather than 40 units (200 units - 160units) from B. Sixty units (160-100) of the increased imports displace previous home production, and 50 units (250 units-200 units) reflects the greater consumption at the new $1.00 price facing country A's consumers. The net welfare impact is the sum of areas b and d.

Figure 3.1: Trade Creation and Welfare

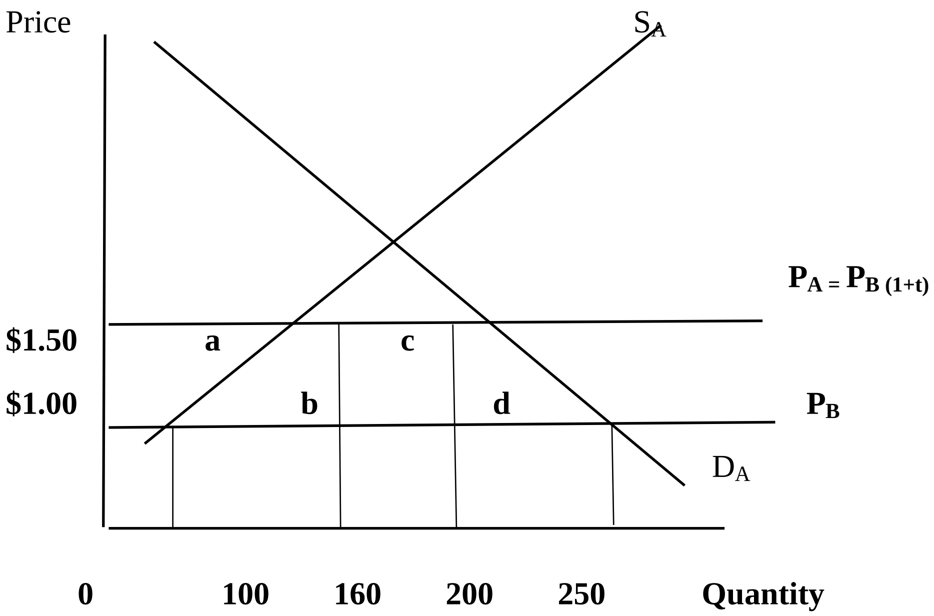


Figure 3.2 : Trade Diversion and Welfare

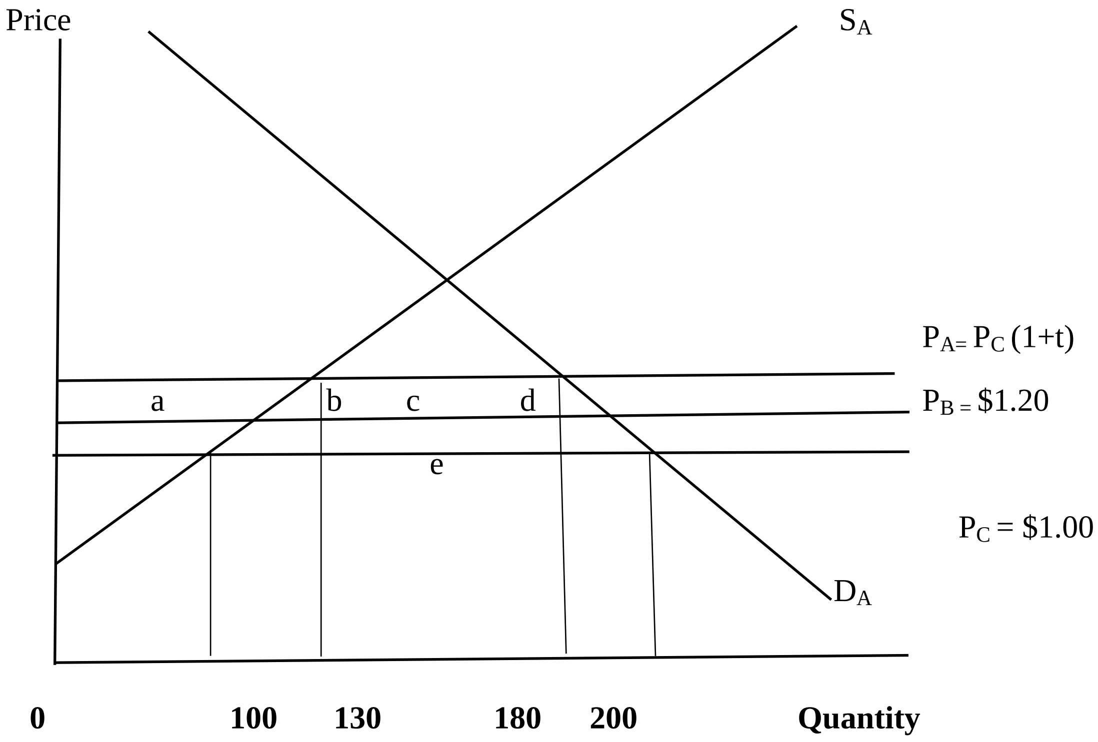


Figure 3.2 describes the case of trade diversion. Before the union with country B, country A has a 50 percent tariff on imports of the good. Thus country C’s tariff-inclusive price in A’s market is $1.50, and country B’s tariff inclusive price is $1.80 (not shown). Before the union, country A imports 50 units (180-130) from C. When the union is formed with B, country A imports 100 units (200-100), all coming from partner B, which no longer faces a tariff. The net welfare change for A is the difference between areas b+ d (a positive effect due to lower price in A) and area e (a negative effect due to lost tariff revenue by A that is not capture by A’s consumers). The value of the tariff revenue is equal to the areas c and e. The area c is the part of government revenue forgone after the integration, and it is transferred to domestic consumers through the reduction in the domestic price. The area e is the difference in cost between the nonmember source and the new higher-cost member source. The net effect of the economic integration between country A and country B depends on the sum (b+d-e). This leads to ambiguity in the case of trade diversion. In this example, welfare is reduced since the areas b+d is greater than area e. After describing the theory of trade creation and trade diversion, we will now test the theory in our special case.

The Case of EU trade policy towards biotech products: Non- Tariff trade barriers

In the context of this paper we define three groups of countries that trade with each other. The European Union is considered as a group importing from the rest of the world , BT- countries as a group of biotech adopting countries exporting their products to EU and the non-BT countries as a group of non-biotech countries exporting their products to EU. The restrictive trade policies of EU towards biotech countries could be interpreted as an import quota equivalent to some specific tariff . We assume that the EU and non-BT countries are member of the same trading group and the BT-countries are nonmember countries of the regional trade area. We further assume that BT countries are the cost efficient partners where the products of origin are produced at a lower cost due to the technology, and the non-BT countries are the cost inefficient countries without the technology. Since EU prefers to import the non-biotech products at higher cost from the non BT trading partner, we expect the outcome to cause trade diversion in the Vinerian sense. In order to test our hypothesis of trade diversion of the EU trade policies, we estimate the gravity model to provide some empirical evidence.

3.3. Theoretical Model

3.3.1. The Gravity Model

The gravity model introduced by Tinbergen (1962) has been widely used in the literature of the international trade to measure the impact of different factors on bilateral trade flows. The model specifies trade between two countries as a function of their GDPs, GDPs per capita, and the geographical distance between them. Many researchers have extended the basic gravity equation by adding other variables to test for the influence of geographic, ethnic, linguistic, and economic conditions. The dependent variable varies across studies depending on the purpose of the researcher. For example, some studies use the sum of import and export flows as dependent variables (Frankel, 1997; Bayoumi and Eichengreen, 1997) while others consider either import or export flows. When it comes to the analysis of trade creation or trade diversion, most studies choose import flows as the dependent variable (Soloaga & Winters, 2001; Fakao et al., 2003; Clausing, 2001; Magee, 2008). In the context of this paper in which the issue of trade creation and trade diversion is the centerpiece, we choose the import flows to European Union from the Rest of the World as the dependent variable. The EU is treated as one country trading with the Rest of the World. The theoretical model is defined as follows:

$$\ln\left(\mathrm{M_{ij}}\right) = \beta_0 + \beta_1 \ln\left(\mathrm{GDP_i} * \mathrm{GDP_j}\right) + \beta_2 \ln\left[\left(\frac{\mathrm{GDP}}{\mathrm{pop}}\right)\mathrm{i}\left(\frac{\mathrm{GDP}}{\mathrm{pop}}\right)\mathrm{j}\right] + \beta_3 \ln\left(\mathrm{Dist_{ij}}\right) + \varepsilon_{ij}$$

(1)

The variables of the model are defined as follows:

$\mathrm{M_{ij}}$: the dollar value of imports of EU from the Rest of the World

$\mathrm{Dist_{ij}}$: distance between the countries and the bloc of EU

Pop: population of all the countries considered and that of EU countries altogether.

The definition of distance between countries has been a controversial issue in the literature of the gravity model of trade. Some authors used latitude and longitude data to measure the distance, while other use the trade costs as proxies of the distance. (Bosker and Garretsen, 2010).

In the context this paper, since EU countries are considered as one country, the difficulty of measuring the distance arises. The distance is proxied by the average of the ratio of imports C.I.F and exports F.O.B minus one [(cif/fop) -1] for the EU countries. Since the gravity model of international trade uses distance to proxy transport and other costs associated with carrying out international transactions, the use of the ratio of C.I.F. to F.O.B. prices may actually come closer to the spirit of the model than the simple geographic distance between individual countries. In order to analyze the effects of European restrictive trade policies against the biotech products on the imports of the EU from the Rest of the World, the equation 1 is extended by including a set of dummy variables standing for European Union trade policies against agricultural biotechnology products, agricultural biotechnology adopting countries, and EU consumer preferences. The policy variable is defined POL =1 in the year 2003 when the ban was more stringent (REGULATION (EC) No 1829/2003) and 0 otherwise. The biotech countries exporting their products to EU are considered as treated group and the remaining countries are the control group. BT =1 for the biotech countries and 0 otherwise. The consumer preferences are proxied by the category of the commodity groups to which the biotech products belong.

3.3.2. The Augmented Gravity model

The hypothetical question of this paper is to determine whether the EU trade policies against biotech products led to trade creation or trade diversion. In order to answer this question, the augmented gravity equation defined below has been estimated. Ten categories of commodities shown in Table 3.1 are considered in this study where the biotech products belong to three groups of commodities: Food and Live Animals, Beverages and Tobacco, Animal and Vegetable Oils and Fats. Table 3.2 details the specific products that belong to the three groups of commodities.

The augmented gravity equation is defined as follows:

$$\ln\left(\mathrm{M_{kijt}}\right) = \beta_0 + \beta_1 \ln\left(\mathrm{GDP_{it}} * \mathrm{GDP_{jt}}\right) + \beta_2 \ln\left[\left(\frac{\mathrm{GDP}}{\mathrm{pop}}\right)\mathrm{it}\left(\frac{\mathrm{GDP}}{\mathrm{pop}}\right)\mathrm{jt}\right] + \beta_3 \ln\left(\mathrm{Dist_{ij}}\right) + \gamma_1(\mathrm{POL})$$

$$+\gamma_2\mathrm{BT} + \gamma_3\mathrm{BT} * \mathrm{POL} + \alpha_0 commodity_0 + \alpha_1 commodity_1 + \alpha_2 commodity_4 + \varepsilon_{kijt} \quad (2)$$

The variable k stands for commodity and t for time period (year).

Positive and significant coefficients on the parameters representing policy, BT countries and consumer preferences are interpreted as trade in excess of what is predicted by the gravity model and are thus considered as evidence of trade creation caused by BT trade policies. Similarly, negative and significant coefficients on those variables are interpreted as less trade than the predicted and are the evidence of trade diversion (Jayasinghe and Sarker, 2007).

3.4. Data

The import data collected from the UN comtrade database are in nominal values ($US millions) and are considered as the dependent variable. The import flows of ten categories of commodities are from 142 countries to the EU between the years 2000 and 2011. One of our goals in this study is to see the impact of EU restrictive trade policy towards biotech products on the import flows from the biotech Countries. Among the biotech Countries, US and China have extremely high imports flows to EU. For example, the coefficient on BT dummy when US and China are include in the data is 30.44216. That is, the import flows increase by 3044% from biotech Countries to EU. In contrast, dropping US and China from the dataset, the coefficient on BT is 0.090 which means that there is 9% increase of import flows from biotech Countries to EU. The main reason US and China are dropped from the dataset is that the dummy variable BT is just capturing the imports of these countries to EU. The GDP and population data are collected from the World Bank. The distance is proxied by the average of the ratio of imports C.I.F and exports F.O.B minus one [(cif/fop) -1] for the EU countries. There were some missing values from year 2009 to 2011 for some countries and these values were replaced with extrapolated values. All the gravity variables are presented in logarithm. The biotech products belong to three categories of the commodities: Food and Live Animals, Beverages and Tobacco, and Animal and Vegetable Oils and Fats. These categories are shown in the disaggregated commodities data presented in Table 3.1 below. The other variables are represented by dummies. The data is organized as unbalanced panel set.

Import flows, the product of GDPs, the product of per capita GDPs, and distance are in logarithmic form, and they are summarized in Table 3.3 below. The other variables are all dummies. With 142 countries, 10 categories of commodities, and 12 years of observations, there should be 17,040 observations. However, because of missing data, we instead estimate an unbalanced panel set with 15,654 observations. The variables import flows, product of GDPs, product of per capita GDP, and distance are all measured in millions of US dollars between 2000 and 2011.

3.5. Estimation and Results

The augmented gravity model described in Equation (2) is estimated using the method of pooled OLS. The results presented in Table 3.4 show positive and significant coefficients for the product of GDPs and GDP per capita. The coefficients for distance for the alternative regressions are significant and negative. These results are in line with the theory of the gravity model. Given the purpose of our study, we add BT countries fixed effects to capture time invariant shocks like other trade agreement between EU and BT countries as well as interaction BT Countries –year fixed effects to control for any other things that might affect imports to the EU. Equation 2 was separately estimated first without any specific fixed effects, then controlling for BT countries, and finally controlling for BT countries-year. The results for the three regressions are reported side-by-side in Table 3.4 below. From the results of the first estimation, the coefficient on BT variable is positive and significant but since the fixed effects terms are excluded, any other trade flows between BT countries and EU were not being controlled. In the second regression, BT variable was dropped since BT countries fixed effects are included in the regressions because the presence of the two variables has caused a dummy trap. In the third regression, since both BT countries fixed effects and BT countries –year fixed effects are included; every other things that might affect trade between EU and BT countries are being controlled. As a result, the estimation results from the third regressions are relatively unbiased compared to the first two.

The interpretation of the parameter estimates (γ_s and α_s) follows the approach of Halvorsen and Palmquist, who calculated the percentage effect of the dummy variables. For example, assuming that the coefficient estimate of the BT dummy variable in equation (2) is γ_1, the result shows that BT countries traded an extra {exp (γ_1)-1} x 100% with EU relative to the amount non-BT country traded with EU. Similarly, if the estimated coefficient, γ_2 is negative, it shows that BT countries traded {exp (-γ_2) -1} x100% less with EU relative to the amount traded with non-BT country traded with EU. The equivalent dollar value of each estimated coefficients are calculated and presented in Table 3.5 by multiplying the percentage changes by imports mean.

The interpretation of the estimated coefficients on commodities has served to provide an idea of the impact of EU preferences of the agricultural biotechnology. Likewise, the interpretation of the estimated coefficients on policy variable was used to provide the impact of the EU restrictive policy on import flows from the rest of the World. The estimation results show trade creation in the category of Food and Live Animals. In other words, there is on average 77.89% increase in imports flows for Food and Live Animals from the rest of World to EU. Furthermore, the estimate of the policy variable is negative, but it cannot be considered as evidence of trade diversion since it is not statistically significant. Trade diversion was found in the categories of Beverages and Tobacco, and Animal and Vegetable Oils and Fats, where the imports flows decrease on average by 72.17% in the former category and by 74.00% in the latter category. Without considering BT countries and BT countries-year fixed effects, trade creation was found for BT countries. This could be explained by the fact that EU has other different form of trade relationship with the BT countries, which has nothing to do with the fact that these countries adopted the agricultural biotechnology. The estimated coefficient for the interaction term (BT*Policy), which is negative in the first estimation result suggests that EU trade policies on biotech products from the treated groups (BT countries) has caused a decrease in the import flows. The estimated coefficients from the second and third regressions suggest that the EU policy on biotech increases imports between EU and BT countries by 1.79% and 15.49% respectively. However, since these coefficients are not statistically significant, this does not constitute evidence of trade creation. In addition, the coefficient of the policy variable is negative in all the three estimation results. Based on the estimated results from the third regression, the import flows have decreased by 2.96% due to BT policy, but this estimate of the coefficient of the policy variable is not significant.

In order the link the estimation results to the theory of trade creation and trade diversion, we follow Jayasinghe and Sarker, 2007 to compute the dollar value corresponding to each estimated coefficient by multiplying the mean value of total imports flows for each category of commodities by its percentage change. The estimated coefficients were taken from the third estimation results in Table 3.4 because the estimation results from the third regressions are relatively unbiased compared to the first two. According to the results in Table 3.5 below, the EU could have imported 782.294 millions of dollars of beverages and tobacco from the rest of the World at lower costs if EU consumers had not pushed their governments to reject-biotech products. Similarly, the

EU could have imported 831.018 millions of dollars Animal and Vegetable Oils and Fats from the rest of the World at lower costs. An additional 2836.946 millions of dollars of Food and Live Animals has been imported from the rest of the world despite consumers' negative attitudes towards biotech products.

3.6. Conclusion

The results show that the impact of EU consumer preferences proxied by three categories of commodities had a significant impact on imports between EU and the rest of the World. Furthermore, these preferences led to trade diversion in the categories of Beverages and Tobacco and that of Animal and Vegetable Oils and Fats. In contrast, trade creation was found in the category of Food and Live Animals. The coefficient of the policy variable is negative but not statistically significant. Therefore, this cannot be considered as evidence of either trade creation or trade diversion.

In sum, the augmented gravity model has enabled us to measure the impact of the EU's restrictive trade policies on trade creation and trade diversion. However, since the coefficient estimates of the policy variable are not significant in this study, further analysis is called for. Further influences on trade must be incorporated into the models, and alternative data must be used. Also, in this study the product categories are rather broad. The data should be further disaggregated in order to better distinguish the policy's effects.

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http://ec.europa.eu/food/dyna/gm_register/index_en.cfm

Table 3.1: Disaggregated Commodities Data

Category Code	Commodity Description
S1-0	**Food and live animals**
S1-1	**Beverages and tobacco**
S1-2	Crude materials, inedible, except fuels
S1-3	Mineral fuels, lubricants and related materials
S1-4	**Animal and vegetable oils and fats**
S1-5	Chemicals
S1-6	Manufactured goods classified chiefly by material
S1-7	Machinery and transport equipment
S1-8	Miscellaneous manufactured articles
S1-9	Commod. & transacts. Not classified. Accord. To kind

Source: UN Comtrade

Table 3.2: Category of Commodities with Biotech Products

Commodity Category	E.U. Trade Restrictions per products	Status
Food and Live Animals	-Tomatoes: Puree made from GM tomatoes is not approved by EU. -Sugar beet: Cultivation of GM sugar beet in the EU is not expected before 2015. -Rapeseed: For the time being, no GM rapeseed is grown in Europe. -Food produced from MON1445 cotton (cp4 epsps gene inserted to confer tolerance to the herbicide glyphosate) -Food additives produced from MON1445 cotton -Feed produced from GMO bacteria: “bacteria biomass” -Feed materials produced from GMO yeast : “ yeast biomass” -maize (Bt176) and its derived products	Authorization expired 12/18/2011 Renewal of authorization ongoing Renewal of authorization ongoing withdrawn
Beverages and Tobacco	Derived products	
Animal and Vegetable Oils and Fats	-oilseed rape (GT73) -oilseed rape (T45) -oil swede-rape (MS8, RF3, MS8xRF3) -hybrid oilseed rape (MS1xRF1) -hybrid oilseed rape and Topas (MS1xRF2) -Derived products	Renewal of authorization ongoing withdrawn

Sources: European Commission Website

Table 3.3: Descriptive Statistics

Variable	**N**	**Mean**	**Std Dev**	**Min**	**Max**
Log of Imports Flows	15654	6.885	1.737	0.954	16.913
Log of Product of GDPs	15654	16.638	0.879	13.323	18.911
Log of Product of per Capita	15654	13.786	0.662	0.00	15.425
GDP	16454	-0.313	0.030	-0.370	-0.269
Log of Distance	15654	0.107	0.310	0	1.000
Food and live animals	15654	0.096	0.295	0	1.000
Beverages and tobacco	15654	0.075	0.264	0	1.000
Animal and Vegetable Oils and	15654	0.188	0.390	0	1.000
Fats	15654	0.083	0.276	0	1.000
BT countries	15654	0.015	0.124	0	1.000
Policy					
BT*Policy					

Table 3.4: Estimation Results

Variables	Coef. **(1)**	S.E.	T-stat	Coef **(2)**	S.E.	T-stat	Coef **(3)**	S.E.	T-stat
Intercept	-27.86	0.39	-71.40	-28.47	0.391	-72.81	-27.62	0.429	-60.25
Product of GDPs	1.111	0.013	82.20	1.127	0.013	83.12	1.103	0.014	76.07
Product of per Capita GDP	1.166	0.017	68.07	1.191	0.017	67.93	1.156	0.019	60.83
Distance	-1.129	0.155	-7.27	-1.174	0.154	-7.60	-1.297	0.172	-7.54
Food and live animals	0.576	0.032	17.57	0.577	0.032	17.71	0.576	0.032	17.61
Beverages and tobacco	-1.280	0.034	-37.09	-1.280	0.034	-37.37	-1.279	0.034	-37.16
Animal and Vegetable Oils and Fats	-1.342	0.038	-34.80	-1.347	0.038	-35.17	-1.347	0.038	-34.98
BT countries	0.083	0.031	2.66	-----	------	------	--------	-------	-------
Policy	-0.014	0.041	-0.34	-0.029	0.041	-0.72	-0.030	0.042	-0.72
BT*Policy	-0.067	0.093	-0.73	0.0177	0.091	0.19	0.144	0.398	0.36
BT countries Fixed Effects	NO			YES			YES		
BT countries-year Fixed Effects	NO			NO			YES		
N =15664 R^2 =	0.47			0.48			0.47		

Table 3.5: Trade Effect of EU Consumers Biotech Preferences

Variables	Estimated Coef.	Percentage Changes	Imports Mean	Equivalent US dollar	Trade Effect
Food & Live Animals	0.576	77.89%	3642.208	2836.946	Trade Creation
Beverages and Tobacco	-1.279	-72.17%	1077.530	-777.636	Trade Diversion
Animal and vegetables Oils	-1.347	-74.00%	1123.027	-831.018	Trade Diversion

CHAPTER 4

SHOULD THE SOUTH AND EU ADOPT THE AGRICULTURAL BIOTECHNOLOGY? GENERAL EQUILIBRIUM AND EFFICIENCY

Abstract: Ongoing debates about the adoption of the agricultural biotechnology in the developing countries and EU have dominated the literature in development economics and biosciences. The current literature emphasizes more current positive aspects of the technology without taking into account the effects of the enforcement of the Intellectual Property Rights, consumers' preferences and the negative externalities which include environmental and social related issues. The goal of this paper is to account for such factors using a general equilibrium approach and comparative statics analysis to determine the impact of the enforcement of the IPRs, consumers' preferences and externalities on the production of biotech crops. The results show that efficient production of biotech crops under the influence of the three factors mentioned above is contingent upon several parameters of the model. These parameters include output elasticity of capital in both biotech and non-biotech productions, total factor productivity in biotech production, and the ratio of the proportions of the biotech and non-biotech products consumed by each consumer. From the economic standpoint, any country that is envisioning in adopting the agricultural biotech should consider the impact of these parameters on the efficient production without ignoring the reality that surrounds the technology itself.

4.1. Introduction and Background

Private firms in North America came up with new technology to create seeds that are more resistant to insects, drought, weeds etc. This innovative step not only increases yields and reduces the amount of insecticides used, but it also has the property of damage control. Moreover, the technology provides environmental benefits to countries by increasing production while reducing the use of chemicals, pesticides, and herbicides (Haghiri and Philips, 2003). Some people and corporations suggest that the agricultural biotechnology is known in the current century as the only way to assure food security in the developing world where the population is growing faster than the food supplies. It means that the rate of increase in the world food supplies cannot match the rate of the population growth (Haghiri and Philips, 2003). This argument is very controversial in the sense that it may not even be true for some specific countries because the nutrition system for each country is very different as well as the agricultural policies. Despite some positive features of the agricultural biotechnology, farmers in the developing countries are still reluctant in adopting it, and consumers are very cautious about the biotech products due to health, cultural, ethical and moral concerns. The major reasons of the delay in the adoption of the agricultural biotech in some developing countries and EU are explained in the following lines.

First, the technology is expensive for the impoverished farmers with little working capital because of the enforcement of the IPRs. In other words, in addition to seed costs, seed companies charge farmers a technology fee. As a result, the seeds become more expensive for farmers who may end up bankrupt mostly in the presence of some uncertainty due to new emerging pests, random weather conditions and even some market distortions. Since the technology is owned by the private seed industry, often protected by the intellectual property rights, many varieties have become expensive and practically inaccessible to poverty-stricken farmers in Africa (Black et al., 2011). High seed costs due to the enforcement of IPRs have some indirect social impacts as well. Cotton cultivation in India has been plagued with rising costs of cultivation, ineffective pesticides, adulterated seeds and other factors leading to consecutive crop failures, and heavy indebtedness has led to suicides by farmers (Lalitha, 2007). For example, “For farmers such as Vithal Bhindarwa, however, investing in BT cottonseeds did not lead to economic security. Hoping to provide a better life for his wife and children, Bhindarwa purchased these higher-priced seeds through loans in excess of Rs. 28,000 [US$566 in 2008] both from the State bank and from private moneylenders. When his crop failed in 2008 as a result of unpredictable weather conditions, Bhindarwa was unable to pay back his loans and took his own life by swallowing rat poison, leaving his 22-year-old son, Gajanan, as the head of the family. Bhindarwa’s story is not uncommon: for too many farmers, investing in BT cottonseeds has not led to greater financial security, but has instead contributed to their financial distress. The reason, as explained below, is that BT cottonseeds demand even more of two resources that are already scarce for many farmers: money and water” (Center for Human Rights and Global Justice and International Human Rights Clinic, 2011). The financial distress is worst for the farmers with very small plots of land, who have to deal with a great deal of yield uncertainty and at the same time incurring high seed costs. Moreover, one could argue that the enforcement of the IRPs is to promote innovation in agricultural but it turned out to be more rent –seeking behavior as private investment becomes heavily higher than public investment. For example, private investment in biotechnology research is far ahead of public investment in developed countries ($5 billion), although public investment in biotechnology ($125 million) with the purpose of benefiting the farmers and consumers is increasing in developing countries (Qaim, 2001). Strong enforcement of the IPRs enable these companies to not only recover their costs, but also to increase profits by capturing much of the surplus generated by the predicted productivity gains. However, the introduction of new seeds can be harmful to farmers because developing new seeds is not enough and other aspects of the agriculture in the developing countries such as land policies, research policies, transfer of the technology, and the acceptance of GMOs techniques should be considered.

The enforcement of the IPRs was supported by WTO through the establishment of Trade-Related Aspects of Intellectual Property Rights (TRIPS) at Uruguay Round negotiations of General Agreement on Tariffs and Trade (GATT). Developed countries managed to negotiate the TRIPS agreement in spite of strong opposition from developing countries (Braga, 1995). Gaisford et al. (2002) suggest that in the context of biotechnology, it is not in the self-interest of producers in developing countries to respect intellectual property rights. Gaisford et al. (2007) using game theory approach and under certain assumptions, found that the TRIPS will not provide sufficient incentive for developing countries to protect intellectual property rights in biotechnology. Given that the enforcement of the IPRs in the context of biotechnology is more harmful to famers than any other stakeholders. Haghiri and Philips (2003) suggest a model for regional intellectual property rights for developing countries especially Iran where individual IPRs are not enforceable. They found that the concept of regional- intellectual property rights would be more beneficial for neighboring countries and there should be joint contributions to R& D in the biotechnology sector which could yield real benefits. In sum, the enforcement of the Intellectual Property Rights supported by WTO through TRIPS and implemented by the seed companies through the charge of the technology fees on biotech seeds had become a heavy financial burden for farmers in developing countries. As a consequence, poor farmers with small plots of land might be better off growing conventional crops than biotech crops at the presence of the enforcement of the IRPs by private seeds companies.

The second reason of the delay of the adoption of Agricultural biotech is consumers' preferences. Consumers preferences towards biotech product significantly depend on the information disseminated about the products. There are two main sources of information on the biotech products and these sources are contentious. The fact that these two or many more sources of information on the biotech products conflict with each other, consumers preferences have become more convoluted in the sense that consumers have to evaluate the accuracy of any information before they can make purchasing decision. Also, we should note that strong economic interests are tied up in GMO seeds. In other words, the issue of trust comes into play in consumers purchasing decisions about the biotech products. For example, the agricultural biotech firms are claiming that

GMO crops will lower food costs worldwide and improve environmental quality (Huffman et al., 2004). Moreover, they have touted the use of biotechnology to create new products as major source of revolution in product innovation (Hoban 1997, 2001). However, two environmental NGOs Greenpeace and Friends of the Earth have provided evidence that raises the possibility of risks to human health, environment, and biodiversity. Given that controversy around the products, consumers in every country are cautious. Some countries require labeling of GMOs products and others reject the products as a whole. Consumers' preferences vary across countries, geographic areas within Europe, and cultures. US consumers are more inclined towards GMO products than EU consumers because the perception of risks associated with biotechnology and overall awareness of biotechnology are somewhat lower among US consumers. Acceptance of the technology in the US is slightly higher (Hanitios, 2000). In Europe, Southern countries tend to accept biotechnology, while Northern countries are more cautious. The remarkable exceptions are the Netherlands and Finland, which are both strongly in favor of biotechnology. In contrast, the Dutch are the most concerned about the potential risks involved (Zechendorf, 1998). Economic concerns, moral, ethical concerns are equally raised to address the issue of the consumer preferences towards biotech products. Cost- benefit analysis has been performed to determine the economic impact of the use of GMOs on consumers. Suppose that the price of GMOs crop drop, then the consumer will choose to consume more of that good and, consumer welfare or utility will increase (Hoban, 1996c; Moschini et al., 1999). Similarly, if the technology leads the prices of GM crops to increase, consumer welfare or utility will decrease

(Giannakos and Fulton, 2000). Some consumers due to their religious beliefs consider the fact that the technology brings change in the processes of natural life of the seeds, are reluctant in accepting GM crops (Huffman et al., 2004).

Finally, negative externalities generated by the technology are causing delay in the adoption of the technology in EU and the developing countries. Biotech seeds create some negative externalities through the proliferation of secondary pests. For example, Bollworm populations are the main target of the technology; however while using biotech seeds which produce toxins designed to kill bollworms, farmers still have to spray some pesticides. The use of biotech seeds reduces the amount of pesticides sprayed because of the toxins produced by the seeds. For example, for the years 2000 and 2001, BT cotton was associated with 55 percent reduction in pesticide for the average Chinese farm (Pray et al. 2002). As a result, by reducing the amount of pesticides, farmers may have unintentionally created a safe haven for other pests not affected by BT technology (Wang et al., 2006). This phenomenon is called a *pest externality,* which occurs when the chemicals or the technology used to target one pest inadvertently increase the concentration of and damage from secondary pest. *Pest externalities* will affect not only the output of biotech crops, but also farmers' decision whether to adopt the technology or not. Unfortunately crop damage is still endemic despite the use of biotech seeds and pesticides. The biotech seeds that were claimed to be very successful in resisting pests have some limits, and this is one of the reasons farmers in the developing world are still hesitant in adopting the technology. The main objective of this paper is to determine the impact of the enforcement of the intellectual property rights, consumers' preferences, and pest externality on the change in the output of biotech crops. Whether farmers will adopt the technology or not has something to do with their knowledge about the impact of these three factors on the output. Our model considers only a small part of the issues concerning the agricultural biotechnology. Our analysis is based on the adoption decision of farmers in the developing countries and EU taking into account these three factors mentioned above. Also we should note that, these factors are usually overlooked in the evaluation of the biotech seeds. Our model includes only farmers and consumers and did not consider the seeds companies, biotech products markets, and the research development sector. The theoretical model accounting for these factors is described below.

4.2.Theoretical Model

4.2.1 General Equilibrium and Efficiency

Consider an economy with two individuals (BT consumers and Non-BT consumers), two firms (BT producers and Non-BT producers) and two goods (BT products and Non-BT products). In order for the South and EU to adopt the technology, the efficiency conditions need to be satisfied. As a result efficiency in exchange, efficiency in production and efficiency in the output market must all be solved for.

4.2.1.1 Efficiency in exchange

Efficiency of exchange is satisfied when the $MRS_1 = MRS_2$. In order to achieve that efficiency, consumer 2 maximizes its utility (U^2) subject to that of Consumer 1 (U^1). The consumers have both BT and non-BT products in their consumption bundle. In order to get clear idea of the degree of substitution between BT and non-BT products for each consumer, we consider CES utility function for consumer 1 and consumer 2 (Arrow et al., 1961). The degree of substitution will be used to determine the level of preferences of BT and non-BT products for each consumer. For example, if consumer 1 prefers BT to non-BT and consumer 2 prefers non-BT to BT, the elasticities of substitution of consumer 1 will be greater than that of consumer 2.

The utility functions of each consumer are defined as follow:

$$U^1(X_{bt}^1, Y_{nbt}^1) = [\alpha_1 (X_{bt}^1)^{\rho} + \alpha_2 (Y_{nbt}^1)^{\rho}]^{1/\rho}$$

$$U^2(X_{bt}^2,Y_{nbt}^2)=[\beta_1(X_{bt}^2)^{\sigma}+\beta_2(Y_{nbt}^2)^{\sigma}]^{1/\sigma}$$

U^1 and U^2 are the utilities functions of the consumer 1 and consumer2, respectively.

X_{bt}^1 and Y_{nbt}^1 are consumer 1's consumptions of biotech and non-biotech, respectively.

X_{bt}^2 and Y_{nbt}^2 are consumer 2's consumptions of biotech and non-biotech, respectively.

X_{bt} and Y_{nbt} are the outputs of biotech and non-biotech products in the economy.

In this closed economy model, we assume that the total production of biotech is consumed among the two consumers as well as the total production of non-biotech. Therefore the constraint equations are expressed as follow:

$$X_{bt}^1+X_{bt}^2=X_{bt} \quad ;Y_{nbt}^1+Y_{nbt}^2=Y_{nbt}$$

Setting up the maximization problem we have:

Max $U^2(X_{bt}^2;Y_{nbt}^2)$

Subject to $U^1(X_{bt}^1;Y_{nbt}^1)=U_0^1$

$$X_{bt}^1+X_{bt}^2=X_{bt} \quad ;Y_{nbt}^1+Y_{nbt}^2=Y_{nbt}$$

Setting the Lagragian we have:

$$L=U^2(X_{bt}^2;Y_{nbt}^2)+\lambda[U_0^1\text{-}U^1(X_{bt}^1;Y_{nbt}^1)]+\lambda_{bt}(X_{bt}-X_{bt}^1-X_{bt}^2)+\lambda_{nbt}(Y_{nbt}-Y_{nbt}^1-Y_{nbt}^2)$$

Solving the first order conditions (FOCs), we end up with:

$$\frac{U_x^1}{U_y^1}=\frac{U_x^2}{U_y^2}=\frac{\lambda_{bt}}{\lambda_{nbt}}$$

$$\frac{\alpha_1}{\alpha_2}\left[\frac{X_{bt}^1}{Y_{nbt}^1}\right]^{\rho-1}=\frac{\beta_1}{\beta_2}\left[\frac{X_{bt}^2}{Y_{nbt}^2}\right]^{\sigma-1} \quad (1)$$

$$\begin{aligned} X_{bt}^1 &= a_1 X_{bt};\, X_{bt}^2 = a_2 X_{bt} \\ Y_{nbt}^1 &= b_1 Y_{nbt};\, Y_{nbt}^2 = b_2 Y_{nbt} \end{aligned} \quad (2)$$

The coefficients $a_1$and a_2 are the proportions of BT products consumed by consumer 1 and consumer 2, respectively; b_1 and b_2 are the proportions of non-BT products consumed by consumer 1 and consumer 2, respectively. Plugging (2) into (1) we have:

$$\frac{\alpha_1}{\alpha_2}\left[\frac{a_1 X_{bt}}{b_1 Y_{nbt}}\right]^{\rho-1}=\frac{\beta_1}{\beta_2}\left[\frac{a_2 X_{bt}}{b_2 Y_{nbt}}\right]^{\sigma-1} (i)$$

The efficiency in exchange (Pareto efficiency allocation) holds at MRS_1=MRS_2 which implies both consumers lie on the contract curve in the Edgeworth box. In other words, the Pareto efficient bundle is determined at the mutual tangency of consumer1's and consumer2's indifference curves in the Edgeworth box along the contract curve. These are the bundles at which consumer1's and consumer 2's marginal rate of substitution are equal.

4.2.1.2. Efficiency in Production

The production function of the agricultural biotech products is defined by considering the fact that there is knowledge spillover from the North to the South. That is, the developing countries use the technology developed by the North American private companies (Monsanto, Syngenta etc.) to produce their agricultural products. Since these private companies are profit maximizing agents, they charged farmers the technology fee for the first time use of the seed. Therefore, we defined p (i) as the regular price of seeds X_{bt} (i) and T the technology fee. The expression $A^S = ZA^N$ depicts the technology transfer from the North to the South. A^S and A^N are the stock of knowledge in the South and the stock of knowledge in the North, respectively. In the South we have both producers of BT and non-BT crops.

Following Either (1982), the production function in the South for the BT producing sectors is defined as follow:

$$Y_{bt} = B^{1-w}\ \ [(1-b_L)L_{bt}]^{1-\tau-\theta} Z_{bt}^{\tau} \int_{i=0}^{A^S} X_{bt}(i)^{\theta}\, di, 0 < \tau, \theta < 1 \quad (3)$$

$$X_{bt}(i) = \begin{cases} \frac{K_{bt}}{A^S}, & 0 \le i \le A^S \\ 0, & otherwise \end{cases} \quad (4)$$

Z_{bt} represents other inputs such as insecticides, fertilizers, manure, and land used in the biotech sector in the South. ω is the parameter representing a variety of externalities such as new pest density, the effect of the insecticides on the ground water (in addition to the biotech seed, farmers still have to use some insecticides). These externalities could be considered as decreasing productivity factors in the production of Biotech crops.

The coefficient 1- b_L is the fraction of labor used in the biotech producing sector, while the coefficient b_L is the fraction of labor used in the non-biotech producing sector. The expression (4) implies that biotech seeds $X_{bt}(i)$ is the amount of capital good i that is used and it is a proportion of the stock of knowledge in the South. This production function is considered as a production function of a representative farmer in the biotech producing sector of a country adopting the technology. Farmers produce a final product by combining human labor, insecticides, fertilizers, manure, and land with different types of seeds $X_{bt}(i)$, where $i \epsilon$ [0,A]. The additive separability of $X_{bt}(i)$ is a crucial property of this production function. It implies that the discoveries of new seeds do not make any existing seeds obsolete (Papageorgiou, 2000). For example, the biotech seeds that are insects resistant will still be used by farmers when drought resistant seeds are discovered. In other words, every type of seeds is necessary for the production of biotech products at country level. Under conditions of prefect competition, the potential gains from seeds innovation are shared among seeds companies, farmers, consumers and others. As for the seeds companies, they earn the technology fee T, in addition to the regular seed prices. Farmers find their output increase due the damage control property of the seeds and also a reduction in the insectides use. The benefits that go to consumers are very unclear due to the influence of consumers' preferences of biotech products.

The production function of non-BT producers which follows Cobb-Douglas specification is defined as follow:

$$G = Y_{nbt} = K_{nbt}^{\delta} L_{nbt}^{1-\delta} \mathrm{Z}_{\mathrm{nbt}}^{\phi} \qquad (5)$$

We assume constant returns to scale. The difference between biotech and non-biotech production functions is that the former is the extended form of the latter. The non-biotech production function excludes the externalities, technology spillover, and also the capital used is not tied to any stock of knowledge.

For simplicity we assume $\tau = \phi = 0$, and then after some algebra the production function of BT producers becomes:

$$F = Y_{bt} = B^{1-\omega}\left[(1-b_L)ZA^N L_{bt}\right]^{1-\theta} K_{bt}^{\theta} \qquad (6)$$

In order to attain efficiency in production we step up the maximization problem as follow:

Maximize:

$$Y_{bt} = B^{1-\omega}\left[(1-b_L)ZA^N L_{bt}\right]^{1-\theta} K_{bt}^{\theta}$$

Subject to:

$$Y_{nbt} = K_{nbt}^{\delta} L_{nbt}^{1-\delta}$$

$$L_{bt} + L_{nbt} = L; K_{bt} + K_{nbt} = K$$

$$\ell = B^{1-\omega}\left[(1-b_L)ZA^N L_{bt}\right]^{1-\theta} K_{bt}^{\theta} + \lambda[\, Y_{nbt} -$$
$$K_{nbt}^{\delta} L_{nbt}^{1-\delta}] + \lambda_L\left(L - L_{bt} - L_{nbt}\right) + \lambda_k\left(K - K_{bt} - K_{nbt}\right)$$

From the FOCs, we end up with:

$$\frac{F_L}{F_K} = \frac{G_L}{G_K} = \frac{\lambda_L}{\lambda_K} \; (7)$$

Equation (7) corresponds to $\text{MRTS}_{\text{bt}}=\text{MRTS}_{\text{nbt},}$ where the efficiency in production is achieved. After rearranging (7) the production efficiency will be satisfied under the following condition:

$$\frac{1-\theta}{\theta} k_{bt} = \frac{1-\delta}{\delta} k_{nbt} \,(ii)$$

The variables k_{bt} and k_{nbt} are the capital labor ratio used in biotech and non-biotech production, respectively. θ is the biotech output elasticity of capital and δ is the non-biotech output elasticity of capital.

4.2.1.3. Efficiency in the output Market

In this case the condition MRT=MRS$_1$ =MRS$_2$ need to be satisfied for the market to be efficient. Since we have already determined the marginal rate of substitutions (MRS) from the consumer problem, we now have to determine the marginal rate of transformation (MRT), which is the ratio of marginal cost of producing BT products to the marginal cost of producing non-BT products. Let us find the marginal cost of BT from the cost minimization problem.

Minimize:

$$C = w_L L_{bt} + (w_K + T)\int_{i=0}^{A_S} X_{bt}(i)^{\theta}\, di$$

$$Subject.to:$$

$$F = Y_{bt} = B^{1-\omega}\left[(1-b_L)ZA^N L_{bt}\right]^{1-\theta} K_{bt}^{\theta}$$

$$L = w_L L_{bt} + (w_K + T)\int_{i=0}^{A_S} X_{bt}(i)^{\theta}\, di + \lambda_{bt}\{Y_{bt} - B^{1-\omega}\left[(1-b_L)ZA^N L_{bt}\right]^{1-\theta} K_{bt}^{\theta}\ \}$$

$$L = w_L L_{bt} + (w_K + T)K^{\theta} A_s^{1-\theta} + \lambda_{bt}\{Y_{bt} - B^{1-\omega}\left[(1-b_L)ZA^N L_{bt}\right]^{1-\theta} K_{bt}^{\theta}\ \}$$

From the FOCs, we have:

$$\lambda_{bt} = \frac{w_L}{F_L} = \frac{\theta K_{bt}^{\theta-1} A_S^{1-\theta}(w_K + T)}{F_K}$$

Furthermore, according to the envelope theorem we have:

$$\frac{\partial L}{\partial Y_{bt}} = \frac{\partial C(w_L, w_K, Y_{bt})}{\partial Y_{bt}} = \lambda_{bt}$$

The constant term λ_{bt} is the marginal cost of producing BT products.

$$\lambda_{bt} = \frac{w_L}{(1-\theta)B^{1-\omega}[(1-b_L)ZA^N]^{1-\theta} L_{bt}{}^{-\theta} K_{bt}^{\theta}} \, (a)$$

$$\lambda_{bt} = \frac{\theta K_{bt}^{\theta-1} A_S^{1-\theta}(w_K + T)}{\theta B^{1-\omega}[(1-b_L)ZA^N]^{1-\theta} L_{bt}^{1-\theta} K_{bt}{}^{\theta-1}} \, (b)$$

Let us find the marginal cost of non-BT products from the Cost minimization problem.

Minimize:

$$C = w_L L_{nbt} + w_K K_{nbt}$$

Subject to:

$$G = Y_{nbt} = K_{nbt}^{\delta} L_G^{1-\delta}$$

From the FOCs, we have:

$$\lambda_{nbt} = \frac{w_L}{G_L} = \frac{w_K}{G_K}$$

The marginal cost of producing non-BT products is λ_{nbt}

$$\lambda_{nbt} = \frac{w_L}{(1-\delta)(k_{nbt})^{\delta}} \, (c)$$

$$\lambda_{nbt} = \frac{w_K}{\delta (k_{nbt})^{\delta-1}} \, (d)$$

We assume that the price of labor (w_L) is identical in the production of BT and non-BT products, but the price of capital (w_K) is not identical in the production of BT and non-BT products. That is:

$$w_{Lbt} = w_{L_{nbt}} = w_L \ ,$$

and

$r= w_k + T$.

The capital labor ratios on BT products and non-BT products are defined as follow:

$$k_{bt} = \frac{K_{bt}}{L_{bt}}; k_{nbt} = \frac{K_{nbt}}{L_{nbt}}$$

Taking the ratio of the marginal cost of the two products, we have:

$$\frac{(a)}{(c)} \Rightarrow MRT_L = \frac{\lambda_{bt}}{\lambda_{nbt}} = \frac{(1-\delta)B^{\omega-1}}{(1-\theta)}[(1-b_L)ZA^N]^{\theta-1}\frac{k_{nbt}^{\delta}}{k_{bt}^{\theta}}$$

$$\frac{(b)}{(d)} \Rightarrow MRT_K = \frac{\lambda_{bt}}{\lambda_{nbt}} = \frac{\delta B^{\omega-1}K_{bt}^{\theta-1}(w_k+T)(1-b_L)^{\theta-1}}{w_K}\frac{k_{nbt}^{\delta-1}}{k_{bt}^{\theta-1}}$$

Therefore, for efficiency in the output market we should have MRT= MRS_1=MRS_2

That is:

$$MRT_L = MRS_1 \Rightarrow \frac{(1-\delta)B^{\omega-1}}{(1-\theta)}[(1-b_L)ZA^N]^{\theta-1}\frac{k_{nbt}^{\delta}}{k_{bt}^{\theta}} = \frac{\alpha_1}{\alpha_2}\left[\frac{a_1X_{bt}}{b_1Y_{nbt}}\right]^{\rho-1},(iii)$$

$$MRT_K = MRS_2 \Rightarrow \frac{\delta B^{\omega-1}K_{bt}^{\theta-1}(w_k+T)(1-b_L)^{\theta-1}}{w_K(b_L)^{\delta-1}}\frac{k_{nbt}^{\delta-1}}{k_{bt}^{\theta-1}} = \frac{\beta_1}{\beta_2}\left[\frac{a_2X_{bt}}{b_2Y_{nbt}}\right]^{\sigma-1},(iv)$$

Under the assumptions of the model, which include the presence of externalities, the enforcement of the IPRs, and consumers' preferences, EU and developing economies using the agricultural biotechnology developed by the North American private firms, should consider the general equilibrium efficiency conditions to make sure that the adoption of agricultural biotechnology would lead to efficiency in the entire economy.

That is, MRS must be equal for all consumers, MRTS must be equal for all farmers, and MRT must be equal to MRS for all consumers.

4.2.1.4. General equilibrium Efficiency Conditions

$$\text{MRS}_1 = \text{MRS}_2 \Rightarrow \frac{\alpha_1}{\alpha_2}\left[\frac{a_1 X_{bt}}{b_1 Y_{nbt}}\right]^{\rho-1} = \frac{\beta_1}{\beta_2}\left[\frac{a_2 X_{bt}}{b_2 Y_{nbt}}\right]^{\sigma-1} \quad (i)$$

$$\text{MRTS}_{bt} = \text{MRTS}_{nbt} \Rightarrow \frac{1-\theta}{\theta} k_{bt} = \frac{1-\delta}{\delta} k_{nbt} \, (ii) \qquad \text{(I)}$$

$$MRT_L = MRS_1 \Rightarrow \frac{(1-\delta)B^{\omega-1}}{(1-\theta)}[(1-b_L)ZA^N]^{\theta-1}\frac{k_{nbt}^{\delta}}{k_{bt}^{\theta}} = \frac{\alpha_1}{\alpha_2}\left[\frac{a_1 X_{bt}}{b_1 Y_{nbt}}\right]^{\rho-1}, (iii)$$

$$MRT_K = MRS_2 \Rightarrow \frac{\delta B^{\omega-1} K_{bt}^{\theta-1}(w_k + T)(1-b_L)^{\theta-1}}{w_K}\frac{k_{nbt}^{\delta-1}}{k_{bt}^{\theta-1}} = \frac{\beta_1}{\beta_2}\left[\frac{a_2 X_{bt}}{b_2 Y_{nbt}}\right]^{\sigma-1}, (iv)$$

4.2.2 Comparative Statics

4.2.2.1 Comparative Statics on the Technology fee, T

The idea is to evaluate the impact of the enforcement of the IPRs in the developing countries, when the seed companies charged farmers for the technology. The impact is measured by looking at the change in the production of biotech and non-biotech products with respect to the technology fee. Since the fee is charged for the first time use of the seed, we have conducted comparative statics analysis. One can argue, as we did in the introduction to this paper, that, despite the fact that the technology fee is paid for the first time use it might have some dynamic impact on production. However, since we are dealing with a short term model, we choose to conduct static analysis. The first step to conduct the comparative statics is to linearize the system (I) by taking log of both sides. The system becomes:

$$
\begin{aligned}
&A_1 + (\rho - 1)\ln X_{bt} + (1-\rho)\ln Y_{nbt} = A_2 + (\sigma - 1)\ln X_{bt} + (1-\sigma)\ln Y_{nbt} \\
&B_1 + \ln k_{bt} = B_2 + \ln k_{nbt} \\
&\ln K_1 + \delta \ln k_{nbt} - \theta \ln k_{bt} = A_1 + (\rho - 1)\ln X_{bt} + (1-\rho)\ln Y_{nbt} \\
&\ln K_2 + (\delta - 1)\ln k_{nbt} + (1-\theta)\ln k_{bt} = A_2 + (\sigma - 1)\ln X_{bt} + (1-\sigma)\ln Y_{nbt}. \\
&A_1 = \ln\left[\frac{\alpha_1}{\alpha_2}\left(\frac{a_1}{b_1}\right)^{\rho - 1}\right] = \ln\frac{\alpha_1}{\alpha_2} + (\rho - 1)\ln\frac{a_1}{b_1} \\
&A_2 = \ln\left[\frac{\beta_1}{\beta_2}\left(\frac{a_2}{b_2}\right)^{\sigma - 1}\right] = \ln\frac{\beta_1}{\beta_2} + (\sigma - 1)\ln\frac{a_2}{b_2} \\
&B_1 = \ln\left[\frac{1-\theta}{\theta}\right] \\
&B_2 = \ln\left[\frac{1-\delta}{\delta}\right] \\
&K_1 = \frac{(1-\delta)}{(1-\theta)} B^{\omega - 1}\left[(1-b_L)ZA^N\right]^{\theta - 1} \\
&K_2 = \frac{\delta B^{\omega - 1} K_{bt}^{\theta - 1}(w_k + T)(1-b_L)^{\theta - 1}}{w_K}
\end{aligned}
\tag{II}
$$

Then, keeping the endogenous variables on the left hand side and sending the exogenous variables to the right hand side, we have:

$$\begin{aligned}
&(\rho-\sigma)\ln X_{bt}+(\sigma-\rho)\ln Y_{nbt}=A_2-A_1\\
&\ln k_{bt}-\ln k_{nbt}=B_2-B_1\\
&(1-\rho)\ln X_{bt}+(\rho-1)\ln Y_{nbt}-\theta\ln k_{bt}+\delta\ln k_{nbt}=A_1-\ln K_1\\
&(1-\sigma)\ln X_{bt}+(\sigma-1)\ln Y_{nbt}+(1-\theta)\ln k_{bt}+(\delta-1)\ln k_{nbt}=A_2-\ln K_2
\end{aligned}\qquad (III)$$

The system (III) can be expressed as the following implicit functions:

$$\begin{aligned}
&F^1(\ln X_{bt},\ln Y_{nbt},\ln k_{bt},\ln k_{nbt},\ln K_1,\ln K_2,A_1,A_2,B_1,B_2,T,\rho,\sigma,\omega)=0\\
&F^2(\ln X_{bt},\ln Y_{nbt},\ln k_{bt},\ln k_{nbt},\ln K_1,\ln K_2,A_1,A_2,B_1,B_2,T,\rho,\sigma,\omega)=0\\
&F^3(\ln X_{bt},\ln Y_{nbt},\ln k_{bt},\ln k_{nbt},\ln K_1,\ln K_2,A_1,A_2,B_1,B_2,T,\rho,\sigma,\omega)=0\\
&F^4(\ln X_{bt},\ln Y_{nbt},\ln k_{bt},\ln k_{nbt},\ln K_1,\ln K_2,A_1,A_2,B_1,B_2,T,\rho,\sigma,\omega)=0
\end{aligned}\qquad (III)$$

To determine the impact of a change in the technology fee on the optimal values of the endogenous variables, we take the total derivative of each of the four functions of the System (III) with respect to T.

$$\begin{bmatrix} (\rho-\sigma) & (\sigma-\rho) & 0 & 0 \\ 0 & 0 & 1 & -1 \\ (1-\rho) & (\rho-1) & -\theta & \delta \\ (1-\sigma) & (\sigma-1) & (1-\theta) & (\delta-1) \end{bmatrix} \begin{bmatrix} \frac{\partial \ln X_{bt}}{\partial T} \\ \frac{\partial \ln Y_{nbt}}{\partial T} \\ \frac{\partial \ln k_{bt}}{\partial T} \\ \frac{\partial \ln k_{nbt}}{\partial T} \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 0 \\ \frac{1}{w_K + T} \end{bmatrix}$$

$$\begin{bmatrix} \frac{\partial \ln X_{bt}}{\partial T} \\ \frac{\partial \ln Y_{nbt}}{\partial T} \\ \frac{\partial \ln k_{bt}}{\partial T} \\ \frac{\partial \ln k_{nbt}}{\partial T} \end{bmatrix} = \begin{bmatrix} (\rho-\sigma) & (\sigma-\rho) & 0 & 0 \\ 0 & 0 & 1 & -1 \\ (1-\rho) & (\rho-1) & -\theta & \delta \\ (1-\sigma) & (\sigma-1) & (1-\theta) & (\delta-1) \end{bmatrix}^{-1} \begin{bmatrix} 0 \\ 0 \\ 0 \\ \frac{1}{w_K + T} \end{bmatrix}$$

$$|J| = 2(\rho-\sigma)[(1-\rho)(\delta-1)+\delta(\sigma-1)] \neq 0$$

Using the method of Cramer the solutions of the system are:

$$\frac{\partial \ln X_{bt}}{\partial T} = \frac{\delta-\theta}{2(w_K + T)[(1-\rho)(\delta-1)+\delta(\sigma-1)]}$$

$$\frac{\partial \ln Y_{nbt}}{\partial T} = \frac{\delta-\theta}{2(w_K + T)[(1-\rho)(\delta-1)+\delta(\sigma-1)]} \;; \frac{\partial \ln k_{bt}}{\partial T} = 0 \qquad \frac{\partial \ln k_{nbt}}{\partial T} = 0$$

4.2.2.2 Comparative Statics on Consumer Preferences, ρ and σ

To determine the impact of a change in the consumers preferences on the optimal values of the endogenous variables, we take the total derivative of each of the four functions of the System (III) with respect to ρ and σ **.**

$$\begin{bmatrix} \frac{\partial \ln X_{bt}}{\partial \rho} \\ \frac{\partial \ln Y_{nbt}}{\partial \rho} \\ \frac{\partial \ln k_{bt}}{\partial \rho} \\ \frac{\partial \ln k_{nbt}}{\partial \rho} \end{bmatrix} = \begin{bmatrix} (\rho-\sigma) & (\sigma-\rho) & 0 & 0 \\ 0 & 0 & 1 & -1 \\ (1-\rho) & (\rho-1) & -\theta & \delta \\ (1-\sigma) & (\sigma-1) & (1-\theta) & (\delta-1) \end{bmatrix}^{-1} \begin{bmatrix} \ln(\frac{a_1}{b_1}) \\ 0 \\ 0 \\ 0 \end{bmatrix}$$

Using the method of Cramer the solutions of the system are:

$$\frac{\partial \ln X_{bt}}{\partial \rho} = \frac{(\delta-\theta)\ln\left(\frac{a_1}{b_1}\right)}{2[(1-\rho)(\delta-1)+\delta(\sigma-1)}$$

$$\frac{\partial \ln Y_{nbt}}{\partial \rho} = \frac{\ln\left(\frac{a_1}{b_1}\right)(\delta-\theta)(\rho-\delta)}{2(\rho-\sigma)[(1-\rho)(\delta-1)+\delta(\sigma-1)]}$$

$$\frac{\partial \ln Y_{nbt}}{\partial \rho} = (\rho-\delta)\frac{\partial \ln Y_{nbt}}{\partial \rho}$$

$$\frac{\partial \ln k_{bt}}{\partial \rho} = 0 \qquad \frac{\partial \ln k_{nbt}}{\partial \rho} = 0$$

$$\begin{bmatrix} \dfrac{\partial \ln X_{bt}}{\partial \sigma} \\ \dfrac{\partial \ln Y_{nbt}}{\partial \sigma} \\ \dfrac{\partial \ln k_{bt}}{\partial \sigma} \\ \dfrac{\partial \ln k_{nbt}}{\partial \sigma} \end{bmatrix} = \begin{bmatrix} (\rho - \sigma) & (\sigma - \rho) & 0 & 0 \\ 0 & 0 & 1 & -1 \\ (1-\rho) & (\rho - 1) & -\theta & \delta \\ (1-\sigma) & (\sigma - 1) & (1-\theta) & (\delta - 1) \end{bmatrix}^{-1} \begin{bmatrix} \ln\left(\dfrac{a_2}{b_2}\right) \\ 0 \\ 0 \\ 0 \end{bmatrix}$$

$$\frac{\partial \ln X_{bt}}{\partial \sigma} = \frac{(\theta - \delta)\ln\left(\dfrac{a_2}{b_2}\right)}{2[(1-\rho)(\delta - 1) + \delta(\sigma - 1)]}$$

$$\frac{\partial \ln Y_{nbt}}{\partial \sigma} = \frac{(\theta - \delta)\ln\left(\dfrac{a_2}{b_2}\right)}{2[(1-\rho)(\delta - 1) + \delta(\sigma - 1)]} \qquad \frac{\partial \ln k_{bt}}{\partial \sigma} = 0 \qquad \frac{\partial \ln k_{nbt}}{\partial \sigma} = 0$$

4.2.2.3 Comparative Statics on externalities, ω

To determine the impact of a change in the externalities on the optimal values of the endogenous variables, we take the total derivative of each of the four functions of the System (III) with respect to ω

$$\begin{bmatrix} \frac{\partial \ln X_{bt}}{\partial \omega} \\ \frac{\partial \ln Y_{nbt}}{\partial \omega} \\ \frac{\partial \ln k_{bt}}{\partial \omega} \\ \frac{\partial \ln k_{nbt}}{\partial \omega} \end{bmatrix} = \begin{bmatrix} (\rho-\sigma) & (\sigma-\rho) & 0 & 0 \\ 0 & 0 & 1 & -1 \\ (1-\rho) & (\rho-1) & -\theta & \delta \\ (1-\sigma) & (\sigma-1) & (1-\theta) & (\delta-1) \end{bmatrix}^{-1} \begin{bmatrix} 0 \\ 0 \\ -\ln B \\ -\ln B \end{bmatrix}$$

$$\frac{\partial \ln X_{bt}}{\partial \omega} = \frac{\theta \ln B}{[(1-\rho)(\delta-1)+\delta(\sigma-1)]} < 0$$

$$\frac{\partial \ln Y_{nbt}}{\partial \omega} = \frac{(\theta-1)\ln B}{[(1-\rho)(\delta-1)+\delta(\sigma-1)]} > 0$$

$$\frac{\partial \ln k_{bt}}{\partial \omega} = \frac{\ln B}{[(1-\rho)(\delta-1)+\delta(\sigma-1)]} < 0$$

$$\frac{\partial \ln k_{nbt}}{\partial \omega} = 0$$

4.2.3 Discussion of the Conclusions of the Model

The results from this model can be applied to several developing countries depending on how the production of the agricultural biotechnology is affected by the enforcement of the property rights (technology fee), consumer preferences and the externalities. Since our model is set up to cover only the production of biotech products, our discussion only distinguishes the impact of the technology fee, consumer preferences and externalities on the biotech crops production. The Summary of the results of the model for the biotech crops production is presented in Table 4.1 below.

4.2.3.1 Impact of the technology fee

The model predicts that the impact of the technology fee charged by the private seed companies on the production of the biotech products depends on several factors: the biotech output elasticity of capital (θ), the non-biotech output elasticity of capital (δ), the preferences (σ and ρ) of the two consumers considered in the economy, and the costs ($w_K + T$) of the biotech seeds.

4.2.3.2 The Impact of the Elasticity of Supply of Capital

For one thing, we see that if non-biotech output elasticity of capital is lower than biotech output elasticity of capital ($\delta < \theta$), any change in the technology fee will positively affect the production of biotech products. In other words, if we can assume that the output elasticity of capital in the biotech production is higher, then an increase in the technology fee will increase the output of the biotech crops. That is, biotech producers will increase their production because the contribution of capital to the biotech output is higher despite the technology fee.

In order to grasp the intuition behind this case, let us assume δ=0.35 and θ=0.65. That is, a 1 percent increase in the use of capital would lead to 0.35 percent increase in the non-biotech production and 0.65 percent increase in the biotech production. Therefore, given that condition, producers of biotech crops could increase their production with an increase in the technology fee, and vice versa. In contrast, if non-biotech output elasticity of capital is greater than biotech output elasticity of capital ($\delta > \theta$), any change in the technology fee will negatively affect the production of biotech products.

4.2.3.3 Impact of the Consumers Preferences

For any country to adopt the technology, we need to make sure that consumers would appreciate the products and buy them. In our model, the production of the biotech products by any country should consider the impact of consumers' preferences. As you can recall, in our model we assume two consumers who each have both biotech and non-biotech products in their consumption bundle. For example, a husband and wife living in the same home may have different preferences for both biotech and non-biotech products. The model considers ρ as the proxy of the elasticity of substitution between biotech and non-biotech products for consumer 1 and σ for consumer 2. That is, by using the model to maximize utility subject to a budget constraint (Arrow et al., 1961), we derive:

$$\varepsilon_1 = \frac{1}{1-\rho} \qquad (8)$$
$$\varepsilon_2 = \frac{1}{1-\sigma}$$

The parameters ε_1 and ε_2 are the elasticities of substitution between biotech and non-biotech products. From (8), we can see that the greater the value of the parameter ρ , the greater the degree of substitutability between the two commodities for consumer 1. Similarly, the greater the value of the parameter σ, the greater the degree of substitutability between the two commodities for consumer 2. Our model shows the impact of preferences on the production of both commodities through the change in the parameters ρ and σ . It demonstrates that the magnitude of the impact of the degree of substitutability between the two commodities on their productions depends on the factors such as output elasticities of capital in biotech and non-biotech productions, the ratio of the proportions of the biotech and non-biotech consumed by each consumer, and the degree of substitutability between the commodities for both consumers. Since the utility function of the two consumers are identical as well as the impact of their preferences on the biotech production, we consider only the case of consumer 1, which is analogous to that of consumer 2. The case for consumer 1 is divided into four sub-cases presented in Table 4.2 below.

Sub-case 1

The model predicts that if non-biotech output elasticity of capital is lower than biotech output elasticity of capital, farmers will be tempted to invest more in biotech products. However, if consumer 1 consumes less biotech than non-biotech products the degree of substitutability of consumer 1 between biotech and non-biotech products is negatively related to the change in the production of biotech. Suppose that the degree of substitutability of consumer 1 decreases that is consumer 1 prefers less biotech products than non- biotech products. Under these conditions, biotech producing farmers should be discouraged in increasing biotech output but in case the preferences of consumer 2 outweigh that of consumer 1, biotech producer will increase its output.

Sub-case 2

We assume as in the previous case that if non-biotech output elasticity of capital is lower than biotech output elasticity of capital, again farmers will be tempted to invest more in biotech products. In addition, if consumer 1consumes more biotech than non-biotech that is the degree of substitutability increases, farmers will produce more biotech products. In economics standpoint, since input capital contribute more in biotech output than non-biotech output and consumers also desire more biotech than non-biotech, it will make sense for farmers to increase biotech output regardless of the preferences of the other consumers.

Sub-case 3

In this sub-case, we assume that non-biotech output elasticity of capital is greater than biotech output elasticity of capital and consumer 1consumes less biotech than non-biotech. In other words, farmers will be tempted to increase the capital in their non-biotech production, but since consumer 1 prefers less biotech than non-biotech, a decrease in the degree of substitutability will lead to lower production of biotech products and vice versa.

Sub-case 4

We assume that non-biotech output elasticity of capital is greater than biotech output elasticity of capital and consumer 1consumes more biotech than non-biotech. That is, farmers will invest more capital in non-biotech production and the degree of substitutability of consumer 1decreases. Under these conditions, the model predicts an increase in the production of biotech which conflicts with economic theory. This situation can only make economic sense if the preferences of biotech of other consumers in the economy outweigh that of consumer 1.

4.2.3.4 Impact of the externalities

The production of the biotech products is subject to various externalities generated by the technology. These externalities may be the proliferation of the new pests causing more damage to the yields, the pollution of the ground water, and the destruction of the biodiversity. The effect of such externalities on the productions of the biotech products are negative and their size depends solely on biotech output elasticity of capital, total factor productivity and other factors of the model. These factors are in the denominator which is already positive. The detailed discussion on the impact of the externalities is presented in Table 4.3.

4.3 Conclusion

Should the South and EU adopt the Agricultural Biotechnology? The answer to this question is complex when the enforcement of IPRs, consumers' preferences and externalities are to be considered. This paper develops a simple model that describes some aspects of the current issues surrounding agricultural biotechnology. This paper then uses the model to determine to what extent developing countries and EU countries should produce biotech crops. The results are contingent upon the parameters of the model, which include output elasticity of capital in both biotech and non-biotech productions, total factor productivity in biotech production, and the ratio of the proportions of the biotech and non-biotech products consumed by each consumer. Considering the impact of consumers' preferences on the production of biotech products, the results show that higher consumers' preference of biotech products coupled with the higher output elasticity of capital will lead to higher production of biotech products. This result lines up with economic theory. As for the impact of the technology fee, biotech producers will increase their production when the contribution of capital to the biotech output is higher despite the technology fee. The impact of the externalities on the biotech production is undoubtedly negative.

The implication of this paper for future research is twofold: First, the results predicted by the model are worthy of further investigation by conducting case studies using empirical data. The case studies could be done by countries of by farmers in order to determine how these results could relate to the actual real world biotech situations. We plan to estimate biotech and non- production functions in order to determine the estimated values of the output elasticities of capital either per countries of per farmers. Second, for this paper to contribute more to our economic knowledge, we plan to conduct welfare analysis to determine the impact of technology fees, consumers' preferences and the externalities on the consumers and producer surpluses.

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Table 4.1: Summary of the Results of the Model: Case of the Biotech Crops Production

	Results	**Sign**
$\frac{\partial \ln X_{bt}}{\partial T} *$	$\frac{\delta-\theta}{2(w_K+T)[(1-\rho)(\delta-1)+\delta(\sigma-1)]}$	**Depends on** $\delta-\theta$
$\frac{\partial \ln X_{bt}}{\partial \rho} *$	$\frac{(\delta-\theta)\ln\left(\frac{a_1}{b_1}\right)}{2[(1-\rho)(\delta-1)+\delta(\sigma-1)]}$	**Depends on** $\delta-\theta, a_1, b_1$
$\frac{\partial \ln X_{bt}}{\partial \sigma} *$	$\frac{(\delta-\theta)\ln\left(\frac{a_2}{b_2}\right)}{2[(1-\rho)(\delta-1)+\delta(\sigma-1)}$	**Depends on** $\delta-\theta, a_2, b_2$
$\frac{\partial \ln X_{bt}}{\partial \omega} *$	$\frac{\theta \ln B}{[(1-\rho)(\delta-1)+\delta(\sigma-1)]} < 0$	**Depends on** θ and B

Table 4.2: The Impact of Consumer 1's Preferences on the Biotech Production

$\frac{\partial \ln X_{bt}}{\partial \rho} = \frac{(\delta-\theta)\ln\left(\frac{a_1}{b_1}\right)}{2[(1-\rho)(\delta-1)+\delta(\sigma-1)]}$	**Sub-case 1** δ <θ $a_1 < b_1$ Non-biotech output elasticity of capital is **lower than** biotech output elasticity of capital and Consumer 1consumes **less** biotech than non-	$\frac{\partial \ln X_{bt}}{\partial \rho} < 0$ The degree of substitutability of consumer 1 between biotech and non-biotech products is **negatively** related to the change in the production of biotech.
	Sub-case 2 δ <θ $a_1 > b_1$ Non-biotech output elasticity of capital is **lower than** biotech output elasticity of capital and Consumer 1consumes **more** biotech than non-	$\frac{\partial \ln X_{bt}}{\partial \rho} > 0$ The degree of substitutability of consumer 1 between biotech and non-biotech products is **positively** related to the change in the production of biotech.
	Sub-case 3 δ >θ $a_1 < b_1$ Non-biotech output elasticity of capital is **greater than** biotech output elasticity of capital and Consumer	$\frac{\partial \ln X_{bt}}{\partial \rho} > 0$ The degree of substitutability of consumer 1 between biotech and non-biotech products is **positively** related to the change in the production of biotech.
	Sub-case 4 δ >θ $a_1 > b_1$ Non-biotech output elasticity of capital is **greater than** biotech output elasticity of capital and Consumer	$\frac{\partial \ln X_{bt}}{\partial \rho} < 0$ The degree of substitutability of consumer 1 between biotech and non-biotech products is **negatively** related to the change in the production of biotech.

Table 4.3: The Impact of the Externalities on the Biotech Production

$\frac{\partial \ln X_{bt}}{\partial \omega} *$	$\frac{\theta \ln B}{[(1-\rho)(\delta-1)+\delta(\sigma-1)]} < 0$	$0 < \theta < 1; 0 < B < 1$ $\frac{\partial \ln X_{bt}}{\partial \omega} > 0$ Lower TFP in the production of biotech means that the technology is not substantially used, thus the impact of the externalities does not impede the production of biotech crops.
		$0 < \theta < 1; B > 1$ $\frac{\partial \ln X_{bt}}{\partial \omega} < 0$ Higher TFP in the production of biotech means that the technology is substantially used, thus the impact of the externalities will impede the production on biotech crops. In other words, a substantial use of the biotech seeds generates more negative externalities which cause more damage to the yield. This case lines up with the proliferation of new pests.

CHAPTER 5

CONCLUSION

5.1. Discussion of Relevance

Despite powerful economic and political forces that are promoting the benefits of the agricultural biotechnology, some countries are still reluctant in adopting it. Why?

Farmers in developing countries need some advanced technology to improve their output. Also developing economies with predominant agricultural sector need to improve their agricultural production in order to gain more from exporting their products to the Rest of the World. Several institutions are claiming that agricultural biotechnology improves yield, reduces the use of pesticides, increases farmers' profit, and reduces poverty. Traditionally, there is no flawless technology but agricultural biotechnology is viewed by some groups of institutions as a perfect technology with solutions to all agricultural problems. Of course, agricultural biotechnology does have some benefits which should not be overlooked. However, it is important to consider not only the economic benefits but also the more complex and varied social, environmental, health and ethical implications of the technology. This dissertation has addressed these issues in several ways by looking at more than just economic and direct benefits of the agricultural biotechnology. Seed companies which are profit driven economic agents are just claiming the positive characteristics of the agricultural biotechnology and are also lobbying several research groups to promote the technology without considering any externality that might occur in the future. For example, the proliferation of new pests upon the use of biotech seeds, the contamination of ground water by herbicide sprayed, and the heavy debt burden on farmers in developing countries were not expected by the scientists who invented the biotech seeds. However, these situations need to be considered with transparency, and seed companies must take a proactive role in addressing the information gap associated with their products, through accurate and transparent risk communication. Furthermore, Government has to play a crucial role in imposing some regulatory restrictions on biotech industries. For example, farmers should be protected from the monopoly power of the seed companies. In addition, since consumers have the right to know the ingredients in the products they are consuming, Govermnent should impose labeling rules of the biotech products. Among other things, this research is relevant because it considers the negative externalities associated with the agricultural biotechnology.

5.2. Concluding Remarks

The issue of negative externality was indirectly investigated by considering the impact of pest density on the output mean and output variance in the first essay. The results from the stochastic production function show that both biotech varieties and insecticides contribute to the increasing yield, while the insecticides experience diminishing returns on yield due to ongoing pest densities. Another thing we should consider from these results is that additional applications of insectides and extra hours of work reduce yield risk, even though they increase costs. Moreover, we found that the yields of the non-biotech crops are almost exempt from the threat of the emerging pests, and the use of insecticides was successful in increasing yield for those crops.

The impact of consumer preferences was considered in the second essay by looking at the trade impact of EU consumer preferences and policy towards biotech products. The results show that the impact of EU consumers' preferences proxied by three categories of commodities had significant impact on the imports between EU and the Rest of the World. Furthermore, these preferences led to trade diversion on the categories of Beverages and Tobacco and that of Animals and Vegetables Oils and Fats. In contrast, trade creation was found in the category of Food and Live Animals. The impact of the policies was not substantial and cannot be considered as either trade or trade diversion.

In the third essay, we determine to what extent developing countries and EU countries should produce biotech crops. The results are contingent upon the parameters of the model, which include output elasticity of capital in both biotech and non-biotech productions, total factor productivity in biotech production, and the ratio of the proportions of the biotech and non-biotech products consumed by each consumer. Considering the impact of consumers' preferences on the production of biotech products, the results show that higher consumers' preference of biotech products coupled with higher output elasticity of capital will lead to higher production of biotech products. This result lines up with economic theory. As for the impact of the technology fee, biotech producers will increase their production when the contribution of capital to the biotech output is higher despite the technology fee. The impact of the externalities on the biotech production is undoubtedly negative.

5.3. Shortcomings and Future Research

This dissertation does have some limits. For example, the first essay shows the impact of new pests on crops yield, but this was just indirect evidence in the sense that the data of pest density was not used. Pest density was proxied by additional sprays of insecticides and extra hours of work due to the presence of new pests. We plan to use pest population in our regression upon the availability of pest density data. Moreover, the damage control production function will be used in order to determine yield loss in the presence of new pests when farmers apply damage control agents like biotech seeds and insecticides.

The second essay, in which gravity model of international trade was used to capture trade consequences of the EU restrictive trade policy, is the starting point of our research agenda. In this essay, we fail to capture the trade effect of EU restrictive trade policy towards biotechnology. The estimates of the policy variable are negative but not significant. Also, we found trade creation in the category of Food and Live Animals. These results conflict with our expectations. We thus plan to break down the data into more than three categories of the commodities. Furthermore, intra EU and growth implications will be investigated as well as the export loss of developing adopting countries.

The shortcoming of the third essay is that seed companies were not considered as an economic agent in the general equilibrium model, and there were also lack of practical analyses. We also made many unrealistic assumptions in order to make the model tractable. The implication of this essay for future research is twofold: First, seed companies will be considered as a third economic agent. Second, empirical investigations will be conducted through case studies for some selected countries and we hope to eventually develop a more realistic model in order to more confidently determine the optimum level of consumption and production for specific countries, as well as offer some plausible level of welfare analysis.