THREE ESSAYS ON THE POTENTIAL ECONOMIC IMPACTS OF BIOTECH CROPS IN THE PRESENCE OF ASYNCHRONOUS REGULATORY APPROVAL

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by
SRINIVASA PRASAD KONDURU

Dr. Nicholas Kalaitzandonakes, Dissertation Supervisor

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The undersigned, appointed by the Dean of the Graduate School, have examined the dissertation entitled

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Presented by Srinivasa Prasad Konduru

A candidate for the degree of Doctor of Philosophy

And hereby certify that in their opinion it is worthy of acceptance.

Dr. Nicholas Kalaitzandonakes

Dr. John Kruse

Dr. Joe Parcell

Dr. Xinghe Wang

Dr. Patrick Westhoff

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THREE ESSAYS ON THE POTENTIAL ECONOMIC IMPACTS OF BIOTECH CROPS IN THE PRESENCE OF ASYNCHRONOUS REGULATORY APPROVAL

Srinivasa Konduru

Dr. Nicholas Kalaitzandonakes, Dissertation Supervisor

ABSTRACT

Since their commercial introduction in 1996, genetically modified (GM) crops have been quickly adopted world wide, but some GM crops/varieties have not received regulatory approval for use in some importing countries, leading to asynchronicity in regulatory approvals. In this context, the international agricultural trade relied on analytical GMO testing which is a statistical process, along with identity preserved systems to segregate GM and non-GM crops. This led to a situation where measurement uncertainty became an important issue that can lead to potential holdups at the point of import. In this background, the first essay examines the implications of measurement uncertainty associated with GMO testing on the behavior of importers and exporters in a game theoretic framework. In the second essay the market and welfare effects due to the trade disruptions from unapproved GM crops are analyzed. In the third essay the potential economic impacts from the introduction of a new GM soybean variety are analyzed. Based on the analysis, conclusions were drawn on the likelihood of various adoption scenarios, the possibility of trade disruptions, and the possibility of redistribution of innovation rents in the event of asynchronous regulatory approval of the new GM soybean variety.

ESSAY ONE:

GMO TESTING STRATEGIES UNDER MEASUREMENT UNCERTAINTY AND IMPLICATIONS FOR TRADE: A GAME THEORETIC APPROACH

I. Introduction

Since their commercial introduction in 1996, biotech or genetically modified (GM) crops have been quickly adopted reaching 282.4 million acres worldwide in just over ten years (James, 2007). GM crops have increased agricultural production, have reduced input use, and have yielded large economic benefits for adopters and consumers around the world (Brookes and Barfoot, 2008; Marra, Pardey, & Alston, 2002; Konduru, Kruse and Kalaitzandonakes, 2008). At the same time, markets seeking to avoid GM crops have also developed. Some of these markets have been driven by the interest of food manufacturers and retailers to avoid GM ingredients in their products in order to cater to certain consumer segments (Kalaitzandonakes & Bijman, 2003) or to sidestep relevant mandatory labels (Carter and Gruere, 2003). Others have been driven by food standards that explicitly prohibit the use of GM ingredients (e.g. standards for organic foods). Yet, others have been created by the need to avoid GM crops that have not received regulatory approval for use in some importing countries but are authorized for production in some exporting ones. These GM crops are frequently referred to as “unapproved events” and have become infamous when they have turned up in markets they were not allowed (e.g., as in the cases of Starlink™ corn and Liberty Link™ Rice – (Lin, Price and Allen, 2003; Carter & Gruere, 2006)).

Separation of GM and non-GM crops is generally difficult within a commodity system that has been built for scale, speed and efficiency achieved through aggregation. For this reason, so-called identity preserved (IP) systems are typically used to segregate GM from non-GM crops and guide them through relevant supply chains and across export markets. These systems often require significant adjustments in supply chain operations along with heavy use of analytical GMO testing.

Specifically, IP systems involve more coordination and planning than commodity systems. In the context of international trade, changes in the supply chain must begin at the time when a cargo is procured by an end user --usually an importer. Under typical conditions an importer's order can be fulfilled within 3-6 months. Non-GM cargos instead require procurement 12-18 months ahead of delivery. Exporters must reach, either directly or through intermediaries, all the way back to individual farms to contract acres for non-GM crop production well ahead of the production season. In some cases, they have to reach all the way back to the seed stock. Additional changes in the functions of the marketing chain are also necessary, as the production of the contracted acres must be protected from commingling with GM crops in the field, during harvest and transport, in storage, in the rail cart or barge, and all the way to the export vessel.

Another key tool in managing compliance in non-GM supply chains is analytical GMO testing which is performed in the field and in laboratories in order to detect the presence or confirm the absence of certain GM crops. In practice, GMO testing occurs multiple times along a supply chain, most frequently, when a cargo changes custody (ownership). GMO testing is indeed a standard procedure for cargoes directed to non-GM markets and when asynchronous approval conditions between export and import markets exist.

Despite the typical reliance on GMO testing in the various non-GM supply chains some key practical issues remain unresolved, chief among them the presence of measurement uncertainty. Since GMO testing is a statistical process, repeated sampling and testing of the very same cargo would regularly produce different results. There are several sources of variance in GMO test results, including differences in the testing and sampling methods and protocols as well as inherent error rates in all types of analytical tests (Laffont et al., 2005; Powell & Owen, 2002; Remund, Dixon, Wright, & Holden, 2001). Even if identical testing methods and protocols were used, conflicting test results would occur, unless the very same sample was tested across all laboratories. However, given the lack of standardization in GMO testing methods and protocols around the world and the inherent variance in sampling, significant differences in GMO testing results across labs are normally expected.

Since differences in sampling procedures and testing methods imply that some divergence of GMO test results at origin and destination are to be expected, could this be a cause of delays or rejections of cargoes at destination? The potential holdup costs from such circumstances can be quite large. Depending on the size of cargo and port of import, demurrage charges from re-directing a vessel to an alternative destination, quality deterioration and other costs could add up to large sums per held-up cargo. These types of uncertainty and costs would be expected to influence the behavior of importers and exporters, their testing strategies and trade (Kalaitzandonakes, 2006).

In this study I examine the implications of measurement uncertainty associated with GMO testing on the behavior of importers and exporters in non-GM markets and in commodity markets where certain GM crops have not received regulatory approval and cannot be exported to some destinations. As I explain below, because of the inherent measurement uncertainty in GMO testing, importers and exporters face incomplete and asymmetric information in their transactions. Under such conditions, the equilibrium testing strategies for the exporters and importers can be obtained through the use of a dynamic game of incomplete information (Gibbons, 1992). In this study I use this framework to derive optimal GMO testing strategies in the presence of measurement uncertainty and to examine the relevance of various organizational and institutional factors for improving the efficiency and performance of market exchanges.

II. Incompleteness and Asymmetries of Information and Economic Behavior

Incomplete and asymmetric information between exporters and importers on the presence of GM crops in shipments is expected to affect their behavior. In his famous "Market for Lemons" paper, Akerlof (1970) explained that when the quality of a good is undistinguishable beforehand by the buyer and incentives exist for the seller to pass off a low-quality good as a higher-quality one, such informational asymmetries can lead to the disappearance of a market for high-quality products. In this case, gains from trade have to be forfeited.

Even though our GM crop trade problem is similar to the problem of lemons, the buyers (importers) in our model can assess, though imperfectly, the quality of the shipment before accepting it through analytical testing. However, the decisions of exporters to certify the absence of GM crops in their shipment and the decision of importers to accept or reject a shipment have to be taken under both imperfect and asymmetric information. In our context, information is imperfect because uncertainties in testing do not permit the exporter or the importer to assess with certainty whether or not GM crops are present or absent in a shipment. GMO tests are designed to indicate with some probability that GM crops are absent in a shipment despite their potential presence (Type I error) or indicate that GM crops are present in the shipment despite their potential absence (Type II error). Hence, there is scope that the importer and exporter arrive at different assessments on the GM content of a shipment despite best and honest efforts by both to arrive at a common one.

At the same time, information is also asymmetric because importers do not typically possess the same information exporters might have about the shipment. For instance, exporters might know the geographic origin of a shipment and the local level of GM crop adoption which could be suggestive of its potential GM content. They might also have information on the rigor of the IP procedures used in the procurement of a given shipment and could infer the extent of successful segregation. As a result, importers may have to decide whether to accept shipments based on the information provided by the exporter in the form of documents accompanying a cargo or by analytically testing the shipment at the point of import on their own. History suggests that the governments of importing countries and importers themselves have typically preferred to perform their own tests (Maskus, Wilson and Otsuki, 2000).

For the purpose of this analysis, I adopt a generalized concept of measurement uncertainty for GMO testing. Specifically, I define measurement uncertainty to be the probability of a shipment which through GMO analytical testing at the point of sale (e.g. export port) confirms the absence of certain GM events but fails to reconfirm their absence when testing is repeated at the point of purchase (e.g. point of import) leading to the commercial rejection of the shipment.

Under these circumstances, a number of questions exist. What are the optimal testing strategies for importers in the presence of measurement uncertainty? What information should exporters convey to importers? And what are the factors that can improve the efficiency of their exchange? Game theory has proved a useful tool in the analysis of such questions because it provides a framework to analyze strategies based on the information agents possess and the rewards they receive. For instance, McCluskey (2002) used game theory to analyze the different strategies that are available to consumers and producers of organic foods in the presence imperfect and asymmetric information. Producers could sequentially decide whether to use costly organic production methods or less expensive conventional ones and then whether or not to market and claim their product as organic, even if it was not produced through organic production practices. Since organic foods are credence goods –goods whose quality cannot be ascertain even after they have been consumed- consumers have to decide whether or not to trust producer claims. In this setting, McCluskey concluded that a third party should monitor the claims and that the involvement of government could improve efficiency in the organic market.

The equilibrium strategies for our exporters and importers in the presence of incomplete and asymmetric information can be obtained from a dynamic game of incomplete information. This approach has not been used in this setting before but Abbot et al. (1996) proposed using dynamic games of incomplete information in analyzing trade policy issues when uncertainty is present and the payoff functions for the players in the market change from time to time. The game that we need here is a dynamic or a sequential one because exporters and importers do not act simultaneously. The exporter first provides information about the GM content of the shipment and then the importer decides whether or not to duplicate the test and accept the shipment. Importantly, the later players must have some information on the first player's choice otherwise the difference in time would have no strategic effect. The game should also be of incomplete information as each player’s payoff function (the function which determines the payoff from the combination of actions chosen by players) is not common knowledge to the other player. For this reasons, I will use a dynamic game of incomplete information (Gibbons , 1992; Gardner, 1996) involving two players (one with private information, the other without) and two moves (first a message sent by the informed player, then a response taken by the uninformed player).

For my analysis then I begin with a simple world state where GM crops produced and traded are approved in all the regions of the world (i.e. a world where there are no unapproved events). In this context, I will study the impact of measurement uncertainty as well as the impacts of rejection costs, market premiums and other factors on the equilibrium testing strategies of importers and exporters. Then in Section IV, I will analyze testing strategies and market equilibriums in a more realistic world where there are both approved and unapproved GM crops. Finally, in Section V I will synthesize the results and provide some concluding comments.

III. Testing Strategies & Equilibriums in Commodity and non-GM Markets

As discussed above, I assume here that both conventional and GM crops are grown and that there is demand for both commodity (where GM and conventional crops are commingled) and non-GM crops. I also assume that there are no unapproved GM crops anywhere in the world and hence there are no inherent trade restrictions on GM crops (e.g. trade bans).

Game Description

The game of interest then has two players, an exporter and an importer. There are two exporter types: The first (IP-type) exports identity preserved (IP) non-GM crops and the second (NIP-type) exports commodities whose identity is not preserved (NIP). The term "identity preserved" in this game means that the exporter has managed the supply chain operations and has used analytical GMO testing in order to avoid commingling of non-GM and GM crops. Accordingly, the exporter can certify that an IP shipment "does not contain GMOs" with some degree of certainty. For exporting IP crops the exporter incurs identity preservation costs and testing costs (Bullock, Desquilbet and Nitsi, 2000, Kalaitzandonakes, Maltsbarger and Barnes, 2001; Wilson, Janzen and Dahl, 2003).

Both direct and indirect IP costs are incurred in non-GM IP systems (Kalaitzandonakes, Maltsbarger and Barnes, 2001). Direct IP costs are payable costs and generally result from:

- Coordination and control: Non-GMO IP systems require more market coordination resulting in higher transaction costs. Such costs typically include salaries and wages for sourcing and management personnel, specialized information systems, third party certification fees, and so on.
- Re-engineering of operations: As firms adapt their production and marketing operations for IP, they often incur extra capital, labor and material costs. For instance, farmers incur higher costs from extra labor for equipment cleaning during planting, harvest and storage as well as increased field isolation to prevent pollen flow from adjacent fields. Elevators incur higher costs from extra labor for facility clean outs, and higher testing costs (Lin et al.). In fact, similar reengineering costs are incurred throughout the chain.

Indirect IP costs are mostly implicit costs that result from loss of flexibility; inefficiencies due to underutilization of production, storage, transportation and processing assets; and lost profits (e.g. foregone storage margins and carrying spreads and potential loss of technology benefits from use of GM crops). In this analysis I consider testing costs separately from all other IP costs incurred in IP systems.

To compensate for the added IP and testing costs and generate interest, importers must offer premiums to exporters for the procurement of non-GM IP crops. The premiums offered are reflective of the underlying consumer demand and willingness to pay in the non-GM markets (Parcell, 2001). In my analysis, the premium paid to IP crops are represented net of IP costs (i.e. actual premiums minus IP costs).

Importers in the game are also of two types. The first type tests the shipments and accepts them if they conform to the exporters' certifications, otherwise they reject them. The second type of importer doesn't test the shipment before accepting it. If a shipment is rejected then it is sold at a discount or rerouted to a different market. The game does not go into the details of what happens to a rejected shipment, but only takes into consideration the cost of rejection.

The payoffs of the players are calculated for different strategies and finally an equilibrium strategy is obtained. In this game we focus on a separating equilibrium[1] in which the IP-type exporter certifies that the shipment "does not contain GMOs" and the NIP-type exporter does not provide any such certification. We specifically focus on the possibility of a separating equilibrium in order to examine if there is incentive for the NIP-type exporter to cheat and whether market segmentation of non-GM and commodity markets can be achieved.[2]

Dynamics of the Game

In a situation where the importer has incomplete information about the exporter's type, the IP-type exporter has no incentive to imitate the NIP-type. The NIP-type exporter, however, has an incentive to imitate the IP-type exporter since there is a

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[1] A separating equilibrium is one in which each type of exporter provides a different type of certification (or market signal). The opposite of this one is pooling equilibrium in which both types of exporters provide the same type of certification.

[2] The NIP-type exporter's incentive to cheat is interpreted broadly here. Commodity exporters from countries with broad adoption of GM crops would be unlikely to attempt to sell a commodity shipment in the non-GM IP market. Nevertheless, there might be situations where "soft" (not rigorous) IP procedures maybe followed to minimize IP costs while attempting to obscure any GM crop presence through commingling with other IP non-GM lots. Similarly exporters from countries with little or no adoption of GM crops might attempt to export shipments that have not been specifically segregated or tested on the assumption that GM crops could not be present. Such behavior has occurred in the market and has led to rejections of export shipments (e.g. rice from China and corn and soybeans from Brazil) especially in import markets with strict standards (e.g. the EU).

premium associated with the export of IP non-GM crops. For this scenario, I will derive the Perfect Bayesian Equilibrium (PBE) according to the procedure below:

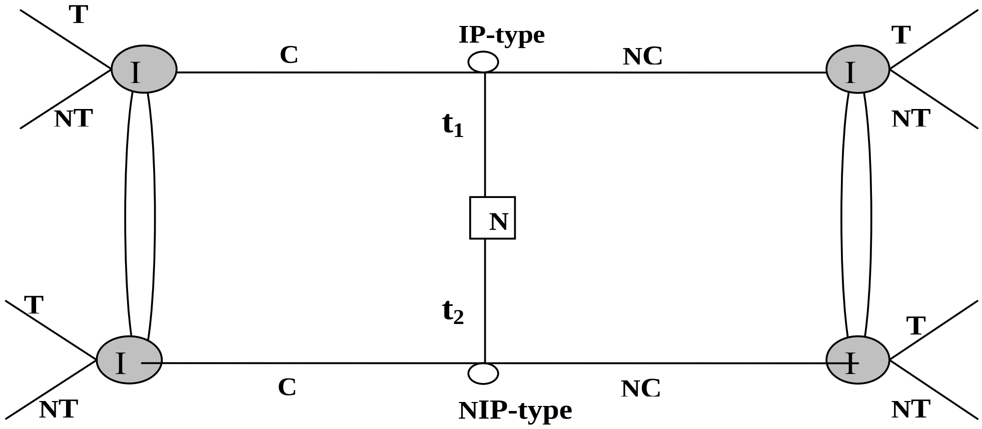
In the dynamic game of incomplete information (see figure1 below), I assume:

- Nature moves first and draws a type t_i for the Exporter from a set of feasible types T = {IP-type, NIP-type} according to a probability distribution $p(t_i)$ where $p(t_i) > 0$ for every i and $p(t_1) + \ldots + p(t_I) = 1$. Therefore p(IP) + p(NIP) = 1.

The exporter observes type t_i and then chooses an action from a set of feasible actions E = {Certification (C), No Certification (NC)}. The action C means that the exporter provides documentation which certifies that the shipment does not contain GMOs. The action NC means the exporter does not provide certification about the presence/absence of GMOs in the shipment.

- The Importer observes E, but not type t_i and then chooses an action from a set of feasible actions F = {test (T), no test (NT)}. (T) implies the importer tests the shipment again and decides whether to accept the shipment or not. If the importer does not accept the shipment, the shipment incurs rejection costs. (NT) suggests that the importer accepts the shipment without testing.

Figure 1: Dynamic Game of Incomplete Information



The probabilities of the shipment passing/failing a GMO test at the points of export and import, the payoff functions for both players, the beliefs for importer according to Bayes' rule and the equilibrium strategies for the exporter and the best response of importer are all derived and presented in A*ppendix I.* Here I discuss the equilibrium conditions and their implications in some detail.

When the dynamic game of incomplete information described above is solved, it shows that a separating equilibrium is possible under the following three conditions:

(i) $\frac{p}{R} > \frac{P(\alpha_I > \alpha_T / \alpha_E \leq \alpha_T)}{P(\alpha_I \leq \alpha_T / \alpha_E \leq \alpha_T)}$

(ii) R >0 and

(iii) $t < [1 - P(q / \alpha_E \leq \alpha_T)](Z_{IP} - Z_{NIP})$ (See appendix for the notations)

In this separating equilibrium, the IP-type exporter certifies that a shipment does not contain GMOs and the NIP-type exporter does not certify the shipment. The best response for the importer is to test only those shipments that claim non-GM status. This suggests that there is no incentive for the NIP-type exporter to cheat through false claims. Finally, the results show that the additional IP costs are borne by IP-type exporters and importers and hence the by the final consumers of non-GM products.

The above separating equilibrium exists only when the three conditions above are satisfied. Condition (i)[3] indicates that the ratio of the probability of rejection over the probability of acceptance of an IP shipment which has been tested and certified by the

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[3] Condition (i) is required to show that the action 'certification' strictly dominates the action 'no certification' for an IP-type exporter. This is possible when the payoffs in equations 1 and 2 are respectively larger than the payoffs in equations 3 and 4 in Appendix I.

exporter should be less than the ratio of the premium paid for a unit of IP crop and the rejection cost per unit of shipment. This condition implies that for any given level of rejection costs, measurement uncertainty in GMO testing should be below a certain limit for the equilibrium to hold. Given the large size of rejection costs relative to the typical IP premiums in non-GM markets, condition (i) implies that the measurement uncertainty in GMO testing should be quite small for the equilibrium to hold and the IP market to exist. It is worth noting that critical values for such measures could be potentially derived in an empirical context from condition (i).

Condition (ii) implies that for a separating equilibrium, there must be positive rejection costs. The existence of positive rejection costs, along with the chance that a shipment would be rejected if analytically tested, discourages the NIP-type exporters to deviate from the equilibrium path and to continue to export commodities.[4]

Condition (iii) suggests that the testing expenses should be less than some fraction of the premium in order for the separating equilibrium to exist. If the testing expenses are large and go beyond a certain limit, there is no incentive for exporting IP non-GM crops and market segmentation weakens.

If conditions (i) through (iii) fail, the separating equilibrium does not exist and a pooling equilibrium may come into existence. A pooling equilibrium in which both types of exporters converge to supply commodities thereby limiting market segmentation.

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[4] In the separating equilibrium of our game, the NIP-type exporter does not certify and receives a payoff which is given in payoff equation 8 in Appendix I. If the NIP-type exporter would deviate from that equilibrium path and attempted to cheat and certify, the importer's beliefs and actions would also change leading to the NIP-type exporter's new payoff equal to that in equation 5 in Appendix I. Because when rejection costs are positive the payoff in equation 8 will be more than the payoff in equation 5, the NIP-type exporter does not have an incentive to deviate from the equilibrium path – which is what condition (ii) determines.

The qualitative inferences from the above equilibrium conditions are quite interesting. For instance, holding all else constant, when relative rejection costs become very large the viability of IP markets diminishes. This suggests that occasional failures in the early stages of the supply chain (e.g. at the elevator) where the rejection cost of a shipment is typically equal to the loss of premium (as the shipment can be easily diverted to the commodity stream) may not be as consequential. However, system failures at the end of the supply chain where shipment sizes are very large (e.g. at the ocean vessel) and relative rejection costs increase exponentially due to large fixed cost charges, even infrequent failure could lead to the collapse of an IP market.

Similarly, since premiums are largely capped by the willingness to pay of a given consumer segment and since failure costs are largely non-negotiable *ex post*, for an IP market to be strengthened measurement uncertainty must be minimized. This result is consistent with observed stakeholder behavior in non-GM markets where exporters and importers for many years have been actively setting private (often bilateral) standards for GM testing and sampling protocols, third party certification schemes for single point testing and in some instance purity thresholds that allow for accidental presence of GM in non-GM IP products.[5] All these private standards would tend to reduce measurement uncertainty from GMO testing in non-GM IP markets and hence strengthen the conditions for a separating equilibrium and market segmentation.

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[5] Unintended or accidental presence of GM crops in non-GM shipments is often called “Adventitious Presence” or AP. AP standards exist not only in bilateral agreements of trading parties in non-GM markets but in many GM mandatory labeling regulations. For instance, the EU’s mandatory labeling regulation allows for up to 0.9% of the content of a non-GM shipment to be GM. Similarly, mandatory labeling in Japan set AP thresholds at 5%. In effect, AP standards define what a “GMO” effectively is.

Finally, the equilibrium conditions from the dynamic game I presented above highlight some inherent tensions in the ways governments have been attempting to set standards seeking to minimize GMO measurement uncertainty and enhance the efficiency of market exchange. For instance, while standardizing sampling procedures along the lines outlined by ISPRA in the EU (EC Recommendation 2004/787, 2004) would tend to reduce measurement uncertainty in GMO testing and could encourage IP markets, they would also tend to increase testing costs exponentially (Kalaitzandonakes, 2006). Condition (iii) clarifies that with capped premiums, such costs increases could more than counter reductions in measurement uncertainty and undercut rather than encourage IP markets.

IV. Testing Strategies in the Presence of Unapproved GM Crops

In this section, I assume a more complete state of the world where certain GM crops are produced in some exporting countries but cannot be traded to some importing countries where they have not yet received regulatory clearance for use. That is, I assume regulatory asynchronicity across countries and hence the presence of unapproved events in international trade. Under these conditions, the best responses of importers and exporters could change relative to those derived in the previous game. Importers and exporters of IP crops continue to avoid all GMOs and hence the presence of unapproved events does not change their practices in a significant way.

The circumstances for exporters and importers in commodity markets, however, change markedly. They must now account for the potential presence of unapproved GM crops in their NIP commodity shipments and prevent their entry to relevant import markets. For this reason they might have to engage in some segregation of crops and GMO testing in order to detect the potential presence of unapproved events and direct them to markets where they can be traded. In this way, commodity importers and exporters are now also exposed to measurement uncertainty associated with the use of GMO tests for unapproved GM crops. In this section, I examine the implications of such changes in the optimal testing strategies of importers and exporters and the equilibrium conditions of IP crop and NIP commodity markets under this new state of the world.

Game Description

This game set up will be similar to the one in section III but with a few important differences. Once again there are two types of exporters: the first type (IP-type) export IP crops whose identity have been preserved through the supply chain and have been tested for the absence of GMOs, including those which are unapproved in some markets. Accordingly, IP crop exporters certify their shipments as "non-GMO." The second type of exporters (NIP-type) export NIP commodities. Because of the presence of unapproved GM crops in some markets they may segregate commodities that are being directed to certain import markets and test them for the presence of unapproved events at incremental marginal costs. In such markets, NIP commodity exporters face not only incremental costs but also measurement uncertainty.

It is assumed that the prices of IP non GM crops are higher than those of NIP commodities by a premium that increases with consumer willingness to pay for non-GM products. As before, the specified premium in IP markets is net of IP costs and hence it increases as such costs decrease.

There are also two types of importers. The first tests the imported shipment before accepting it and the second type does not. Importers who accept shipments that contain unapproved GM crops or IP crops that do not meet certification standards are assumed to incur losses (e.g. due to reputation effects, loss of sales and other factors). The optimal testing strategies of importers are of interest in this study and their derivation within the context of a PBE is detailed in *Appendix II.* As in the previous game, the probabilities of a shipment passing/failing a GMO test at the points of export and import, the payoff functions for both players, the beliefs for importers according to Bayes' rule as well as the equilibrium strategies for the exporters and the best response of importers are all derived and presented in A*ppendix II*. Here, I focus my discussions on the conditions for a separating equilibrium where the market stably segments into an IP non-GM and a commodity market.

Dynamics of the Game

When the dynamic game of incomplete information described above is solved, a separating equilibrium is obtained under the same three general conditions derived in the previous game, namely:

(i) $\frac{p}{R} > \frac{P(\alpha_I > \alpha_T / \alpha_E \leq \alpha_T)}{P(\alpha_I \leq \alpha_T / \alpha_E \leq \alpha_T)}$

(ii) R >0 and

(iii) $t < [1 - P(q / \alpha_E \leq \alpha_T)](Z_{IP} - Z_{NIP})$

This is not surprising since the incentives for the segmentation of the IP crop and commodity markets are similar in both games. The most significant variation in the equilibrium conditions of the two games is that testing costs, IP costs, rejection costs, and measurement uncertainty are different from the previous game as they must now account for any additional effort to segregate and test for the unapproved events as well.

Generally, IP costs, testing costs, and measurement uncertainty should be only marginally different. Since rigorous IP procedures are applied across the supply chain the marginal segregation and testing for additional GM events should be relatively low. The rejection costs in the second game, however, can be drastically different. The rejection costs of any shipment which tests positive for unapproved events at the point of import will be much higher than the typical rejection costs considered in the previous game. This is because the salvage value of such shipments is zero since they are illegal and cannot be sold at any price in the specific market. Hence, they must either be destroyed or redirected to a different market, typically at great cost (Lin et al., 2003). If conditions (i) through (iii) do not hold the separating equilibrium does not exist and a pooling equilibrium may come into existence where both types of exporters converge to export commodities.

While the separating equilibrium conditions are similar in the first and second game the optimal testing strategies are not. The best response for the importers in this game is to test all the shipments whether they carry certification or not. Those who import shipments of IP crops test them for the presence of all GMOs whereas those importing commodities with no certification test the shipments for the presence of unapproved GM crops only. Accordingly there is no incentive for the NIP-type exporters to cheat by falsely claiming the absence of unapproved events. Since the best strategy of the importers is to test all commodity imports for unapproved GM crops, higher risks of rejection would exist. It is therefore in the interest of the NIP exporters to segregate and test relevant commodity streams in order to minimize the risk of exporting unapproved GM crops. Even so, because of measurement uncertainty there is still a chance that commodity shipments could be rejected. Under these circumstances the following condition must hold:

$$\text{(iv)} \qquad \frac{\Pi^{e}_{NIP}}{C_{NIP}+R} > \frac{P(\alpha^{U}_{I} > \alpha^{U}_{T} / \alpha^{U}_{E} \leq \alpha^{U}_{T})}{P(\alpha^{U}_{I} \leq \alpha^{U}_{T} / \alpha^{U}_{E} \leq \alpha^{U}_{T})}$$

Condition (iv) implies that the ratio of the probability of rejection over the probability of acceptance of a NIP shipment that has been tested for unapproved events at the point of export must be less than the ratio of the exporters' profit over the sum of marginal production and rejection cost per unit of NIP commodity.

Since there is no premium in NIP commodity shipments the above condition highlights that as the costs for segregating and testing for unapproved events increase the ability of commodity exporters to pass such costs onto importers is critical. In competitive import markets with alternative NIP suppliers and/or close substitute products, NIP exporters from countries producing unapproved GM crops would likely find it difficult to absorb the incremental segregation, testing and potential rejection costs and could exit the market. In import markets where NIP exporters have some market power, they might be able to increase their prices to reflect the incremental costs and uncertainty in commodity exports.

As in the IP market, the potential rejection costs of any shipment which tests positive for unapproved events at the point of import are very high due to the lack of salvage value and high destruction or redirection costs. Given condition (iv), the increased levels of potential rejection costs and the possible lack of premium to cover the segregation and testing costs for unapproved GM crops suggest that the very existence of commodity exports in the presence of measurement uncertainty from unapproved events may be quite tenuous. As measurement uncertainty increases (e.g. because of increased level of adoption of an unapproved GM crops or because of an increased number of unapproved GM crops are used) there might be a limit where commodity exports cease. This is consistent with market conditions observed in certain international trade flows confronted with the presence of unapproved events.

Consider the EU corn gluten market as an example. Corn gluten is a co-product of the corn wet milling industry and a moderately high source of protein used in ruminant feeds, pet foods, poultry and swine. Historically, US corn gluten feed exports to the EU have been fairly stable. Roughly 5 million MT valued at almost $0.5 billion were being exported from the US to the EU in the late 1990s according to data from the US Commerce Department. By 2007 US gluten feed exports to EU had fallen to under 0.6 million MT, or almost 10% of the normal level of exports. Much of the deterioration in the US exports owes to the production of GM crops in the US which were not approved for use in the EU, first the Bt10 event and subsequently the DAS-59122-7 or Herculex event. The first significant drop in US exports of corn gluten feed occurred in 2005 when the EU began requesting certificates assuring the absence of Bt 10 in corn gluten shipments. Then in 2007, three separate US cargoes which had tested negative for Herculex in the US tested positive upon arrival in EU ports and led to a 40% drop in US exports within the year. A large portion of the relatively small US corn gluten exports to the EU now are directed to the IP non-GM market.

V. Synthesis of the Results and Concluding Comments

A number of conclusions can be drawn from the preceding analysis about the impacts of measurement uncertainty in GMO testing on the behavior of importers and exporters in IP non-GM and in commodity markets. While GMOs are credence goods (Giannakas and Fulton, 2002) their presence can be analytically tested and hence informational asymmetries as in McCluskey (2000) do not arise. Similarly, while there are markets where IP non-GM crops receive premium prices, asymmetries between buyers and sellers do not result in "markets for lemons" because of the availability of analytical testing. But while analytical GMO testing limits certain informational asymmetries it also involves measurement uncertainty which also affects behavior. In this context, dynamic games of incomplete information as those I have used in this analysis are useful for examining the behavior of importers and exporters and the various factors that might affect the efficiency and performance of their exchanges.

The first general result from my analysis is that not all GMO measurement uncertainties are created equal. Measurement uncertainty for approved GMOs affects the IP non-GM markets alone but measurement uncertainty for unapproved GMO events affects all markets, imposes larger rejection costs and can deter even commodity trade. Hence, the potential deadweight loss associated with the increased costs, higher prices or potential loss of exchange from measurement uncertainties in GMO testing created from the presence of unapproved events in the market is generally more significant.

My analysis also indicates that the relative size of IP, segregation, testing and rejection costs, the premiums offered in the IP markets and measurement uncertainty all have direct impacts on the emergence of separating equilibriums and their stability. Yet, these figures tend to vary from one supply chain to another; they vary by crop and region; they vary with underlying supply and demand conditions; and they often influence one another. For instance, the more stringent the IP procedures are the higher the IP costs and the lower measurement uncertainty would tend to be (Kalaitzandonakes, Maltsbarger and Barnes, 2001). Similarly, the more extensive testing is performed (i.e. more samples taken, at more points of exchange in the supply chain), the higher the testing costs and the lower the measurement uncertainty would tend to be (Wilson, Dahl and Jabs, 2007).

Because of this link between IP effort, costs and measurement uncertainty, my analysis shows that when IP and testing costs increase in IP crop markets, the separating equilibriums and the market segmentation become more robust.[6] This result, however, holds only when IP premiums increase as well.[7] Hence, when IP exporters have market power and/or when consumer willingness to pay for non-GMO products (Lusk et al., 2005, Noussair et al., 2004, Matsumoto, 2006) is high, market segmentation is strengthened. When premiums are not responsive or capped at low levels, then increasing IP and testing costs make the market segmentation weak. Hence, under certain market conditions strategies that seek to strengthen the presence of IP non-GM markets by

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[6] From the payoff functions 1 and 3 of the I-type exporter in appendix II, it follows that as the marginal cost of IP-type exporter (C_I) increases due to an increase in identity preservation and testing costs, the probability that the shipment is accepted at both the point of import and export increases as the measurement uncertainty is reduced. Under these conditions the payoff of the IP-type exporter who certifies the shipment as ‘does not contain GMOs’ increase and the payoff of the IP-type exporter who does not certify the shipment is reduced suggesting that the separating equilibrium becomes more robust.

[7] We can examine the impact of the premium received by IP crops on the equilibrium by analyzing the condition (given in footnote 10, Appendix II) that should be satisfied in order for ‘Certification(C)’ to dominate the ‘No Certification (NC)’strategy. From this analysis I can infer that as the premium decreases the equilibrium becomes weaker and as the premium approaches zero the equilibrium no longer stands. On the other hand, if the premium for IP non-GM crops increases, the equilibrium becomes more robust.

reducing measurement uncertainty via expanded sampling regimes (e.g. Paoletti et al., 2006) could in fact have the opposite effect.

Alternatively, technical solutions like standardization of GMO testing methods and protocols which would tend to reduce measurement uncertainty without increasing the variable costs of IP and commodity markets. Based on the results of my analysis, these would tend to universally improve market separation, trade and the overall efficiency of market exchange. Achieving standardization of GMO testing methods and protocols appears difficult for the moment as numerous technical issues remain and there is no obvious international forum/organization to facilitate adoption of such standards could be imposed through industry or government action. In the absence of imminent standardization, some governments have resorted to certifying the accuracy of laboratories through GMO ring trials while reporting the size of measurement uncertainty in those trials to increase market transparency about relevant exchange risks (e.g. see USDA/GIPSA Proficiency Program and the International Seed Testing Association Proficiency Test Program).

A number of private and public institutional arrangements have also been considered for managing GMO testing measurement uncertainty and reducing market inefficiency. Private institutional arrangements include use of insurance schemes and third party certification systems (Golan, Kuchler and Mitchell, 2000). With such arrangements measurement uncertainty is typically not reduced. Instead, risks are shared at some cost to facilitate trade. The results of my analysis therefore suggest that depending on the amount of uncertainty absorbed by third parties and the level of the added costs, these private institutional arrangements may or may not have much of an impact in the market. While third party certification services are actively offered by GMO testing and other certification firms, insurance schemes that pool rejection risks and spread associated costs have so far proven difficult to establish.

A few government policies have also been proposed for improving market efficiency in the presence of GMO testing measurement uncertainty, chief among them the use of adventitious presence (AP) thresholds. As AP thresholds increase, measurement uncertainty as well as IP and testing costs would tend to decline (Kalaitzandonakes and Magnier, 2004). Based on my analysis, these effects would tend to universally improve market segmentation, trade and the overall efficiency of market exchange. While such policies would tend to improve market efficiency for non-GM markets, they would likely have little impact in the case of unapproved events as AP allowances for unapproved event are not typically made (often referred to as “zero tolerance standard”). Based on my analysis, this suggests that the most significant source of market instability would likely be removed only through synchronicity in the regulatory approvals of new GM events across all major markets. Alternatively, self-imposed restraints by innovators stopping short of introducing unapproved events in the market may also achieve the same outcome. In all, my analysis provides a framework for examining in a structured fashion the incentives, tensions, and relative effectiveness of alternative technical, institutional and market solutions to the problem of measurement uncertainty in GMO testing and its impacts on trade.

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Appendix I

In this Appendix, I derive a separating equilibrium for a game where I assume there are no unapproved events in international commodity markets. The notations and assumptions as well as the payoff functions of the exporters and importers are presented first. In the second part of this section, I present the conditions necessary for a separating equilibrium.

Notations and Assumptions:

Notations

- P_{IP} = Price paid to the exporter for each unit of IP crop
- P_{NIP} = Price paid to the exporter for each unit of NIP commodity. Since identity preservation systems are costly to operate and exporters need be to be compensated accordingly, I assume that $P_{IP} > P_{NIP}$. Accordingly, the premium p paid for the IP crop is p= $P_{IP} - P_{NIP}$
- Z_{IP} = Price paid by the end user in the importing country for each unit of IP crop.
- Z_{NIP} = Price paid by the end user in the importing country for each unit of NIP commodity.
- C_{IP} = Marginal cost to produce and identity preserve each unit of IP crop
- C_{NIP} = Marginal cost to produce each unit of NIP commodity. Since identity preservation system incurs costs to operate, we assume $C_{IP} > C_{NIP}$
- R = Rejection cost of a shipment is rejected at point of import
- t = Testing cost per unit of crop

- $\Pi_{IP}^{m} = Z_{IP} - P_{IP}$ = Importer's profit when a unit of IP crop is imported and sold to the end user
- $\Pi_{NIP}^{m} = Z_{NIP} - P_{NIP}$ = Importer's profit when a unit of commodity whose identity is not preserved (NIP) is imported and sold to the end user
- $\Pi_{IP}^{e} = P_{IP} - C_{IP}$ = Exporter's profit when a unit of IP crop is exported.
- $\Pi_{NIP}^{e} = P_{NIP} - C_{NIP}$ = Exporter's profit when a unit of NIP commodity is exported.

Probabilities of the shipment getting passed in the tests at the point of import and export:

- α_E = GMO content of shipment (% of total) at point of export
- α_I = GMO content of shipment (% of total) measured at point of import
- α_T = Threshold limit below which the shipment is "non-GM"
- Probability that the shipment of IP crop passes the test at point of export $= P(\alpha_E \leq \alpha_T)$
- Probability that the shipment of NIP commodity passes the test at point of import $= P(\alpha_I \leq \alpha_T)$
- Probability that the shipment of IP crop fails the test at the point of export = $1 - P(\alpha_E \leq \alpha_T) = P(\alpha_E > \alpha_T)$
- Probability that the shipment of NIP commodity fails the test at point of export = $1 - P(\alpha_I \leq \alpha_T) = P(\alpha_I > \alpha_T)$
- Probability that the shipment of IP crop passes the test at the point of import given that it had passed the test at the point of export $P(\alpha_I \leq \alpha_T / \alpha_E \leq \alpha_T)$

- Probability that the shipment of IP crop does not pass the test at the point of import given that it had passed the test at the point of export $P(\alpha_I > \alpha_T / \alpha_E \leq \alpha_T)$
- Probability that the importer gets IP crop given that he does not test the shipment and that the shipment has passed the test at point of export = $P(q / \alpha_E \leq \alpha_T)$
- Probability that the importer does not get IP crop given that he does not test the shipment and that the shipment has passed the test at point of export = $1 - P(q / \alpha_E \leq \alpha_T)$

Payoffs for the exporter:

In the following payoff functions, IP denoted that the crop has been identity-preserved by the exporter; NIP indicates that the commodity has not been identity preserved; C indicates that the exporter provides “non-GMO” certification; NC that the exporter provides no certification; T that the importer tests the shipment while NT denotes that the importer does not test the shipment.

1. IP crop, certification from the exporter and testing by the importer:

$$Y_E(IP, C, T) = [P(\alpha_I \leq \alpha_T / \alpha_E \leq \alpha_T)(P_{IP} - C_{IP}) + P(\alpha_I > \alpha_T / \alpha_E \leq \alpha_T)(P_{NIP} - C_{IP} - R\ )]$$

The first part of the above equation denotes the payoff of the exporter when the shipment passes the test both at the point of import and export. The second part of the payoff indicates that when the importer rejects the shipment, the exporter gets paid the price of the NIP commodity (salvage value) although he incurs identity preservation costs C_{IP}. In this last situation, the exporter also incurs separate rejection costs (R) for finding another buyer, rerouting expenses, etc.

1. IP crop, certification from the exporter and no testing by the importer:

$$Y_E(IP, C, NT) = P_{IP} - C_{IP} = \Pi^e_{IP}$$

The importer does not test the shipment and trusts the claim of the exporter. Accordingly, the exporter receives the price of IP crop but also incurs the cost of identity preservation.

2. IP crop, no certification by the exporter and testing by the importer:

$$Y_E(IP, NC, T) = P_{NIP} - C_{IP} = \Pi^e_{IP} - p$$

The exporter does not certify the shipment even though it has been identity preserved, the importer tests the shipment and pays P_{NIP} (i.e., “even if he gets IP crop”).

3. IP crop, no certification from the exporter and no testing by the importer:

$$Y_E(IP, NC, NT) = P_{NIP} - C_{IP} = \Pi^e_{IP} - p$$

4. NIP commodity, certification by the exporter and testing by the importer:

$$Y_E(NIP, C, T) = P_{NIP} - C_{NIP} - R = \Pi^e_{NIP} - R$$

In this case, the exporter does not ship the IP commodity but attempts to cheat and certifies the shipment as IP crop. The importer tests the shipment and pays the exporter according to the test results.

5. NIP commodity, certification by the exporter and no testing by the importer:

$$Y_E(NIP, C, NT) = P_{IP} - C_{NIP} = \Pi^e_{NIP} + p$$

The exporter cheats and claims that the shipment is IP crop and the importer pays the price of IP crop without testing the shipment.

6. NIP commodity, no certification by the exporter and testing by the importer:

$$Y_E(NIP, NC, T) = P_{NIP} - C_{NIP} = \Pi^e_{NIP}$$

The importer tests the shipment but pays the price of the NIP commodity.

8. NIP commodity, no certification by the exporter and no testing by the importer:

$$Y_E(NIP, NC, NT) = P_{NIP} - C_{NIP} = \Pi^e_{NIP}$$

The importer does not test the shipment and pays accordingly.

Payoffs for the importer:

9. IP crop, certification from the exporter and testing by the importer:

$$Y_M(IP, C, T) = [P(\alpha_I \le \alpha_T / \alpha_E \le \alpha_T)(Z_{IP} - P_{IP} - t) - P(\alpha_I > \alpha_T / \alpha_E \le \alpha_T)(t)]$$
$$= [P(\alpha_I \le \alpha_T / \alpha_E \le \alpha_T)(\Pi^m_{IP})] - t$$

In case the shipment passes the test, the importer can sell at the price of IP crop but still incurs the testing expenses. The second part of this payoff function shows that the importer incurs only the testing expenditure when he does not accept the shipment.

10. IP crop, certification from the exporter and no testing by the importer:

$$Y_M(IP, C, NT) = [P(q / \alpha_E \le \alpha_T)(\Pi^m_{IP}) + (1 - P(q / \alpha_E \le \alpha_T))(\Pi^m_{NIP} - p)]$$

The importer does not test and accepts the shipment as certified. In the case the exporter cheats or erroneously certifies the shipment as “non-GMO” the importer pays P_{IP} but can sell the shipment to the end user only at Z_{NIP}.

11. IP crop, no certification from the exporter and testing by the importer:

$$Y_M(IP, NC, T) = [P(\alpha_I \le \alpha_T / \alpha_E \le \alpha_T)(\Pi^m_{IP} - p - t) + P(\alpha_I > \alpha_T / \alpha_E \le \alpha_T)(\Pi^m_{NIP} - t)]$$

The importer tests the shipment even though the exporter provides no certification. The first part of the equation indicates the importer pays P_{NI} and sells at price Z_{IP}. The second part of the equation indicates that the importer does not reject the shipment if it fails the test and pays P_{NIP}.

12. IP crop, no certification from the exporter and no testing by the importer:

$$Y_M(IP, NC, NT) = [P(q / \alpha_E \leq \alpha_T)(\Pi_{IP}^m + p) + (1 - P(q / \alpha_E \leq \alpha_T)\Pi_{NIP}^m]$$

The importer does not test the shipment and pays P_{NIP} for the non-certified shipment.

13. NIP commodity, certification from the exporter and testing by the importer:

$$Y_M(NIP, C, T) = -t$$

The exporter falsely claims the shipment to be IP crop. The importer tests the shipment and rejects it. The importer incurs the testing expenditure.

14. NIP commodity, certification from the exporter and no testing by the importer:

$$Y_M(NIP, C, NT) = Z_{NIP} - P_{IP} = \Pi_{IP}^m - p$$

The importer pays P_I for the commodity since the exporter provides certification and the importer does not perform any test. However, the chance that the importer obtains IP crop is nil and he gets paid for NIP commodity by the end user.

15. NIP commodity, no certification from the exporter and testing by the importer:

$$Y_M(NIP, NC, T) = Z_{NIP} - P_{NIP} - t = \Pi_{NIP}^M - t$$

The importer tests the shipment even though the exporter sends the true signal about the shipment. The importer incurs the testing expenditure, but the chance of getting IP crop is nil.

16. NIP commodity, no certification from the exporter and no testing by the importer:

$$Y_M(NIP, NC, NT) = Z_{NIP} - P_{NIP} = \Pi_{NIP}^m$$

The importer pays P_{NIP} and there is no chance that the commodity is IP crop.

Finding a Separating Perfect Bayesian Equilibrium (PBE)

In a separating PBE, each type of player chooses a different strategy so that his type can be perfectly identified by the strategy he uses. If all types of players use the same strategy then it is a pooling equilibrium. We identify a PBE for our game by following the steps below.

- Assign a strategy to each type of Exporter
- Derive beliefs of Importer according to Bayes' rule for each information set reached with positive profitability along the equilibrium path. Set arbitrary beliefs for Importer for information sets that are never reached along the equilibrium path.
- Determine the Importer's best response.
- In view of Importer's response, check to see whether the Exporter has an incentive to deviate from the strategy assigned in any state of the world (i.e, any type). If the Exporter does not deviate, then it a separating PBE.

Assignment of strategies and derivation of the beliefs

In the context of our game, there are only two possibilities for separating strategies for the Exporter. One possibility is that the IP-type Exporter chooses C and NIP-type Exporter chooses NC. The second possibility is that the IP-type Exporter chooses NC and NIP-type Exporter chooses C. But in our case C strictly dominates NC[8]

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[8] The following condition should be satisfied $\frac{p}{R} > \frac{P(\alpha_I > \alpha_T / \alpha_E \leq \alpha_T)}{P(\alpha_I \leq \alpha_T / \alpha_E \leq \alpha_T)}$ in order for Payoff 1 to be greater than Payoff 3. From the above condition, the ratio of probability of acceptance and probability of rejection of an IP crop shipment given it has already been tested by the exporter should be less than the

for IP-type exporter[9] so if a separating PBE exists then the IP-type Exporter will systematically play C while the NIP-type Exporter will systematically play NC. We can therefore specify the rational belief of the importer:

$$\sigma_E\,(t) = \begin{cases} \text{C if type = IP} \\ \text{NC if type = NIP} \end{cases}$$

Now let $\mu\ (t_i\ /\ A)$ be the probability that the Importer assigns to type i after observing action A.

If Importer observes that the Exporter chooses C, he assigns probability 1 to type IP. If he observes Exporter choosing NC, he assigns probability 1 to type NIP. These beliefs are consistent with Bayes' rule for both information sets that are reached with positive probability along the equilibrium path.

To simplify, I assume that the probabilities of IP-type, and NIP-type exporters are equal[10] so: P (IP) = P (NIP) = 1/2.

We just established that,

$$P(C\ /\ IP) = 1 \qquad\qquad P\ (NC\ /\ IP) = 0$$

$$P(C\ /\ NIP) = 0 \qquad\qquad P\ (NC\ /\ NIP) = 1$$

So by applying Bayes' theorem, we obtain

$$\mu\ (IP\ /\ C)^{11} = 1 \qquad\qquad \mu\ (NIP\ /\ C) = 0$$

$$\mu\ (IP\ /\ NC) = 0 \qquad\qquad \mu\ (NIP\ /\ NC) = 1$$

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ratio of premium for a unit of IP crop and rejection costs per unit of shipment. Payoff 2 is greater than Payoff 4 by an amount equal to the premium for I-type crop. From these two results we can conclude that C strictly dominates NC.

[9] We can prove that Payoffs 1 and 2 are respectively greater than Payoffs 3 and 4.

[10] Even if the probabilities are not equal, the results do not change when we apply Bayes' theorem.

[11] By applying Bayes' theorem, we get:

$$\mu(IP/C) = \frac{P(C/IP)P(C)}{P(C)} = \frac{P(C/IP)P(I)}{P(C/IP)P(IP) + P(C/NIP)P(NIP)} = \frac{1(0.5)}{1(0.5) + 0(0.5)} = 1$$

Best Response for Importer:

When Exporter chooses C:

- The Importer’s expected profit from choosing (T) in response to Exporter choosing (C) is:

  EU_I (T, C) = μ (IP / C) * Y_M(T, C; IP) + μ (NIP / C) * Y_M (T, C; NIP) =

  $$[P(\alpha_I \le \alpha_T / \alpha_E \le \alpha_T)(\Pi_{IP}^m - t) - P(\alpha_I > \alpha_T / \alpha_E \le \alpha_T)(t)] = \Pi_{IP}^m - t$$

This payoff function can be also written as $\Pi_I^m - t$ as the importer receives the profit of IP-type shipment from a replacement shipment if the first fails the test. So, with a probability of 1, he receives the profit of IP-type crop and incurs testing expenses with the same probability.

- The Importer’s expected profit from choosing (NT) in response to Exporter choosing (C) is:

  EU_I (NT, C) = μ (IP / C) * Y_M (NT, C; IP) + μ (NIP/ C) * Y_M (NT, C; NIP) =

  $[P(q / \alpha_E \le \alpha_T)(\Pi_{IP}^m) + (1 - P(q / \alpha_E \le \alpha_T))(\Pi_{NIP}^m - p)]$

From expected profit derived above we obtain the first condition for a PBE to hold:

EU_I (T, C) > EU_I (NT, C) if $t < [1 - P(q / \alpha_E \le \alpha_T)](Z_{IP} - Z_{NIP})$ So the best response of the importer if the exporter chooses to certify is **BR_I (C) = T**.

When Exporter chooses NC:

- The Importer’s expected profit from choosing (T) in response to Exporter choosing (NC) is:

EU_I (T, NC) = μ (IP/ NC) * Y_M (T, NC; IP) + μ (NIP / NC) * Y_M (T, NC; NIP) = $\Pi^m_{NIP} - t$

- The Importer's expected profit from choosing (NT) in response to Exporter choosing (NC) is:

  EU_I (NT, NC) = μ (IP / NC) * Y_M (NT, NC; IP) + μ (NIP / NC) * Y_M (NT, NC; NIP) = Π^m_{NIP}

We readily obtain that EU_I (NT, MC) > EU_I (T, MC) as there is no additional benefit of testing the shipment by the importer. The importer is left with the same kind of the commodity whether or not he tests the shipment. Consequently 'testing' is not a best response and the best response of Importer, if Exporter chooses NC = **BR_I (NC) = NT**.

Checking deviations

We can confirm that the equilibrium is a PBE only if neither type of Exporter has an incentive to deviate. We know that IP-type Exporter will not deviate as C strictly dominates NC. The NIP-type Exporter follows the assigned strategy as long as the payoff it yields is at least as high as the one he would get if he deviated.

In our case, the NIP-type's payoff along the equilibrium path is Π^e_{NIP} . If he deviated and choose C instead of NC, the Importer would choose T since his beliefs continue to be as above. Therefore, if R>0, the payoff of Exporter of type NIP from deviating is $Y_E(NI,C,T) = \Pi^e_{NIP} - R$, which is smaller than the payoff from following the equilibrium.

In the situation when neither type of exporter deviates, it can be proved that there exists a ***separating PBE***,[12] which is as follows:

$$\sigma_E\,(t) = \begin{cases} C, & \text{if type} = IP \\ NC, & \text{if type} = NIP \end{cases}$$

$$\sigma_I\,(E, \mu\,(E)) = \begin{cases} \text{Test}, & \text{if } E = C \\ \text{No Test}, & \text{if } E = NC \end{cases}$$

Note 1: The game was also checked for the existence of a pooling equilibrium (i.e. both the types of exporters will be choosing C), but no such equilibrium was found on the basis of the conditions derived.

Note 2: Even if a third type of exporter, e.g., who exports a substitute commodity was added to the game, there will be no change in the results shown above.

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[12] Given the following three conditions: (i) $\frac{p}{R} > \frac{P(\alpha_I > \alpha_T / \alpha_E \le \alpha_T)}{P(\alpha_I \le \alpha_T / \alpha_E \le \alpha_T)}$

(ii) R>0 and (iii) $t < [1 - P(q / \alpha_E \le \alpha_T)](Z_{IP} - Z_{NIP})$

Appendix II

In this game I derive a separating equilibrium for a state of the world where there are unapproved events—GMOs grown in the exporting country which are unapproved in the importing country. I first provide relevant notations and assumptions followed by the payoff functions of all the types of exporters and importers. Next, I present the derivation of separating equilibrium.

Notations and Assumptions:

Notations

- P_{IP} = Price paid to the exporter for each unit of IP crop
- P_{NIP} = Price paid to the exporter for each unit of NIP commodity. with $P_{IP} > P_{NIP}$ and with the premium p paid for the IP crop equates to p= $P_{IP} - P_{NIP}$
- Z_{IP} = Price paid to by the end user of IP crop
- Z_{NIP} = Price paid to the end user of NIP commodity
- C_{IP} = Marginal cost to produce and identity preserve each unit of IP crop
- C_{NIP} = Marginal cost to produce each unit of NIP commodity. Since identity preservation systems are costly to operate, I assume $C_{IP} > C_{NIP}$
- R = Rejection costs for each shipment
- t = Testing cost per unit of commodity
- $\Pi_{IP}^{m} = Z_{IP} - P_{IP}$ = Importer's profit when a unit of IP crop is imported and sold to end user
- $\Pi_{NIP}^{m} = Z_{NIP} - P_{NIP}$ = Importer's profit when a unit of NIP commodity is imported and sold to the end user.

- $\Pi^e_{IP} = P_{IP} - C_{IP}$ = Exporter's profit when a unit of IP crop is exported
- $\Pi^e_{NIP} = P_{NIP} - C_{NIP}$ = Exporter's profit when a unit of NIP commodity is exported

Probabilities of the shipment getting passed in the tests at the point of import and export:

- α_E = GMO content of shipment (% of total) at point of export
- α_I = GMO content of shipment (% of total) at point of import
- α_T = Threshold limit below which the shipment is "non-GM"
- α_I^U = Unapproved GMO content of shipment (% of total) at point of import
- α_E^U = Unapproved GMO content of shipment (% of total) at point of export
- α_T^U = Threshold limit of the unapproved events
- Probability that α shipment of IP crop passes the test at point of export $= P(\alpha_E \leq \alpha_T)$
- Probability that α shipment of NIP commodity passes the test at point of import $= P(\alpha_I \leq \alpha_T)$
- Probability that α shipment of IP crop does not pass the test at point of export = $1 - P(\alpha_E \leq \alpha_T) = P(\alpha_E > \alpha_T)$
- Probability that α shipment of NIP commodity does not pass the test at point of export = $1 - P(\alpha_I \leq \alpha_T) = P(\alpha_I > \alpha_T)$
- Probability that α shipment of IP crop passes the test at the point of import given that it had passed the test at the point of export $P(\alpha_I \leq \alpha_T / \alpha_E \leq \alpha_T)$

- Probability that *α* shipment of IP crop does not pass the test at the point of import given that it had passed the test at the point of export $P(\alpha_I > \alpha_T / \alpha_E \leq \alpha_T)$
- Probability that the importer IP crop given that he does not test the shipment and that the shipment has passed the test at point of export = $P(q / \alpha_E \leq \alpha_T)$
- Probability that the importer does not get IP crop given that he does not test the shipment and that the shipment has passed the test at point of export = $1 - P(q / \alpha_E \leq \alpha_T)$
- Probability of the shipment does not pass the test for unapproved events at the point of export = $1 - P(\alpha_E^U \leq \alpha_T^U) = P(\alpha_E^U > \alpha_T^U)$
- Probability that shipment is tested for unapproved events only and is accepted by the importer, (i.e., the shipment has passed the test at both the points of import and export) = $P(\alpha_I^U \leq \alpha_T^U / \alpha_E^U \leq \alpha_T^U)$
- Probability of the shipment does not pass the test for unapproved events at the point of import = $1 - P(\alpha_I^U \leq \alpha_T^U) = P(\alpha_I^U > \alpha_T^U)$
- Probability that shipment is tested for unapproved events and is not accepted by the importer (i.e., the shipment has failed the test at the point of import, even though it passed at the point of export) = $P(\alpha_I^U > \alpha_T^U / \alpha_E^U \leq \alpha_T^U)$
- Probability that the importer gets shipment without unapproved events even if he does not test the shipment which however has passed the test at the point of export = $P(q / \alpha_E^U \leq \alpha_T^U)$

- Probability that the importer does not get shipment without unapproved events if he does not test the shipment but it has passed the test at point of export = $1 - P(q / \alpha_E^U \leq \alpha_T^U)$

Payoffs for the exporter:

The following payoff functions are relevant for this game:

1. IP crop, certification from the exporter and testing by the importer:

$$Y_E(IP, C, T) = [P(\alpha_I \leq \alpha_T / \alpha_E \leq \alpha_T)(P_{IP} - C_{IP}) + P(\alpha_I > \alpha_T / \alpha_E \leq \alpha_T)(P_{NIP} - C_{IP} - R\ )]$$

The first part of the function denotes the payoff of the exporter when the shipment passes the test at both the points of import and export. The second part of the payoff indicates that when the importer rejects the shipment, the exporter gets paid the NIP commodity price even though he incurs identity preservation costs C_I. In this last situation, the exporter also incurs rejection costs (R) for finding another buyer, rerouting expenses, etc.

2. IP crop, certification from the exporter and no testing by the importer:

$$Y_E(IP, C, NT) = P_{IP} - C_{IP} = \Pi_{IP}^e$$

The importer does not test the shipment and trusts the claim of the exporter. Accordingly, the exporter receives the price of IP crop and incurs the cost of identity preservation.

3. IP crop, no certification by from exporter and testing by the importer:

$$Y_E(IP, NC, T) = P_{NIP} - C_{IP} = \Pi_{IP}^e - p$$

The exporter does not certify the shipment even though it has been identity preserved and the importer tests the shipment and pays only P_{NI} even if as he receives IP shipment.

1. IP crop, no certification from the exporter and no testing by the importer:

$$Y_E(IP, NC, NT) = P_{NIP} - C_{IP} = \Pi_{IP}^{e} - p$$

Same as above from the exporter's perspective except that the importer does not test the shipment.

2. NIP commodity, certification by the exporter and testing by the importer:

$$Y_E(NIP, C, T) = P_{NIP} - C_{NIP} - R = \Pi_{NIP}^{e} - R$$

The exporter does not ship the IP crop but attempts to cheat and certifies the shipment as IP crop. The importer tests the shipment and rejects it leading to rejection costs for the exporter. The chances of importer receiving IP crop are nil.

3. NIP commodity, certification by the exporter and no testing by the importer:

$$Y_E(NIP, C, NT) = P_{IP} - C_{NIP} = \Pi_{NIP}^{e} + p$$

The exporter cheats and claims that the shipment is IP crop and the importer pays the IP premium without testing the shipment.

4. NIP commodity, no certification by the exporter and testing by the importer:

$$Y_E(NIP, NC, T) = [P(\alpha_I^U \le \alpha_T^U / \alpha_E^U \le \alpha_T^U)(P_{NIP} - C_{NIP}) + P(\alpha_I^U > \alpha_T^U / \alpha_E^U \le \alpha_T^U)(P_{NIP} - C_{NIP} - R)]$$

The exporter segregates and tests the shipment for the presence of unapproved events. He exports the shipment on the belief it does not contain unapproved events but does not certify it as IP crop. The exporter bears the costs of rejection in the case that the importer tests the shipment and finds unapproved events.

8. NIP commodity, no certification by the exporter and no testing by the importer:

$$Y_E(NI, NC, NT) = P_{NIP} - C_{NIP} = \Pi^e_{NIP}$$

The importer does not test the shipment and pays accordingly.

Payoffs for the importer:

9. IP crop, certification from the exporter and testing by the importer:

$$Y_M(IP, C, T) = [P(\alpha_I \leq \alpha_T / \alpha_E \leq \alpha_T)(Z_{IP} - P_{IP} - t) - P(\alpha_I > \alpha_T / \alpha_E \leq \alpha_T)(t)]$$
$$= [P(\alpha_I \leq \alpha_T / \alpha_E \leq \alpha_T)(\Pi^m_{IP})] - t$$

In case the shipment passes the test, the importer can sell at the price of IP crop and incurs testing expenses. However (as the second part of this payoff function shows) the importer incurs only the testing expenditure when he does not accept the shipment.

10. IP crop, certification from the exporter and no testing by the importer:

$$Y_M(IP, C, NT) = [P(q / \alpha_E \leq \alpha_T)(\Pi^m_{IP}) + (1 - P(q / \alpha_E \leq \alpha_T))(\Pi^m_{NIP} - p)]$$

Since the importer accepts the shipment without testing, he may receive an IP crop only with some probability. When he does not test (as the second part of the payoff function shows) the importer pays P_I but can sell to the end user only at Z_{NI}.

11. IP crop, no certification from the exporter and testing by the importer:

$$Y_M(IP, NC, T) = [P(\alpha_I \leq \alpha_T / \alpha_E \leq \alpha_T)(\Pi^m_{IP} - p - t) + P(\alpha_I > \alpha_T / \alpha_E \leq \alpha_T)(\Pi^m_{NIP} - t)]$$

In this case, the importer tests the shipment even though the exporter provides no certification. The first part of the equation indicates the importer pays P_{NI} and sells the commodity at price Z_I to the end user even when the commodity passes the test. The second part of the equation indicates that the importer does not reject the shipment if it fails the test and pays P_{NI} .

12. IP crop, no certification from the exporter and no testing by the importer:

$$Y_M (IP, NC, NT) = [P(q / \alpha_E \leq \alpha_T)(\Pi^m_{IP} + p) + (1 - P(q / \alpha_E \leq \alpha_T)\Pi^m_{NIP}]$$

In this case, the importer does not test the shipment and pays P_{NI} for all shipments. In the absence of testing, there is still a chance that the importer obtains IP crop.

13. NIP commodity, certification from the exporter and testing by the importer:

$$Y_M (NIP, C, T) = [P(\alpha_I \leq \alpha_T / \alpha^U_E \leq \alpha^U_T)(\Pi^m_{IP} - t) - P(\alpha_I > \alpha_T / \alpha^U_E \leq \alpha^U_T)(t)]$$

If the importer accepts the shipment, he pays the premium for IP. If he tests and rejects the shipment, he incurs only the testing expenditure.

14. NIP commodity, certification from the exporter and no testing by the importer:

$$Y_M (NIP, C, NT) = [P(q / \alpha^U_E \leq \alpha^U_T)(\Pi^m_{IP}) + (1 - P(q / \alpha^U_E \leq \alpha^U_T))(-P_{IP})]$$

The importer pays P_I for all shipments, but has little chance of receiving IP crop.

15. NIP commodity, no certification from the exporter and testing by the importer:

$$Y_M (NIP, NC, T) = [P(\alpha^U_I \leq \alpha^U_T / \alpha^U_E \leq \alpha^U_T)(\Pi^m_{NIP} - t) - P(\alpha^U_I > \alpha^U_T / \alpha^U_E \leq \alpha^U_T)(t)]$$

The importer tests the shipment for unapproved events. If the importer finds unapproved events, he rejects the shipment and incurs only testing expenditures.

16. NIP commodity, no certification from the exporter and no testing by the importer:

$$Y_M (NIP, NC, NT) = [P(q / \alpha^U_E \leq \alpha^U_T)(\Pi^m_{NIP}) + (1 - P(q / \alpha^U_E \leq \alpha^U_T))(-P_{NIP})]$$

The importer does not test the shipment for unapproved events. He pays P_{NI} as claimed by the exporter, but he incurs loss equal to P_{NI} if the shipment contains unapproved events and is rejected by the end user.

Finding a Separating Perfect Bayesian Equilibrium (PBE)

Following the same steps as in Game 1, I derive here a PBE.

Assignment of strategies and derivation of the beliefs

There are only two possibilities for separating strategies for the Exporter. One possibility is that IP-type Exporter chooses C and NIP-type Exporter chooses NC. The second possibility is that the IP-type Exporter chooses NC and NIP-type Exporter chooses C. But since C strictly dominates NC[13] for IP-type exporter[14] if a separating PBE exists then the IP-type Exporter will systematically choose C while the NIP-type Exporter will systematically choose NC. We can therefore summarize the rational belief of the importer as follows:

$$\sigma_E(t) = \begin{cases} \text{C if type = IP} \\ \text{NC if type = NIP} \end{cases}$$

Now let $\mu(t_i / A)$ be the probability that the Importer assigns to type i after observing action A.

If Importer observes that the Exporter chooses C, he will assign probability 1 to type IP. If he observes Exporter choosing NC, he will assign probability 1 to type NIP.

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[13] The following condition should be satisfied $\frac{p}{R} > \frac{P(\alpha_I > \alpha_T / \alpha_E \leq \alpha_T)}{P(\alpha_I \leq \alpha_T / \alpha_E \leq \alpha_T)}$ in order for Payoff 1 to be greater than Payoff 3. From the above condition, the ratio of probability of acceptance and probability of rejection of an IP shipment given it has already been tested by the exporter should be lesser than the ratio of premium for a unit of IP and rejection costs per unit of shipment. The Payoff 2 is more than Payoff 4 by an amount equal to the premium for IP crops. From these two results we can say that C strictly dominates NC.

[14] We can prove that Payoff 1 and 2 are respectively greater than Payoffs 3 and 4.

These beliefs are consistent with Bayes' rule as both the information sets are reached with positive probability along the equilibrium path.

Again for simplification, I assume that the probabilities of I-type, and NI-type exporters are equal[15] so: P (IP) = P (NIP) = 1/2.

We just established that,

$P(C / IP) = 1$ $\qquad$ $P (NC / IP) = 0$

$P(C / NIP) = 0$ $\qquad$ $P (NC / NIP) = 1$

By applying Bayes' theorem, I obtain

$\mu (IP / C)$[16] $= 1$ $\qquad$ $\mu (NIP / C) = 0$

$\mu (IP / NC)=0$ $\qquad$ $\mu (NIP / NC)= 1$

Best Response for Importer:

When Exporter plays C:

- The Importer's expected profit from choosing (T) in response to Exporter choosing (C) is:

  $EU_I (T, C) = \mu (IP / C) * Y_M(T, C; IP) + \mu (NIP / C) * Y_M (T, C; NIP) =$

  $$[P(\alpha_I \le \alpha_T / \alpha_E \le \alpha_T)(\Pi^m_{IP} - t) - P(\alpha_I > \alpha_T / \alpha_E \le \alpha_T)(t)] = \Pi^m_{IP} - t$$

This payoff function can be also written as $\Pi^m_I - t$ as the importer receives the IP Premium from a second shipment if the first one fails the test. So, with a probability of 1, he will get the profit of IP crop and will incur testing expenses with the same probability.

- The Importer's expected profit from choosing (NT) in response to Exporter choosing (C) is:

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[15] Even if the probabilities are not equal to each other, there will not be a change in the results Bayes' theorem is applied.

[16] By applying Bayes' theorem, we get:

$$\mu(IP / C) = \frac{P(C / IP)P(C)}{P(C)} = \frac{P(C / IP)P(IP)}{P(C / IP)P(IP) + P(C / NIP)P(NIP)} = \frac{1(0.5)}{1(0.5) + 0(0.5)} = 1$$

EU$_I$ (NT, C) = μ (IP / C) * Y$_M$ (NT, C; IP) + μ (NIP/ C) * Y$_M$ (NT, C; NIP) =

$[P(q/\alpha_E \leq \alpha_T)(\Pi^m_{IP}) + (1 - P(q/\alpha_E \leq \alpha_T)(\Pi^m_{NIP} - p)]$

From the above it follows,

EU$_I$ (T, C) > EU$_I$ (NT, C) if $t < [1 - P(q/\alpha_E \leq \alpha_T)](Z_{IP} - Z_{NIP})$

So, the Best Response of Importer, if Exporter chooses 'Contains' = **BR$_I$ (C) = T**.

When Exporter chooses NC:

- The Importer's expected profit from choosing (T) in response to Exporter choosing (NC) is:

  EU$_I$ (T, NC) = μ (IP / NC) * Y$_M$ (T, NC; IP) + μ (NIP / NC) * Y$_M$ (T, NC; NIP) = $[P(\alpha^U_I \leq \alpha^U_T / \alpha^U_E \leq \alpha^U_T)(\Pi^m_{NIP} - t) - P(\alpha^U_I > \alpha^U_T / \alpha^U_E \leq \alpha^U_T)(t)]$

- The Importer's expected profit from choosing (NT) in response to Exporter choosing (NC) is:

  EU$_I$ (NT, NC) = μ (IP / NC) * Y$_M$ (NT, NC; IP) + μ (NIP / NC) * Y$_M$ (NT, NC; NIP) = $[P(q/\alpha^U_E \leq \alpha^U_T)(\Pi^m_{NIP}) + (1 - P(q/\alpha^U_E \leq \alpha^U_T))(-P_{NIP})]$

From the above, EU$_I$ (T, NC) > EU$_I$ (NT, NC) if

$t < Z_{NIP}[P(\alpha^U_I \leq \alpha^U_T / \alpha^U_E \leq \alpha^U_T) - P(q/\alpha^U_E \leq \alpha^U_T)] + P_{NIP}[1 - P(\alpha^U_I \leq \alpha^U_T / \alpha^U_E \leq \alpha^U_T)]$.

The exporter procures NIP-type commodity, confirms absence unapproved events through testing, but does not provide certification. But the exporter can also cheat claiming no presence of unapproved events without testing or segregating the shipment. The best alternative for the importer is then to test the shipment even though he incurs additional testing expenditure. So, the Best Response of Importer, if Exporter chooses NC = **BR$_I$ (NC) = T**.

Checking deviations

We have to determine whether the strategies of the Exporter and the Best Responses of the Importer given existing beliefs, is a PBE equilibrium. We can confirm it as a PBE only if neither type of Exporter has an incentive to deviate. We know that IP-type will not deviate as C strictly dominates NC. The Exporter type NIP will follow the assigned strategy as long as the payoff it yields is at least as high as the one he would get if he deviated.

NI-type's payoff along the equilibrium path = Y_E (NIP, NC, NT) = Π^e_{NIP}

If he deviated and chose C instead, the Importer's beliefs would continue to be as above, and seeing C chosen and that the Exporter is of IP-type with probability 1, and would therefore choose T. Therefore, if R>0, the payoff of Exporter of type NIP from deviating is $Y_E(NI,C,T) = \Pi^e_{NIP} - R$, which is smaller than the payoff from following the equilibrium.

In this situation when neither type of exporter deviates, the proposition given above will be a ***separating PBE***,[17] which is as follows:

$$\sigma_E(t) = \begin{cases} C, & \text{if type = IP} \\ NC, & \text{if type = NIP} \end{cases}$$

$$\sigma_I(E, \mu(E)) = \text{Test, if } E = C \text{ or } NC$$

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[17] Given the conditions below: (i) $\frac{p}{R} > \frac{P(\alpha_I > \alpha_T / \alpha_E \leq \alpha_T)}{P(\alpha_I \leq \alpha_T / \alpha_E \leq \alpha_T)}$

(ii) R>0 and (iii) $t < [1 - P(q / \alpha_E \leq \alpha_T)](Z_{IP} - Z_{NIP})$

Note 1: The game was also checked for the existence of a pooling equilibrium (i.e. both the types of exporters will be choosing C), which could not be confirmed.

Note 2: It should be noted that even if we add a third type of exporter, e.g., one who exports a substitute commodity, there be no change in the results shown above.

ESSAY TWO:

MARKET AND WELFARE EFFECTS OF TRADE DISRUPTIONS FROM UNAPPROVED BIOTECH CROPS

I. Introduction

Modern biotechnology methods have been used to enhance the performance and quality of crops for more than 30 years. Unlike most other crop genetic improvement methods, however, modern biotechnology and biotech crops are strictly regulated for food and environmental safety. All biotech or genetically modified (GM) crops are submitted to a battery of tests and regulatory scrutiny before they can be approved for commercialization. A number of GM crops have passed the regulatory hurdle and have been commercialized over the last twelve years. Indeed, since 1996, over one billion cumulative acres of GM soybeans, corn, cotton, canola, sugar beets, and other crops have been grown around the world (James, 2007). Economists have estimated the social benefits from GM crops to be in the billions of dollars, with the benefits shared among the biotechnology innovators, agricultural producers, and consumers in both exporting and importing countries (Falk-Zepeda et al., 2004; Lapan and Moschini, 2004; Konduru et al., 2008; Sobolevsky et al., 2005).

Because of their extensive adoption in major exporting countries, GM crops represent a dominant share of a few key agricultural commodities that are broadly traded in international markets. The trade of GM crops, however, has not always been uneventful. There are six documented cases where unapproved GM crops found their way into the food and feed supply chain: Starlink, Bt 10 corn, Prodigene corn, Liberty Link rice 601 and 604, and Event 32 corn. In some of these instances trade disruptions have followed (Schmitz et al., 2004, 2005; Carter and Smith, 2005; Lin et al., 2003)

More recently, concerns about trade disruptions from unapproved GM crops have increased as the GM crop pipeline moving towards or awaiting regulatory approval has expanded while the speed of regulatory approvals across different countries has become less synchronized (Krueger and Buanec 2008; EC DG AGRI, 2007; Backus et al.,2008). To fully appreciate the problem one must be mindful of certain nuisances in the regulatory process of new GM crops.

Regulatory reviews and approvals for the cultivation and marketing of GM crops are country-specific. Hence, at some point in the R&D cycle, biotech crop developers must decide in which countries they must seek regulatory approval for their products. In this context, they must take into account not only the countries where the cultivation of the new biotech crops could take place (requiring regulatory approval for cultivation) but also where the consumption of such crops might ultimately occur (requiring regulatory approval for marketing and/or use). Given the large and expanding agricultural commodity trade flows across the globe, these considerations become complex as biotech developers must balance their desire for broad regulatory approval with practical budget constraints (Kalaitzandonakes, Alston and Bradford, 2006).

Currently, nineteen countries have well-developed systems that handle submissions seeking regulatory approval for the cultivation and marketing of new GM crops while a number of others are in the process of developing theirs. There are, however, significant differences in the procedures of regulatory approval of GM crops used in different countries including the amount required to complete them (Kalaitzandonakes et al., 2006).

At one extreme the US, Canada, Japan and some other countries have continued to review and approve new biotech crops, at variable but similar speeds. At the other extreme, the European Union (EU) has been slow and unpredictable in reviewing and approving new biotech crops. Indeed, the EU stopped considering petitions for regulatory approvals in 2001 and began reviewing regulatory dossiers in 2004 again, only after mandatory labeling laws and full traceability of foods and feeds along the EU supply chain were both implemented. This *de facto* moratorium on regulatory approvals of new GM crops prompted the filing of a WTO complaint by the US, Argentina and Canada in 2003. Yet even today when the EU has continued to review and approve new GM crops for marketing, the review process has, on average, taken almost twice as long as in the US (EC DG AGRI, 2007; FEFAC, 2007).

Significant discrepancies in the amount of time required to review and approve new GM crops has led to “asynchronous approvals.” Under such conditions, new GM crops can be cultivated and marketed for food and feed in some countries but not in others. This asynchronicity becomes a particularly difficult problem for broadly traded commodities as perfect segregation of approved from unapproved GM crops is difficult within the global agricultural commodity system. As I discussed in essay I, identity preservation (IP) systems and analytical GMO testing can be used but segregation is less than perfect and subject to measurement uncertainty and added costs. As I showed in essay I, under these conditions trade disruptions are expected and can quickly deteriorate into effective trade bans.

What are the potential market and welfare impacts from trade disruptions that might be caused by asynchronous regulatory approvals of new GM crops? This is the key question I examine in this essay. A handful of empirical studies have tackled this issue in the context of specific market disruptions from specific unapproved GM crop in some market. Schmitz et al., (2004, 2005) examined the price impacts caused by the trade disruptions from Starlink corn using a partial equilibrium model while Carter and Smith (2005) examined the same issue through a time series analysis.

Brookes and Barfoot (2008) used industry case studies to examine the price impacts of trade disruptions in the EU rice market caused by the discovery of Liberty Link Rice in the US as well as similar interruptions in the supply of certain food ingredients. DG AGRI of the EU Commission (2007) used partial equilibrium analysis to examine the price impacts of both actual trade disruptions (in the case of the EU corn gluten feed market) and potential ones (in the case of the EU soybean meal and oil markets). Hence, both Brookes and Barfoot (2008) and DG AGRI (2007) were primarily interested in the price impacts on EU consumer food products caused by trade disruptions associated with the presence of unapproved GM crops in the market.

For the current essay, I am interested in the impacts the trade disruptions have on the prices paid by the consumers and on consumer consumption levels. I am also interested in how producer profits are affected and in the end what are the net welfare effects from all relevant changes. I begin my analysis by setting up a relevant trade model and deriving the baseline equilibrium conditions when no unapproved GM crops exist. Then I introduce regulatory asynchronicity and relevant trade disruptions and analyze the market and welfare impacts.

II. Baseline Development

In setting up the model I develop for the analysis in this essay I follow the same conventions and notation I used in essay I. Specifically, I assume that there are two separate supply chains – one that moves identity preserved (IP) crops which are strictly segregated and analytically tested to exclude all GM crops. Identity preservation procedures and GMO testing imply added costs. There is also a commodity supply chain that moves crops that are not identity preserved (NIP).

I assume consumers to be heterogeneous in their preferences towards NIP and IP products. Because I assume heterogeneous consumer preferences, I also assume separate markets for IP and NIP products. There is also a market for a product, S, that substitutes for the commodity NIP.

I assume that there are two importing countries and one exporting one. The trade flows between the exporting and importing countries represent net exports and imports. Hence, while an importing country might have a production and export sector, its demand deficit and net import position fully describes it in the model. The same principle applies for the exporting country. Because of this set up, the exporting country is where producers are and the importing countries where the consumers are[18].

When an importing country has not approved a given GM crop for marketing, the particular GM crop cannot be legally traded in the market of this country. This implies that when the unapproved GM crop is produced in an exporting country, unless specific

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[18] Relaxing this assumption and including producers and consumers in all countries complicates the set up but does not change the essential results I will present here.

segregation and testing efforts are expended to exclude the GM crop from the commodity supply chain, it may likely be present. IP crops therefore ensure that the unapproved GM crop is absent from any given shipment. NIP commodities, however cannot. This implies trade restrictions on NIP commodities from the exporting country to the importing country that has not approved the particular GM crop. As I explained in Essay I, because of measurement uncertainty and segregation, testing and rejection costs, these implied trade restrictions typically amount to effective export bans of the NIP commodities to the importing country.

Based on these assumptions, I can now begin to analyze the pricing strategies of producers in the exporting country and the buying decisions of consumers in the importing countries. In this context, I first establish equilibrium prices and quantities under a benchmark case where there are no trade restrictions. Then, in the next section I build on this framework to analyze the effects of unapproved GM crops on trade and on the welfare of producers and consumers.

Consumer choice and market demand

For my analysis, I follow Giannakas and Fulton (2002) and Fulton and Giannakas (2004) to model IP and NIP products as vertically differentiated goods. In this type of model, consumers rank the two products uniformly (i.e., all consumers prefer the IP product if offered at the same price as the NIP) but they differ in their valuation of the perceived quality differences.

Each consumer determines whether to buy a single unit of either the IP or the NIP product. If consumers do not buy either of those products, they buy one unit of a substitute product S. I do not consider income effects so I assume that consumers spend only a small fraction of their total expenditures on these goods. Consumers are differentiated with respect to the characteristic *m* which captures the heterogeneity of their preferences relative to the IP and NIP products. Based on these assumptions, the consumer utility functions can be expressed as:

$$U_{IP}^{k} = U - P_{IP}^{k} + \mu\, m \tag{1}$$

if a unit of IP product is consumed

$$U_{NIP}^{k} = U - P_{NIP}^{k} + \lambda\, m \tag{2}$$

if a unit of NIP product is consumed

$$U_{S}^{k} = U \tag{3}$$

if a unit of substitutes product is consumed

U_{IP}^{k}, U_{NIP}^{k} and U_{S}^{k} are the utilities associated with the consumption of one unit of the IP, NIP and S products, respectively. The parameter U is a unit base level of utility. P_{IP}^{k} and P_{NIP}^{k} are the unit prices of IP and NIP products respectively, and k denotes either country *A* or country *B*. I assume that $P_{IP}^{k} > P_{NIP}^{k}$ to allow for a positive market share of the NIP product.

The parameters μ and λ are utility enhancement factors associated with the consumption of IP and NIP products, respectively. The parameter $\lambda < \mu$ since all consumers prefer the IP product if offered at the same price. Consumers are assumed to be uniformly distributed between the polar values of the preference parameter *m,* $m \in (0,1)$ A *m* value of zero corresponds to consumers who are indifferent between the IP and NIP while a *m* value of one corresponds to consumers for which the perceived difference between the two products is strongest. Combining the value of the preference parameter and the utility discount factors, $m(\mu-\lambda)$ denotes the degree of aversion to the NIP product for a consumer with differentiating attribute *m*.

A consumer's choice is determined by the relationship between the utilities derived from IP, NIP and S products – net of price. The consumer with characteristic m_{NIP}^{k} is indifferent between consuming a unit of IP and NIP product and derives the same utility from the consumption of either product when:

$$U_{IP}^{k} = U_{NIP}^{k} \Leftrightarrow U - P_{IP}^{k} + \mu m_{NIP}^{k} = U - P_{NIP}^{k} + \lambda m_{NIP}^{k}$$

Solving this equation for m_{NIP}^{k} yields

$$m_{NIP}^{k} = \frac{P_{IP}^{k} - P_{NIP}^{k}}{\mu - \lambda} \tag{4}$$

Along the same lines, a consumer with characteristic m_S is indifferent between the NIP product and S-type product when the following conditions hold:

$$U_{NIP}^{k} = U_{S}^{k} \Leftrightarrow U - P_{NIP}^{k} + \lambda m_{IP}^{k} = U$$

Solving this equation for m_S^k yields

$$m_S^k = \frac{P_{NIP}^{k}}{\lambda} \tag{5}$$

These consumer choices can be illustrated for more clarity. As indicated in figure 1, consumers for whom $m \in (m_{NIP}^{k}, 1)$ buy the IP product. Consumers for whom $m \in (m_S^k, m_{NIP}^k)$ buy the NIP commodity. And consumers for whom $m \in (0, m_s^k)$ consume the S product. Since we have assumed that the consumers are uniformly distributed with respect to *m* and that the consumption of each individual is restricted to one unit of either product, the demand for the IP product is given by $1-m_{NIP}^{k}$; the demand for the NIP commodity by $m_{NIP}^{k}-m_{S}^{k}$, the demand for the S products by m_{S}^{k} . Based on the value of the parameters derived in equation (4) and (5) I derive the demand for each product as a function of the prices and utility discount factors as follows:

$$\begin{aligned} x_{IP}^{k} &= \frac{\mu-\lambda-P_{IP}^{k}+P_{NIP}^{k}}{\mu-\lambda} \\ x_{NIP}^{k} &= \frac{\lambda P_{IP}^{k}-\mu P_{NIP}^{k}}{\lambda(\mu-\lambda)} \\ x_{S}^{k} &= \frac{P_{NIP}^{k}}{\lambda} \end{aligned} \tag{6}$$

Conditions in (6) conform to basic economic theory since the demand for the IP commodity and the NIP commodity increase as the prices decrease and vice versa. However, the demand for the IP product also decreases as the price of the NIP commodity increases. The same logic applies for the demand of the NIP commodity which indicates that the two goods are substitutes. Since the NIP commodity substitutes also for the substitute product, an increase in the price of the NIP commodity will contribute to an increase both in the demand for the substitute product and in the demand of the NIP commodity. Condition (6) also indicates that if P_{NIP}^{k} is greater than P_{IP}^{k}, the NIP commodity will be driven out of the market and the market share of the NIP commodity will become zero. Figure 1 provides a graphical representation of the utility curves derived and the quantities demanded for all three types of products.

Equilibrium prices and quantities

The two importing countries are denoted here by *A* and *B.* As I indicated earlier, the relative market size of the two importing countries is an important consideration in this analysis. I incorporate such consideration in the model by specifying the ratio of the market size in country *A* relative to that in country *B* as β. This implies that the number of consumers in country *B* is β times greater than in country *A*. Assuming that the aggregate preferences of consumers in both importing countries are the same I can then relate consumption in the two importing countries by the following conditions:

$$\begin{aligned} x_I^B &= \beta x_{IP}^A \\ x_{NIP}^B &= \beta x_{NIP}^A \\ x_S^B &= \beta x_S^A \end{aligned} \tag{7}$$

Aggregating the demand in the two importing countries I obtain

$$\begin{aligned} x_I &= x_{IP}^A + x_{IP}^B \\ x_{NI} &= x_{NIP}^A + x_{NIP}^B \\ x_S &= x_S^A + x_S^B \end{aligned} \tag{8}$$

Since I am interested in the aggregate quantities consumed across the two countries, and to simplify the notation, from this point forward I drop the superscripts indexing each country.

In order to derive the equilibrium conditions in my trade model, I assume that because of arbitrage, the prices for each product in the two importing countries are equal. In other words, it is not possible to make a profit by purchasing the commodity in one of the importing country at a discount and reselling it in the other importing country at a premium. In reality, transport and transaction costs would likely differ across different destinations for an export country but explicitly incorporating such differences would not change the analysis in any way. By combining the system of equations in (6) and (8) I derive the inverse aggregate demand curves for each of the products:

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$$P_{NIP} = \frac{\lambda[P_{IP}(1+\beta) - (\mu-\lambda)x_{NIP}]}{\mu(1+\beta)}$$
$$P_{IP} = P_{NIP} + \frac{(\mu-\lambda)(1+\beta-x_{IP})}{(1+\beta)} \qquad (9)$$

Equation (9) implies that the prices of the two products are positively related and move in the same direction. Based on those inverse demand curves, I can also derive the marginal revenue curves which are illustrated in Figure 2 for each type of exporter. The inverse demand curve and the marginal revenue curve for each product have the same intercept which can be obtained by setting x_{NIP} and x_{IP} equal to 0 in the system of equations in (9). The intercept for the demand and the marginal revenue curve for the NIP type and the IP type product are therefore $\lambda P_{IP} / \mu$ and $P_{NIP} + (\mu - \lambda)$

The slope of the marginal revenue curve is equal to $(1+\theta)$[19] time the slope of the demand curve, where the parameters θ represent conjectural variations elasticities capturing the degree of market power of the exporters (Tirole, 1988). Using equation (9) again I derive the slope of the marginal revenue curve for the IP and NIP products which are, respectively,

$$\frac{-(\mu-\lambda)(1+\theta)}{(1+\beta)} \text{ and } \frac{\lambda(\mu-\lambda)(1+\theta)}{\mu(1+\beta)}$$

In oligopolistic models, a conjecture refers to the expectations that a firm has about the reaction of other firms. In our model the conjectural variation elasticities θ indicates that a given firm believes that increasing the quantities it produces by one unit will induce all other firms to increase the aggregate quantity they produce by θ units.

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[19] For the sake of simplicity, I assume that conjectural variations elasticities are the same for both IP and NIP products but the results in this essay are qualitatively the same if conjectural variations elasticities are different for each product type.

Hence a value of 0 for the parameter θ implies that the firm believes that the quantity it chooses will not affect the quantities chosen by other firms. The slope and intercept equations derived above also indicate that a value of 0 for the parameter θ means that the marginal revenue curve and the demand curve coincide as in the case of perfect competition. A value of 1 for the parameter θ implies that the firm believes it is the only firm in the market since a one unit increase on its part will lead to the same unit increase in the aggregate. The slope equations also indicate that a value of 1 for the parameter θ means that the slope of the marginal revenue curve is twice as large in absolute value as the slope of the demand curve, as in the case of a monopoly market structure defined by a linear demand.

Revenue maximization by the exporter implies that the marginal cost equals marginal revenue. Based on the slope and intercept of the marginal revenue curve derived earlier, the following must hold:

$$MR_{NIP} = \lambda P_{IP} / \mu - \frac{\lambda(\mu-\lambda)(1+\theta)}{\mu(1+\beta)} x_{NIP} = C_{NIP}$$

$$MR_{IP} = P_{NIP} + (\mu-\lambda) - \frac{-(\mu-\lambda)(1+\theta)}{(1+\beta)} x_{IP} = C_{IP}$$

where C_{IP} and C_{NIP} are the marginal costs faced by the exporters of the IP and NIP products. Solving the two equations, I obtain the quantities that maximize revenue for each product type

$$x_{IP} = \frac{(1+\beta)(C_{IP} - P_{NIP} + \lambda - \mu)}{(1+\theta)(\lambda-\mu)}$$

$$x_{NIP} = \frac{(1+\beta)(P_{IP}\lambda - C_{NIP}\mu)}{(1+\theta)\lambda(\mu-\lambda)}$$

Substituting those expressions for the values obtain in system (9) and solving simultaneously for the prices, I derive the equilibrium prices expressed uniquely as a function of the exogenous parameters of the model:

$$P_{IP} = \frac{-C_{IP}(1+\theta)\mu - C_{NIP}\mu\theta + \mu(1+\theta)(\lambda-\mu)}{\lambda\theta^2 - \mu(1+\theta)^2} \tag{11}$$

$$P_{NIP} = \frac{\lambda\theta(\lambda\theta - C_{IP}) - (C_{NIP} + C_{NIP}\theta + \lambda\theta^2)\mu}{\lambda\theta^2 - \mu(1+\theta)^2} \tag{12}$$

Substituting those expressions for the values obtained in (10) I can also derive the equilibrium quantities expressed uniquely as a function of the exogenous parameters of the model:

$$x_{IP} = \frac{(1+\beta)[C_{IP}\theta\lambda - C_{IP}(1+\theta)\mu - (C_{NIP} - (1+\theta)(\lambda-\mu))\mu]}{\lambda(\lambda-\mu)[\lambda\theta^2 - \mu(1+\theta)^2]} \tag{13}$$

$$x_{NIP} = \frac{(1+\beta)\mu[C_{IP}\lambda + C_{NIP}\theta\lambda - C_{NIP}\mu(1+\theta) + \lambda\theta(\mu-\lambda))}{\lambda(\lambda-\mu)[\lambda\theta^2 - \mu(1+\theta)^2]} \tag{14}$$

Finally, the profit equations can be readily obtained from the price and quantities in (11) through (14) as follows:

$$\Pi_{IP} = (P_{IP} - C_{IP})x_{IP} = \frac{-(1+\beta)\theta[C_{IP}\lambda\theta - C_{IP}(1+\theta)\mu + (C_{NIP} - (1+\theta)(\lambda-\mu))\mu]^2}{(\lambda-\mu)[\lambda\theta^2 - (1+\theta)^2\mu]^2} \tag{15}$$

$$\Pi_{NIP} = (P_{NIP} - C_{NIP})x_{NIP} = \frac{-(1+\beta)\theta\mu[C_{IP}\lambda + C_{NIP}\lambda\theta - C_{NIP}(1+\theta)\mu + \lambda\theta(\mu-\lambda)]^2}{\lambda(\lambda-\mu)[\lambda\theta^2 - (1+\theta)^2\mu]^2} \tag{16}$$

In this section, I derived the baseline equilibrium prices and quantities in the one exporter two importers trade model where IP and NIP products are freely traded. On the demand side, consumers in the importing countries have heterogeneous preferences for vertically differentiated products. On the supply side, producers market IP and NIP products and may be able to exercise some degree of market power in both markets. In the next section, I derive those same prices and quantities for a new market equilibrium when, because of the presence of unapproved GMOs in the exporting country, NIP commodities cannot be traded from the exporting to one of the importing counties. Then I compare them with the equilibrium prices and quantities in the baseline in order to assess the impacts of the asynchronous approval of GM crops on the free movement of commodities between countries.

III. Impact of Trade Restriction on Unapproved Biotech Crops

As I explained in section 2, when an importing country has not approved a given GM crop for consumption, the particular GM crop cannot be legally traded in the market of this country. Because of measurement uncertainty and large segregation, testing and rejection costs, I assume here that the implied trade restrictions will amount to an effective export bans of the NIP commodities to the importing country that has not approved it. Here I assume that regulatory authorities in importing country *A* have approved all GM crops that are currently commercially available but that regulatory authorities in importing country *B* have not yet approved one of these GM crops. Based on all these, I assume that the exporting country can ship NIP and IP products to the importing country *A* but only IP products to importing country *B*. The substitute product S can also be consumed in both importing countries. Based on these assumptions, the aggregate demand curves for both importing countries are expressed as follows:

$$
\begin{aligned}
x_I &= x_{IP}^A + x_{IP}^B \\
x_{NI} &= x_{NIP}^A + 0 = x_{NIP}^A \\
x_S &= x_S^A + x_S^B
\end{aligned}
\tag{17}
$$

Following similar procedures as in the previous section, I can derive the inverse demand functions, which are specified as:

$$
\begin{aligned}
P_{NIP} &= \frac{\lambda}{\mu}[P_{IP} - (\mu - \lambda)x_{NIP}] \\
P_{IP} &= \frac{P_{NIP} + (x_{IP} - \beta - 1)(\lambda - \mu)\mu}{\mu + \beta(-\lambda + \mu)}
\end{aligned}
\tag{18}
$$

As in the case of the baseline, the prices of the two products are positively related and move in the same direction. Following the steps as in the baseline, I can now obtain the equilibrium prices and quantities for this scenario:

$$
P_{IP}'' = \frac{-\theta(C_{NIP} - (1+\beta)(1+\theta)(\lambda-\mu))\mu + C_{IP}(1+\theta)(\lambda\beta - (1+\beta)\mu)}{(\theta^2 + \beta(1+\theta^2)\lambda - (1+\beta)(1+\theta)^2\mu} \tag{19}
$$

$$
P_{NIP}'' = \frac{C_{IP}\theta\lambda(\beta\lambda - (1+\beta)\mu) - \mu[-(1+\beta)\lambda\theta^2(\lambda-\mu) + C_{NIP}(1+\theta)(\mu + \beta(\mu-\lambda))]}{\mu[(\theta^2 + \beta(1+\theta^2)\lambda - (1+\beta)(1+\theta)^2\mu]} \tag{20}
$$

$$
x_{IP}'' = \frac{(\beta\lambda - (1+\beta)\mu)(-C_{IP}(\beta+\theta+\beta\theta)\lambda + C_{IP}(1+\beta)(1+\theta)\mu - C_{NIP} - (1+\beta)(1+\theta)(\lambda-\mu))\mu)}{(\lambda-\mu)\mu[(\theta^2 + \beta(1+\theta^2)\lambda - (1+\beta)(1+\theta)^2\mu]} \tag{21}
$$

$$
x_{NIP}'' = \frac{-\mu[-C_{NIP}(\beta+\theta+\beta\theta)\lambda + (1+\beta)\lambda\theta(\lambda-\mu) + C_{NIP}(1+\beta)(1+\theta)\mu] + C_{IP}\lambda(\mu + \beta(\mu-\lambda))}{(\lambda-\mu)\lambda[(\theta^2 + \beta(1+\theta^2)\lambda - (1+\beta)(1+\theta)^2\mu]} \tag{22}
$$

Market Effects

By comparing equations (10) and (11) with equations (19) and (20), I can show that the prices of both the IP and NIP commodities increase once a ban on NIP commodity exports to country *B* are imposed. That is,

$$P_{IP}'' - P_{IP} = \frac{\theta\beta(1+\theta)(\lambda-\mu)(C_{IP}\theta\lambda + (C_{NIP}(1+\theta) - \lambda(1+2\theta)\mu))^2}{(\theta^2\lambda - (1+\theta)^2\mu)[(\theta^2 + \beta(1+\theta)^2\lambda - (1+\beta)(1+\theta)^2\mu]^2} > 0$$

$$P_{NIP}'' - P_{NIP} = \frac{\theta\beta^2\lambda(\lambda-\mu)(C_{IP}\theta\lambda + (C_{NIP}(1+\theta) - \lambda(1+2\theta)\mu))^2}{\mu(\theta^2\lambda - (1+\theta)^2\mu)[(\theta^2 + \beta(1+\theta)^2\lambda - (1+\beta)(1+\theta)^2\mu]^2} > 0$$

Those inequalities can be shown to hold as long as the NIP commodity is not driven out of the market in the baseline.

The disappearance of NIP commodity in country *B* creates the equivalent of a shift to the right of the demand for the IP product in this country. As a result, consumer prices for the IP product in country *B* would tend to increase. However, because of arbitrage the price of the IP product would also increase in country *A*. The mechanism of price transmission attenuates the rise in price in country *B* but implies that consumers in country *A* now also pay higher price for the IP product.

While the increase in the price of IP products is intuitively expected, the increase in the price of the NIP products is somewhat more surprising. However, as the conditions in (18) establish, the prices of IP and NIP products would tend to move in the same direction due to their substitutability. The implication here is that the price increase for the IP product that started in country *B* spills over to country *A* and eventually also results in higher NIP commodity prices even though their consumption occurs only in country *A*. Hence, even if the regulatory authorities in country *A* work diligently to provide regulatory approvals that allow trade to continue in an orderly fashion, regulatory delays in other countries can still lead to higher prices both for the IP crops and the NIP commodities.

Trade disruption in one of the importing countries also affects the total quantities consumed of each of the products. By comparing the equations (21)-(22) to equations (12)-(13), we can infer that the aggregate demand for I-type and S-type products increases, i.e., $(x_{IP}'' + x_S'') > (x_{IP} + x_S)$. However, the equilibrium quantity for the IP product alone could decrease if the ratio of market size β is larger than a critical value[1] β_{IP}^x, or:

$$\beta > (\leq) \beta_{IP}^x \Leftrightarrow x_{IP}'' < (\geq) x_{IP} .$$

Once again, this result appears less than intuitive since it could be expected that the overall quantities of the IP product would increase after the NIP commodity is banned in country *B*. However, the results have indicated that this is not necessarily the case. As I have shown above, the price of the IP product in country *A* where there are no trade restrictions would increase. As a response to this price increase, demand for the IP product tends to decrease in country *A*. If the demand for the IP product in country *B* does not increase enough to make up the difference then the overall quantity of the IP product would tend to decrease. Indeed, depending on the degree of market power in the export market to country *B,* exporters may reduce their supply at the same time they increase prices – as economic theory would predict. Supply declines may be exacerbated if the demand for the IP product in country *B* becomes more inelastic after the disappearance of

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[1] The critical market size value can be shown to be:

$$\beta_{IP}^x = (-C_{IP}\lambda(\theta^3(\lambda-\mu)^2 + \mu^2 + 2\theta\mu^2 + 2\theta^2\mu(-\lambda+\mu)) + \mu(\theta^2(1+\theta)\lambda(\lambda-\mu)^2 + C_{NIP}(\mu^2 2\theta\mu^2 + \theta^2(-\lambda^2+\mu^2)))) /$$
$$((1+\theta)(\lambda-\mu)(C_{IP}\lambda(\theta^2(\lambda-\mu) - \mu - \theta\mu) + \mu(C_{NIP}\mu + C_{NIP}\theta\mu + \theta^2\lambda(-\lambda+\mu))))$$

the NIP commodity. As a result, the equivalent of the shift to the right for the IP product may not be enough to compensate for these quantity reductions. As the size of country *B* increases and the potential profit for the IP product increases in this country, it may be more profitable for exporters to restrict overall quantities.

A similar result is derived for the change in the equilibrium quantity of the NIP commodity. The equilibrium quantity for the IP product decreases when the ratio of market size β is more than the critical value[2] β_{NIP}^{x}

$$\beta > (\leq)\beta_{NIP}^{x} \Leftrightarrow x_{NIP}'' < (\geq)x_{NIP}$$

If the market size in country *B* is large, then banning NIP exports in this market could contribute to a decline in the overall quantity of the NIP commodity consumed. The reasoning is similar as above. The restriction of NIP exports to country *B* leads to higher prices for both IP and NIP product. When the price of the IP product increases, the demand for the NIP commodity can become more inelastic. As a result, if exporters of NIP commodities exercise market power, they may find it profitable to reduce their supplies (exports) to consumers in country *A*.

It is also possible that the quantity of the NIP consumed may increase. This result is less intuitive especially since its price increases and it is also banned from country *B*. However, if the price of the IP product increases relatively more than the price of the NIP commodity, then some consumers that were previously buying the IP product in country *A* would now consume the NIP commodity.

I can now summarize the main results on market effects as follows:

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[2] $\beta_{NIP}^{x} = (C_{IP}\lambda(\mu^2 + 2\theta\mu^2 + \theta^2(-\lambda^2 + \mu^2)) - \mu(-\theta(1+\theta)^2\lambda(\lambda - \mu)^2 + C_{NIP}(\theta^3(\lambda - \mu)^2 + \mu^2 + \theta^2(\lambda^2 - 4\lambda\mu + 3\mu^2) + \theta(\lambda^2 - 2\lambda\mu + 3\mu^2))))/((1+\theta)^2(\lambda - \mu)\mu(C_{IP}\lambda + \theta\lambda(-\lambda + \mu) + C_{NIP}(\theta\lambda - \mu - \theta\mu)))$

Result 1: Trade restrictions because of asynchronous approvals of a new GM crop in a given importing country will tend to increase the prices of identity-preserved (non-GMO) and NIP commodities, irrespective of the size of the importing country imposing the restrictions.

Result 2: The effect of trade restrictions on the equilibrium quantities of IP and NIP commodities depends on the relative size of the market (country) where the restrictions are imposed. For each product, if the relative size of this country is larger than some critical value, then the aggregate quantity consumed in both countries will decrease.

Welfare effects - exporter profits

Based on the prices and quantities derived above, I can now calculate the profits of IP and NIP product exporters as follows:

$$\Pi_{IP}'' = \frac{\theta(\beta\lambda-(1+\beta)\mu)(C_{IP}(\beta+\theta+\beta\theta)\lambda - C_{IP}(1+\beta)(1+\theta)\mu + C_{NIP} - (1+\beta)(1+\theta)(\lambda-\mu))\mu)^2}{\mu(\lambda-\mu)[(\theta^2+\beta(1+\theta)^2\lambda-(1+\beta)(1+\theta)^2\mu]^2} \quad (23)$$

$$\Pi_{NIP}'' = \frac{-\theta C_{IP}\lambda(\beta\lambda-(1+\beta)\mu)+\mu(-C_{NIP}(\beta+\theta+\beta\theta)\lambda+(1+\beta)\theta\lambda(\lambda-\mu)+C_{NIP}(1+\beta)(1+\theta)\mu)]^2}{\lambda\mu(\lambda-\mu)[(\theta^2+\beta(1+\theta)^2\lambda-(1+\beta)(1+\theta)^2\mu]^2} \quad (24)$$

By comparing equations (15)-(16) with equations (23)-(24), it follows that the profits of IP exporters increase irrespective of the market size parameter β, i.e. $\beta > 0 \Leftrightarrow \Pi''_{IP} > \Pi_{IP}$.

This result appears to be consistent since the trade restrictions of the NIP commodity in country *B* create the equivalent of a shift in demand to the right for the IP product. Quantities of the NIP commodity may increase or decrease but the price of the IP product would always rise in response to the restrictions. The profit of NIP-type exporter, however, can decrease if the relative size of the country *B* is more than a critical value[22] β^{Π}_{NIP} :

$$\beta > (\leq)\beta^{\Pi}_{NIP} \Leftrightarrow \Pi''_{NIP} < (\geq)\Pi_{NIP}.$$

The producers of the NIP commodity may benefit from the price increase induced by the complementarities between the IP of the NIP commodity. However, the price increase of the NIP commodity may not be large enough to compensate for the overall drop in quantity from the export restrictions. In the case where the market of country *B* is large, the profits of the NIP-type exporter would tend to decrease.

I can now summarize the main results regarding the impact of the trade restrictions on the exporters' profits:

Result 3: Trade restrictions implied by the asynchronous approval of a new GM crop in an importing country will tend to increase the profits of the IP exporter, irrespective of the size of the country imposing the trade restrictions.

Result 4: Trade restriction because of the asynchronous approval of a new GM crop in an importing country will tend to decrease the profits of NIP commodity exporters if the relative size of the importing country imposing the restrictions is larger than some critical value.

Consumer welfare

The change in the aggregate consumer welfare due to trade restrictions from the presence of an unapproved GM crop imposed by importing country *B* can be observed from Figures 3 and 4. Before the trade restrictions were put in place, consumer welfare

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[22] $\beta^{\Pi}_{NIP} =$ As the value is too big to be kept here, it will be provided on request.

was represented by area under the line *abcd* in Figure 1 which corresponds to the area under the highest utility curve each consumer can reach. Figure 3 which corresponds to the market in country *A,* shows that the utility curves for both the IP and NIP commodities will shift downward after the trade restriction is put in place. The downward shift of the utility curve is entirely explained by the increase in the prices of both products. As result, welfare declines in the importing country *A* for both the consumers of IP and NIP products. The loss is represented as the area *befdc* in Figure 3. There may be situations when the quantity of the NIP commodity increases as consumers shift away from the IP product due to relevant price increases. But even in this case, the welfare of the consumers in country *A* decreases.

Figure 4, which corresponds to the market in importing country *B* shows that the utility function for the IP product shifts downward after the trade restriction is in place because of the corresponding price increase. Since the NIP commodity is effectively banned from the market, the utility function for this product disappears completely. Some of the consumers who were buying the NIP commodity may now consume the IP products but the overall welfare decreases for those consumers who were consuming either the IP or the NIP commodity. The loss of consumer welfare in the importing country *B* is represented by the area *befdc* in Figure 4.

Based on these results, I can now summarize the impacts from the effective trade ban due to the lack of regulatory approval for certain new GM crops on consumer welfare as follows:

Result 5: In an importing country where certain new GM crops are not approved, consumer welfare will tend to be reduced due to the rise in prices of the IP products and the disappearance of the NIP commodity caused by the implied trade restrictions.

Result 6: In an importing country where all current commercial GM crops have been approved, consumer welfare will tend to be reduced due to the rise in the prices of both IP and NIP products imposed by market disruptions caused by asynchronous approvals in other importing countries.

III. Synthesis of Results and Concluding Comments

In this essay, I have derived the market and welfare effects of trade disruptions from the presence of unapproved GM crops in international agricultural commodity markets. I have developed a stylized but general trade model which allows for heterogeneous consumer preferences; segmentation of commodity and identity preserved non-GM markets; possible market power in different markets; and consideration of market size among importing countries with asynchronous approvals and restricted trade flows.

The results of my analysis appear consistent with observed behavior of various stakeholders in exporting and importing countries lending credence to their generality. A key result from the analysis suggests that the profits of exporters of agricultural commodities would tend to suffer when trade restrictions are imposed by importing countries that are large in size because of the presence of unapproved GM crops. This conclusion might then explain the behavior of separate stakeholder groups in agricultural exporting countries who have gone to great pains to align the introduction of new GM crops with their regulatory approvals in large importing countries.

For instance, the biotech industry (both through industry-wide actions and via individual firm decisions) has adopted voluntary restraints and has pledged to introduce new GM crops in the US only after regulatory approvals for these crops have been received in all of its major import markets. Commitment to such voluntary restraints are often referred to as "Stewardship Policy" and seek to reassure US farm producer groups and grain traders, the very groups that could see their profits suffer from potential disruptions in the US agricultural commodity trade (for instance see announcements by the Biotechnology Industry Organization (BIO) or Monsanto's Pledge[23]).

Similarly, as pointed out in a recent report of the DG AGRI of the EU Commission (EC DG AGRI 2007 pp. 2), regulatory agencies in some other major exporting countries, like Argentina and Brazil, appear to manage regulatory approvals for plantings of new GM crops in order to follow relevant approvals in their key importing markets. This behavior would be consistent with the results of my analysis and with the history of active government involvement in the agricultural trade of these major agricultural exporting countries.

My analysis further indicates that the profits of producers and exporters of IP non-GM products would tend to increase in the presence of trade restrictions on commodity trade because of the presence of unapproved GM crops. One might expect such groups

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[23] The full content of Monsanto's Pledge and references to BIO's position for instance can be found at http://www.monsanto.com/monsanto/ag_products/pdf/stewardship/Monsanto_Commitment_to_BIO_PLSP_05-23-2007.pdf

then to position themselves against measures that would limit the chance trade restrictions on commodities from regulatory asynchronicity. Consequently, the behavior of EU organic producers that have strongly opposed the introduction of allowances for low level adventitious presence of unapproved GM crops in the agricultural supply chain would seem quite rational in the context of our analysis.

The results I derived here also indicate that consumer welfare in importing countries would tend to decrease from disruptions in commodity trade caused by asynchronous approvals of GM crops. As a result, commodity buyers, consumer groups and governments in countries that import large amounts of certain agricultural crop commodities would be expected to support orderly regulatory approvals and trade. In this context, and since the EU is the second largest importer of commodity soybeans in the world, the calls of various European soybean buyers[24] as well as that of the DG AGRI of the EU Commission for timely regulatory approvals and the adoption of AP thresholds for low level presence of unapproved GM crops in the EU, would therefore seem reasonable.

The results in my analysis also suggest that consumer welfare losses are not limited to importing countries where trade disruptions occur but extend to other importing countries which do not experience direct disruptions in their commodity trade. These welfare losses appear particularly acute when the importing country with regulatory asynchronicity is large in size causing equilibrium prices to increase and quantities to decline in both the IP and NIP markets. Consequently, asynchronous

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[24] For instance see declaration of the European Feed Manufacturers (FEFAC) on zero tolerance of unapproved events in the face of asynchronous approvals in the EU at http://www.fefac.org/file.pdf?FileID=12138

regulatory approvals of GM crops and their implications on trade and social welfare may not be an issue of single national concern. The recent involvement of the CODEX Alimentarius in the development of international guidelines for low level of accidental presence of GM crops would therefore seem quite appropriate.

The potential market and welfare impacts I have discussed here become particularly important when one considers key emerging trends, including: (a) the fast-expanding pipeline of novel GM crops; (b) the fast-expanding GMO acreage in major agricultural export countries; (c) the expanding number of GM crops being grown and traded; (d) the expanding share of GM crops in international commodity trade; and (e) the increasing number of countries with nascent and inexperienced regulatory programs that will be called to manage a large number of regulatory submissions for new GM crops in the coming years. These trends speak to the need for significant coordination in the international regulatory system in order to avert systemic trade disruptions and associated losses in producer profits and consumer surplus. In this context, the introduction of AP thresholds provides temporary relief to regulatory asynchronicity of new GM crops by minimizing the chance of trade disruptions. In the long run, however, harmonization in the regulatory approval process of new GM crops across countries will be necessary.

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Figure 1: Utility Curves and Consumer Surplus when there are no Unapproved Crops.

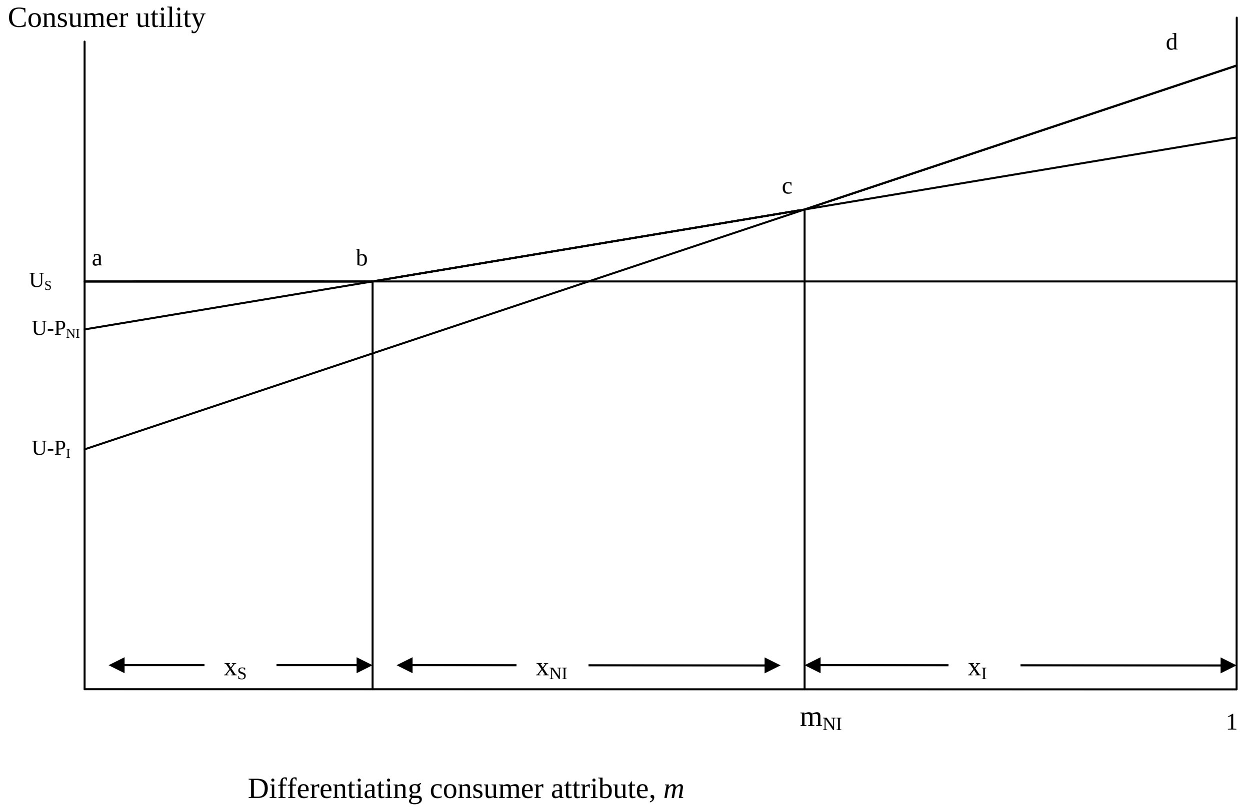


Figure 2: Demand and Marginal Revenue Curves for IP-Type and NIP-Type Products

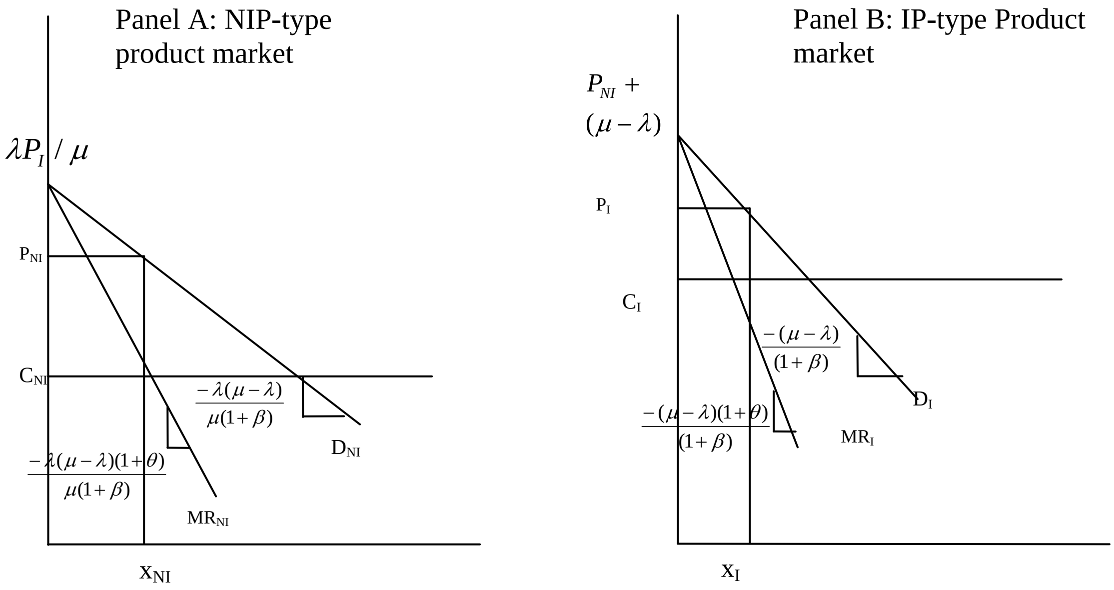


Figure 3. Utility Curves and Consumer Surplus for the Country with no Unauthorized Crops when there are Trade Restrictions.

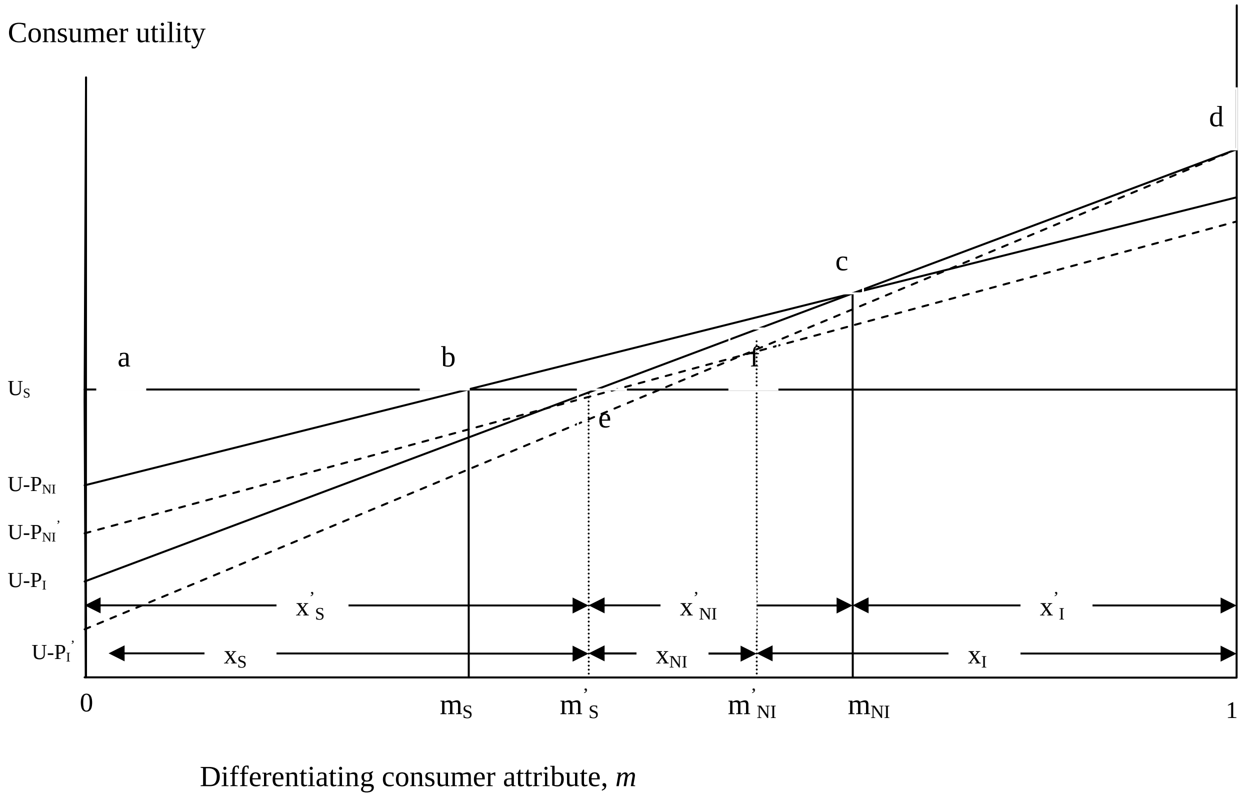
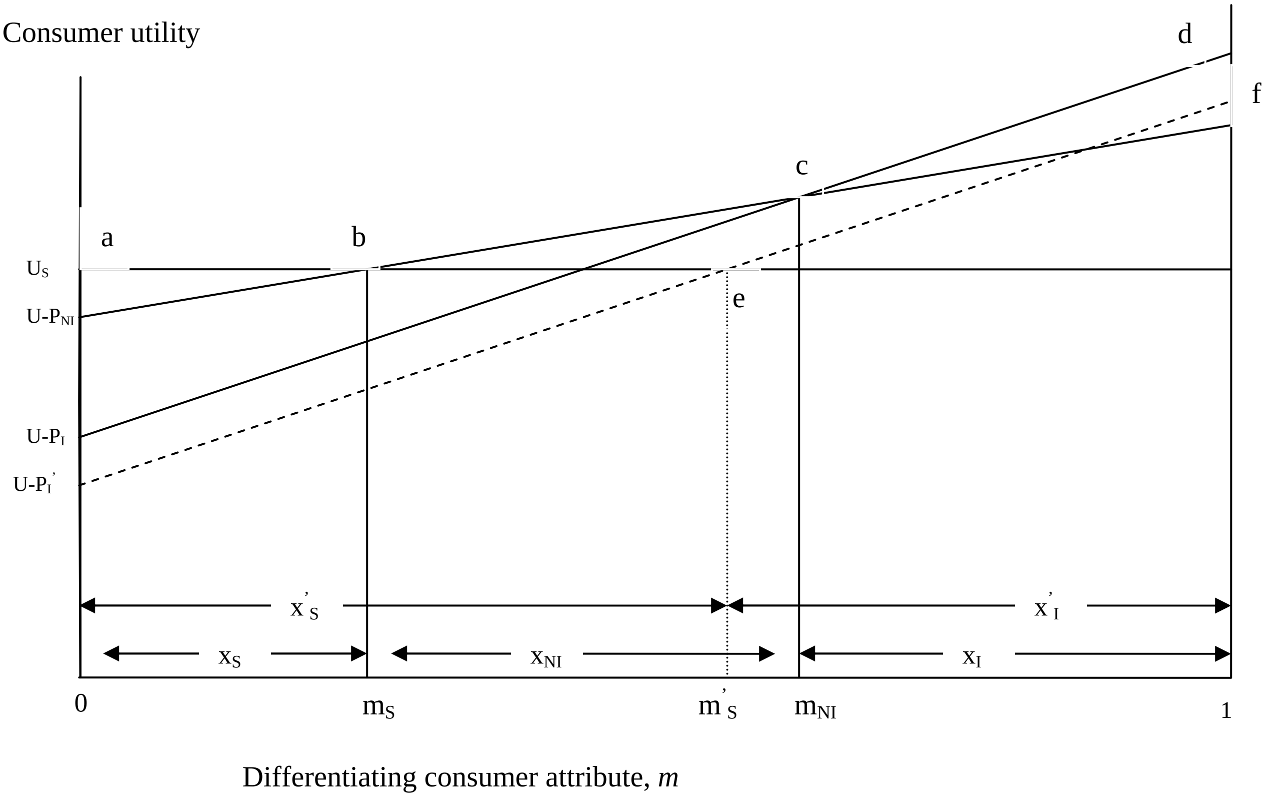


Figure 4: Utility Curves and Consumer Surplus for the Country where GM Crops are not Approved



ESSAY THREE:

THE ECONOMIC IMPACTS OF A NEW AND ASYNCHRONOUSLY DEREGULATED BIOTECH EVENT

1. Introduction

The commercialization of Roundup Ready™ soybeans in 1996 changed the way soybeans are grown in United States. Roundup Ready™ varieties have reduced the cost and improved the efficiency of weed control in soybean production and have yielded large gains for agricultural producers adopting the technology (Konduru et al., 2008). Today, more than 90% of the soybeans grown in US are Roundup Ready™ (NASS, ISAAA). The developer of Roundup Ready™ soybeans, Monsanto, has recently advanced a second generation Roundup Ready™ technology promising higher yielding soybean varieties. Monsanto has announced its intentions to launch the new technology – called Roundup Ready2Yield™ -- in the US during the 2009 growing season and to fully commercialize it in 2010 (Monsanto News Release, 2008a).

Roundup Ready2Yield™ (RRII) soybeans have received regulatory approval for food and feed use in key markets like the US, Canada, China, and Japan but they are still under regulatory review in the European Union (EU), one of the largest importers of soybeans in the world (ASA News Release, 2008). It is possible that regulatory approval in the EU could be forthcoming. Nevertheless, the European regulatory review and approval process for new biotechnology crops has been unpredictable and often slow in the past (WTO News Item, 2006). Accordingly, it is possible that RRII could be grown for one or more years while still lacking regulatory approval in a major soybean market. Under these circumstances, interruptions in certain trade flows are inevitable (FEFAC, 2007; Europabio 2008)

A number of recent studies have examined how asynchronous regulatory approvals of biotech crops can impact the trade of agricultural commodities (Thorne, et al., 2007; EC DG AGRI, 2007). These have highlighted the potentially damaging impacts of such trade interruptions on the food and livestock sectors of various countries (Backus et al, 2008; Brookes, 2008; Hirzinger and Menrad, 2005; Meijer, et al., 2007; Europabio, 2008; FEFAC, 2008). In fact, a study by the DG AGRI of the EU Commission specifically examined the potential economic impacts of the introduction of RRII in the absence of EU regulatory approval. The study concluded that feed supplies to the EU could be interrupted and feed prices in the region could, in some instances, increase significantly (EC DG AGRI 2007). The EU Commission study did not, however, provide any formal analysis of the potential benefits and costs of the innovation or of the alternative trade flows and did not draw any definitive conclusions on the potential adoption of RRII in key producing countries.

In this essay I examine the potential economic impacts from the introduction of RRII under different scenarios of adoption on the acreage, quantities produced, prices, and trade of soybeans and other related oilseeds. The levels and distribution of these impacts provide insights on the incentives of the various stakeholders and on the direction of the innovation. Based on these results, I draw conclusions on the likelihood of various adoption scenarios, the possibility of trade disruptions, and the possibility of redistribution of innovation rents in the event of asynchronous regulatory approval of the new technology.

In order to estimate the potential economic impacts of RRII soybeans I develop a partial equilibrium, multi-region, multi-crop model that captures the global interrelationships among oilseeds, competing oilseed products, as well as between oilseeds and the rest of the agricultural sector. In section II, I explain the structure of the model and how I use it to calculate shifts in the demand and supply of soybeans and other oilseeds induced by the introduction of RRII.

In section III, I present the empirical results for the baseline of my analysis – a forecast of a future where RRII would not be available. In this context, I provide forecasts of the demand and supply conditions in the global oilseed complex for the period 2009-2013. Then in section IV, I account for the potential introduction of RRII in the three top producing and exporting country – the US, Argentina and Brazil-- using different adoption scenarios. In this context, I provide forecasts for the demand and supply conditions in the global oilseed complex in the presence of RRII. Comparisons of these forecasts against the baseline represent the potential economic impacts of RRII.

In section V, I examine the trade implications of the different adoption paths under the assumption that RRII soybeans are allowed in all major importing countries except in the EU. Hence, I effectively assume that lack of regulatory approval equates to an effective import ban as identity preservation and other segregation methods (EC DG AGRI, 2007) are assumed insufficient to ensure absolute separation of RRII soybeans from the commodity system. Based on these results and those presented in sections III and IV, I draw conclusions on the likelihood of adoption of RRII and on resulting trade flows. I provide some closing comments in section VI.

II. Methodology

In order to estimate the aggregate economic impacts of RRII soybeans, I develop a conventional partial equilibrium multi-region multi-crop model. The model follows closely the general structure of the oilseed complex model developed by Kruse (2003). The model quantifies the global interrelationships among oilseeds and competing crops as well as among competing oilseed products. The oilseeds commodities covered by the model include soybeans, soybean meal, soybean oil, sunflower, sunflower meal, sunflower oil, rapeseed, rapeseed meal, rapeseed oil, and palm oil. The specific countries covered in the model include the US, Canada, Mexico, Brazil, Argentina, the European Union, China, Japan, India, Malaysia, Indonesia and all the remaining countries grouped as Rest of the World (ROW).

In the oilseed sector crushing plays an important role in the economics and trade of oilseeds. The gross crushing margins were constructed for each country after taking into consideration crushing yields and the prices the crusher receives and pays. The price transmissions between different countries account for any tariffs that exist while linking the port prices with the world prices.

On the demand side, the total demand for protein from livestock is estimated and then the share of each of the meals is calculated on a soybean meal equivalent basis. Again, I follow Kruse (2003) who used theoretically derived specifications to capture feed demand linkages with the livestock sector. This specification results in high degree of substitution among the meals providing a realistic representation of market conditions. Similarly the total demand for oils in each country is estimated and then the share equations are estimated for each type of oil.

The general structure of the model can be summarized by a set of equations which form the basis of the supply and demand conditions for each oilseed, country and year, as follows:

Beginning Stocks = Ending stocks$_{t-1}$

*Production = Harvested Area * Yield* ………………………………………….(Oilseed)

*Production = Crush * Crushing Yield* …………………………………...…(Meal and Oil)

Total Supply = Beginning Stocks + Production + Imports

Total Demand = Crush + Food Use + Other Use + Exports + Ending Stocks ....(Oilseed)

Total Demand = Food Use + Feed Use + Industrial Use + Exports + Ending Stocks …...
(Meal and Oil)

Domestic Use = Crush + Food Use + Other Use + Ending Stocks ………………...(Oilseed)

Domestic Use = Food Use + Feed Use + Industrial Use + Ending Stocks ….. (Meal and Oil)

To run this partial equilibrium model, one country is chosen as the residual supplier wherein the price is determined. The price from this country is then linked to every other trading country using price linkage equations that include relevant import tariffs and taxes. For soybeans, the residual supplier is the US and the price determined in this country is taken as the international market price.

Adoption of RRII is introduced exogenously in the model through an overall increase in total soybean crop yield in proportion to the RRII adoption rate. For example if RRII (with a yield advantage of 8 percent) is adopted in 10 percent of the soybean acreage in a given country, the yield of all soybean acreage in this country is increased by 0.8 percent.

Adoption of RRII brings about supply and demand shifts which can be isolated through the accompanying changes in the equilibrium prices, acreage, production and trade. To illustrate the basic workings of this framework consider a simple two-region example as in Figure 1. Panels A, B and C represent respectively the home country where RRII is initially adopted (Country A), the interaction of excess supply and excess demand and the Rest of World (ROW). To simplify exposition, all the supply and demand curves are assumed linear in this example. The international equilibrium price P_0 is obtained from the intersection of excess supply ($ES_{A,0}$) and excess demand curves ($ED_{B,0}$). Due to the introduction of the innovation in country A, there would be a parallel shift in domestic supply from $S_{A,0}$ to $S_{A,1}$, and consequently a shift in the excess supply from $ES_{A,0}$ to $ES_{A,1}$. If there is introduction of the technology in the rest of the world the technology spillover would induce a supply shift from $S_{B,0}$ to $S_{B,1}$ in ROW and, correspondingly, a reduction in excess demand from $ED_{B,0}$ to $ED_{B,1}$. Accordingly, the world price would fall from P_0 to P_1.

Due to the innovation and its spillover, country A producers benefit as long as the overall price reduction (from P_0 to P_1) is smaller than the initial vertical supply shift in country A. The benefits to producers in country A are represented by the area P_1bcd in panel A. As illustrated in figure 1, ROW producers are net losers, even after the adoption of the innovation as the area P_1ij is less than the area P_0hk, but, in general, they could gain or lose. The benefits to consumers in country A are P_0aeP_1 in panel A and the benefits to consumers in the ROW are P_0fgP_1 in panel C.

Alston, Norton and Pardey's (1995) economic surplus method has been commonly used for estimating economic impacts and associated welfare changes from the introduction of innovation (e.g. Falck-Zepeda, et al. (2000), Moschini, Lapan and Sobolevski (2000)). For our simple example, the change in consumer surplus (ΔCS) and the change in producer surplus (ΔPS) could be calculated as:

$$\Delta CS = (P_o - P_1)C_o + \frac{1}{2}(C_1 - C_0)(P_0 - P_1)$$

$$\Delta PS = P_0 Q_0 (K - Z)(1 + 0.5Z\varepsilon) \Rightarrow \ for \cdot soybean \cdot producers$$

$$\Delta PS = -P_0 Q_0 Z (1 + 0.5Z\varepsilon) \Rightarrow \ for \cdot other \cdot oilseed \cdot producers$$

where P_0 is the baseline price, P_1 is the price after the innovation is introduced and Z is the relative price change given by $-(P_1 - P_0)/P_0$. The baseline quantities produced and consumed are given by Q_0 and C_0 respectively. The quantities produced and consumed after the introduction of the innovation are denoted by Q_1 and C_1 respectively. ε is the elasticity of supply and K is the percent vertical shift in supply following the introduction of the innovation.

Unfortunately, welfare measures like these do not easily generalize in the case of more complex models like the multicrop, multiproduct, multiregion model I use here. A number of complications emerge. The welfare formulas presented above assume linear supply and demand functions and vertically parallel supply shifts, whereas more complex empirical specifications often imply non-linear functions and multiplicative shifts.

Similarly, the above welfare measures were developed for a single-market analysis and generalizing them in the context of a multi-market analysis can be tricky. As discussed by Alston, Norton, and Pardey (1995) the appropriate measures to take in a multimarket case depend on what is being held constant in the simulation--in particular, what is being assumed about the prices of other outputs. As the number of markets and products considered increases such complications also increase. For this reason, in this study I use the estimated changes in producer profits and consumer expenditures that could result from the introduction of RRII as indicators of the potential welfare changes among the producers and consumers in various countries instead of the more standard producer and consumer surplus measures.

III. Baseline Development

In recent years, the international oilseed market has been impacted by key structural changes including significant increases in the soybean acreage of South America and increased food and feed demand for oilseeds in China. Soybean acreage in key South American soybean producing countries, mainly Argentina and Brazil, has grown strongly in the last two decades. Over the 1990-2008 period soybean production increased by 330 percent in Argentina and 310 percent in Brazil. As the domestic use of soybeans in Brazil and Argentina is relatively limited, exports of soybeans, soymeal and soyoil from these countries have also increased quickly. Soybean exports from Argentina almost doubled from 1990 to 2008, even though its share of world exports declined from 20 to 12 percent (Figure 2). Argentina is also a major exporter of soymeal and soyoil representing approximately 54 and 65 percent of the 2008 world soymeal and soyoil exports respectively (Figure 3). Brazil, on the other hand increased its share of world soybean exports from 6 percent in 1990 to 42 percent in 2008.

Due to the rise of these two South American countries in soybean production and trade, the prominence of the US in international soybean markets has comparatively diminished over the last two decades. Its share of world soybean exports has decreased from 74 percent in 1990 to 45 percent in 2008 (Figure 2). This has been the result of a relatively lower rate of growth in soybean production --3.5 percent in US as compared to 9.6 percent in Argentina and 6.7 percent in Brazil-- and an increase in the domestic use of soybeans.

Another key change in the global soybean complex in the last two decades is the steep rise in the demand for soybean imports from China. Rising living standards have led to increasing consumption of meat which in turn has caused the continuous increase in demand for soymeal. As its own soybean production has not grown fast enough to meet the burgeoning demand, China has become the largest importer of soybeans in the world in recent years (Figure 4). Soybean imports to China now constitute about half of world exports. China has not been a major importer of soybean meal or soyoil and hence import shares in these markets have been more stable (Figure 5).

To examine the future market trends in the global soybean complex, I use the partial equilibrium model I described in the previous section. I first analyze market developments in the absence of the new biotechnology (a world without RRII) over the period 2009-2013. This constitutes the baseline forecast for this period and the results are presented in Tables 2-4.

The results of the baseline forecast suggest that over the 2009-2013 period, historical trends would persist. The world soybean acreage would grow at a rate of 1-2 percent per year. Most of the growth would come from Argentina and Brazil as US would see its soybean acreage decrease slightly. Brazil's share of world soybean production would rise from 26.5 percent to 29.5 percent and the share of Argentina from 20.3 to 21.2 percent. Over the same period, the US share of world soybean production would decrease from 35 percent to 31 percent. The share of the US in the world soybean export market would also decrease from 45 percent in 2008 to 35 percent in 2013, mostly due to the increased competition from Brazil and increased level of domestic crush (Table 4).

The baseline forecast also shows that Argentina and China would continue to expand their shares of world soymeal and soyoil production while Brazil and the US would see theirs decline over the 2009-2013 period (Table 2). Both Argentina and China have significantly increased their soybean processing capacity in recent years. Argentina and, in particular, China could expand soymeal and soyoil production even in the absence of any additional short run investment due to existing excess processing capacity.

It is worth noting that domestic consumption of soymeal as a proportion of production in Argentina is only about 2 percent, whereas it is 50 percent in Brazil and 80 percent in the US. This is not surprising as Argentinean crushing capacity has been built with export markets in mind through the imposition of taxes (subsidies) on exports of soybeans (soymeal, soyoil). These policies have turned Argentina into the preeminent exporter of soybean meal and oil in the world market. According to the baseline forecast, during the 2009-2013 period such trends would continue to strengthen. Argentina's share in soymeal exports would increase from 55 percent to 58 percent. Similarly, its position in soyoil exports would expand. Given the interest of the EU in oil imports for industrial uses like biodiesel, Argentina's soyoil exports could find opportunity.

The baseline forecast also suggests that China would continue to expand its position as the dominant importer of soybeans in the world market. China's share of world soybean imports would increase from 52 percent to 58 percent during the 2009-13 period. The increase would be driven by expanding demand for feed from the meat and poultry sectors. Over the 2002-08 period, soybean crush in China grew at an average annual rate of 11 percent. It is estimated that soybean crush would grow at 4-5 percent from 2009-13. China's import demand for soymeal has generally been negligible in the past and would continue to be so through 2013. Imports of soyoil would decline at a slow pace and remain modest in size.

According to the baseline forecast, the other major importer of soybeans, the EU, would maintain its imports of soybeans and soymeal over the 2009-2013 period at about the same levels as in recent years. EU soybean imports represented 22 percent of total world imports in 2008 and would remain at similar levels in the 2009-2013 period. EU's soymeal imports represented 42 percent of the total world imports in 2008. These would decline slightly over the 2009-2013 period due to a softening demand for feed.

Given these demand and supply conditions, soybean prices would decline slightly over the 2009-13 period. Prices for soymeal and soyoil would follow divergent trends due to differential demand conditions (Table 3). Overall, price changes are projected to be quite moderate.

IV. Scenarios of RRII Adoption and Potential Economic Impacts

How would these baseline forecasts change if RRII was introduced and adopted in major producing and exporting countries? And what would be the likely impacts on acreage, production, prices, trade as well as producer income and consumer expenditures? The introduction of this new yield-increasing technology would generally be expected to expand production; increase the profitability of the adopters; reduce soybean prices; decrease the profitability of non-adopters; expand consumer demand; and, potentially, reduce consumer expenditures. The exact effects however depend on the pattern of adoption and key structural characteristics of the oilseed complex and hence can only be quantified through empirical analysis. I calculate such effects under different scenarios of RRII adoption here.

I begin by making certain assumptions on the agronomic effects of the technology and its potential adoption paths. These assumptions are summarized in Table 1. First, I assume that adoption of RRII leads, on average, to an 8% yield growth but provides no additional variable cost efficiencies against existing technologies. As RRII is yet to be commercially introduced, there is no available information regarding its actual yield or cost performance in producers' fields. However, Monsanto has indicated that based on multiyear experimental yield trials the technology has displayed a 7-11% yield advantage (Monsanto News Release, 2008b). Accordingly, in this essay I assume that RRII offers a yield advantage close to the lower bound suggested by the technology developer.

Second, I assume that RRII could be potentially available for adoption in the US, Argentina and Brazil though the technology developer has not declared its intentions for release in countries outside the US. I also assume certain adoption paths for all adopting countries. For the US, I assume that introduction would occur in 2009 at a limited scale where RRII would be grown on 3% of all soybean acreage. I also assume that adoption would expand to 14% in 2010. These adoption levels correspond to the stated acreage targets set out by the developer of the technology. I then assume that adoption would expand to 41, 68, and 100% in the following three years. For Brazil and Argentina the assumed adoption paths are the same as in the US but introduction of the technology would occur in 2010. These assumptions are not meant to accurately anticipate the future adoption paths of RRII but rather provide a context where benefits and costs from the introduction of the technology in the presence of asynchronous approval can be examined. In this way, relevant incentives and associated actions by various stakeholders can be examined.

Finally, I make no assumptions of increased seed prices or technology fees that farmers may have to pay to Monsanto for the use of the RRII technology. It is almost certain that such incremental seed prices will exist and that they will influence the adoption of the technology and the distribution of economic surplus between producers and the technology developer. Nevertheless, since adoption paths are imposed exogenously on the model, considerations on the pricing of the technology are effectively subsumed in these paths.

Under the first scenario then the US would be the only country where the technology is available for adoption. Because of RRII adoption in the US, soybean production would increase by 0.2 percent in 2009 with the rate of growth becoming progressively faster reaching 6.9 percent by 2013 (Table 5a). As US soybean production and supply would continue to expand the US and other international prices would begin to gradually decline in response (Table 5b). The US and international soybean price (CIF Rotterdam) would decrease by 0.4 percent in 2009 and would drop by 7.3 percent in 2013. Hence, the rate of price decline would be slightly faster than the rate of supply expansion in the US. In all, the average decline in the CIF Rotterdam, FOB Argentina, and FOB Rio Grande prices over the period of analysis would be 3.6, 3.9 and 3.7 percent respectively.

Because of the price pressure, soybean acreage in the US, Argentina, Brazil and other parts of the world would gradually fall leading to an average annual reduction of 0.6 percent in world soybean acreage over the period of the analysis (Table 5a). Acreage declines are higher in Argentina and Brazil leading to parallel falls in soybean production in these countries. These would be more than made up by production increases in the US, however. As a result, the productivity of the soybean sector would increase significantly from the introduction of RRII in the US as world soybean production increases by an average of 0.5 percent while using 0.6 percent less land every year.

Price reductions in soybeans would be passed on to soybean meal and oil markets (Table 5b). However, the rate of price decline is different for the two value added products. The demand for soybean oil is more elastic and as result the rate at which world soy oil prices decline would be lower -- approximately 1.6 percent per year over the period of analysis. Soymeal demand is less elastic and under expanding supply soymeal prices in the US, Argentina and Brazil would all decline by more than 10% in 2013. These represent an average rate of decline of more than 5% per year over the period of analysis. The prices of competing oils and meals would also be affected. Sunflower, palm and rapeseed meal and oil prices decline in response to the expanding supply of soybeans and soybean products resulting from the introduction of RRII. Prices of rapeseed and sunflower oil are the most closely affected experiencing average price declines of 3.6 and 1.9 percent per year over the period of analysis.

With declining prices both domestic and import demand for soybeans, soybean meal and soybean oil would expand (Table 5c). In the US domestic use of soybeans would expand by almost 2 percent per year over the 2009-2013 period. Similarly, domestic use of soybeans would expands in the EU (2.2% per year), China (0.6% per year), and other parts of the world. Demand for soybean oil and meal would expand in every part of the world as well at an overall average rate of 0.5 percent per year.

Because of the shifts in soybean supply and demand conditions the patterns of trade would also adapt (Table 5c). US exports of soybeans would increase from 0.5 percent in 2009 to 14.3 percent in 2013 while at the same time soybean exports from Brazil and Argentina would decline by an average annual rate of 1.7 and 5.7 percent respectively. Soybean meal and oil exports from South America would remain stable, however, while US exports of these value-added products would expand significantly. Hence, the adoption of RRII in the US has significant implications for the competitiveness of the country and that of its main competitors in South America.

With expanding use and declining prices, consumers around the world gain handsomely from the new soybean biotechnology (Table 5d). To consume the same amounts of soyoil and soymeal used under scenario 1 in the absence of the RRII technology, Chinese consumers would have had to spend in excess of $1.2 billion more in 2013 alone; EU consumers would have spent over $1.0 billion more in the same year;

and consumers in the ROW would have spent over $2.5 billion more. Indeed, in 2013 when adoption of RRII would reach 100% in the US, consumers around the world would gain approximately $9.0 billion from the introduction of the new biotechnology. More than half of these consumer gains would be transfers from soybean producers in the US, Argentina, Brazil and elsewhere. These are producers who would not adopt the new technology and whose profits would fall in the face of declining prices. The rest of the consumer gains are net increases from productivity improvements.

The adopters of the technology in the US would also be rewarded sizably, especially in the early stages of the innovation cycle where gains would reach $776 million in 2011 (Table 5d). As the rate of price decline increases, profits from the innovation erode. Nevertheless, at 100% adoption level US producers would gain $43million per year from the new technology.

There is an additional gain from the adoption of RRII that would come in the form of land release from soybean production to alternative uses. To appropriately evaluate this gain, one must price the released acreage at the per acre profitability of its best alternative use. This is a difficult calculation in the aggregate as best alternative uses would likely vary from one location to the other. I use the average national land rental rates as an approximation of such value here. Valued at these rates, released soybean acreage would add $76 million per year by 2013.

Under scenarios II, III and IV, adoption of RRII would expand beyond the US. The resulting changes in soybean acreage, production, prices, trade and producer and consumer gains under these scenarios would be qualitatively similar to those described under scenario I above but they would be swifter and deeper. Productivity would increase across all adoption scenarios as world soybean acreage would decline and production would increase in all cases. World soybean acreage would decline from 0.8 percent per year under scenario II to 1.1 percent per year under scenario IV when producers in all three major soybean exporting countries would use the RRII technology (Tables 6a, 7a, 8a). At the same time, world soybean production would grow by an average 0.7 percent per year under scenario II up to 0.9 percent per year under scenario IV.

As world production and supply would expand, soybean prices would decline in response (Tables 6b, 7b, 8b). The rate of decline in soybean prices would accelerate with the level of adoption and would be slightly faster than the rate of supply expansion in the adopting countries. In all, the average decline in the CIF Rotterdam soybean price would be 5 percent per year under scenario II and up to 6 percent per year under scenario IV.

Price reductions in soybeans would be passed on to soybean meal and oil markets but soymeal prices would drop faster at an average 6.7 percent per year under scenario II up to 8 percent per year under scenario IV. Soybean oil prices would also decline but a much slower rate – just over 2 percent per year under all three adoption scenarios.

The prices of competing oils and meals would also be affected. Sunflower, palm and rapeseed meal and oil prices would decline in response to the expanding supply of soybeans and soybean products caused by the adoption of RRII. Prices of rapeseed and sunflower meals would be the most closely affected experiencing average price declines of almost 5 percent per year under scenario II and up to 6.8 percent per year under scenario IV.

With expanding use and declining prices, consumer gains around the world would continue to swell as technology adoption would expand beyond the US (Tables 6d, 7d, 8d). Consumers would gain between $11.5billion under scenario II and $14 billion under scenario IV. Over half of these consumer gains would be transfers from producers and the rest would be net productivity gains. Innovation rents captured by producers who adopt the new technology would dissipate fast, however, as soybean prices would ultimately decline faster than yields grow.

V. Potential Impacts of Regulatory Asynchronicity in the Soybean market

From the analysis in the previous section it follows that the introduction and adoption of RRII would cause strong productivity gains, land savings, growth in the supply and demand for soybeans, soymeal and soyoil as well as declining prices for these commodities. The potential for higher profits provide incentives to producers for adopting the new technology. Pressures from potential losses of competitiveness also create incentives for producers to adopt. Countries which produce and export large amounts of soybeans and value added products –like the US, Argentina and Brazil -- would therefore have a keen interest in the new technology.

The empirical results of the previous section also indicate that consumers across the world –many of them in importing countries – would be primary beneficiaries from the introduction of the new technology due to expanded product use at reduced prices. Countries which import large amounts of soybeans and value added products – like China and the EU – would therefore have strong incentives to provide timely regulatory approval so that the new soybeans could be freely traded.

Nevertheless, a variety of factors could interfere with and delay the regulatory process in any given country (e.g. country-specific safety concerns, bureaucratic inertia, or stakeholder resistance). In such an event, regulatory approval across the world could occur asynchronously. Lack of approval in one or more markets would act as an import ban and would result in a segmented world market with one segment trading soybeans and value added products that would exclude RRII soybeans and another trading products that could include them.

The partial equilibrium analysis I presented in section 4 evaluated the economic impacts of RRII adoption in a world uninhibited by trade bans. How would the empirical results of this analysis change then if restrictions were imposed on certain trade flows due to lack of regulatory approval of RRII in the EU? I consider this question in this section.

To fully explore this question, specific constraints on trade flows would need to be explicitly modeled. However, it is not possible to explicitly represent an EU import ban on RRII soybean imports from a particular country within the modeling framework I have used so far. This is because the partial equilibrium oilseed model I have used in this study assumes products from all countries to be homogenous and perfect substitutes of each other. In this context, the model includes only information about the net trade position of each country but not of its bilateral trade flows. In order to explicitly impose restrictions on certain trade flows of soybeans and value added products from a particular country to another the use of a spatial equilibrium model would be necessary (Takayama and Judge (1966)). In spatial equilibrium models distribution and transportation costs, trade policies, and other country-specific supply and demand conditions determine the equilibrium prices and trade flows. Accordingly, certain directional trade flows could be constrained and the impacts of such constraints on the equilibrium conditions could be explicitly measured.

While the use of a spatial equilibrium model could capture the impact of an EU ban on imports from RRII producing soybean countries, empirical implementation of such a model is less than straightforward. A spatial equilibrium model for the global oilseed complex is rather demanding in data that is not easily accessible (e.g. country and product specific price, transport and other cost data, production and trade data by product type, origin and destination, etc).

Despite its analytical limitations in explicitly imposing an EU trade ban through the absence of regulatory approval of RRII, the partial equilibrium model and the empirical results derived in the previous section do allow further insight to the question in hand. Specifically, production, processing, and trade under the various adoption scenarios presented in section 4 can be examined to assess what adjustments in adoption and trade would be necessary, if any, to facilitate market segmentation. Given the dominant position of the US, Argentina and Brazil in the production and trade of soybeans and value added products (Figures 2 and 3), the adoption scenarios considered in the previous section are adequate for examining whether an EU import ban on RRII could be facilitated and its market be supplied without significant disruptions.

The need for possible adjustments in the face of an EU import ban on RRII soybeans and resulting market segmentation depends on the adoption path of the new technology. It is easier to begin by considering the case where the technology is adopted by the US, Argentina and Brazil (scenario IV). Under this scenario, all three major producers and exporters produce soybeans that contain RRII and hence the EU market could not be effectively supplied under a RRII ban. Even if the technology was available to all key exporting countries this scenario would be unrealistic and could not occur in reality. Given the importance of soybean meal to the EU livestock industry and the lack of a viable substitute ((EU DG Report, 2007) the EU would be expected to offer appropriate compensation in the form of price premiums to the producers of one or more key exporting countries to pass up adoption of RRII and ensure supplies for its market. As a result, scenarios I, II and III are more likely in the event of an EU import ban. For these scenarios the implied net export and import positions of all relevant countries are presented in Table 9.

Scenarios II &III represent the cases where the technology would be available only to one of the South American countries or cases where the EU would offer compensation to either Argentina or Brazil to avoid adoption of RRII in order to ensure that its market is supplied. In scenario II, RRII would be adopted by the US and Argentina while Brazil would the only major supplier of the EU market. Brazilian soybean exports more than double the net soybean imports of the EU in any given year (Table 9 – scenario II). At the same time, its total soymeal exports fall well short of the total EU soymeal demand. Hence, either the EU or Brazil or both would have to increase soybean crushing to meet current market conditions. In the EU, soybean crushing capacity has been decreasing in recent years as rapeseed crushing capacity has been growing to meet the needs of its biodiesel market (FAS Attaché report, 2007). Brazil's soybean crushing capacity is currently underutilized and could be increased if sufficient demand for soybean meal existed. Specifically, in 2007 the total installed soybean crushing capacity of Brazil was about 143000 tons per day (FAS Attaché report, 2008).

Assuming it remained the same in 2009, the needed amount of approximately 26 million metric tons could be produced in 170 days. Hence, while imbalances exist, Brazil could alone adequately supply the EU soybean and soymeal markets over the period of the analysis.

In scenario III, RRII would be adopted in the US and Brazil while Argentina would be the only remaining major supplier for the EU markets (Table 9-scenario III). Imbalances in net imports and exports of soybeans and soymeal are reversed in this scenario. While Argentina's net exports of soymeal well exceed the EU's net imports, its exports of soybeans fall short of the current needs of the EU market. To meet current market conditions, either Argentina would have to export more soybeans and process less of them at home or the EU would have to import more soymeal and reduce its utilization of its soybean processing capacity. Given Argentina's bias towards value added exports, either adjustment would likely involve added costs. Despite such incremental costs and while imbalances exist, Argentina could alone adequately supply the EU soybean and soymeal markets over the period of the analysis.

In scenario I where RRII would be adopted only in the US, both Brazil and Argentina remain viable suppliers for the EU soybean and soymeal markets and major adjustments in trade flows or processing activities are not necessary to meet current market conditions. Scenario I would be preferred by the EU as it would likely involve smaller adjustment costs and lower price premiums (if any) to generate supplies. On the other hand, this scenario would be unattractive to both Argentina and Brazil as they would see their competitiveness against the US diminish, experience lower profits from lower prices and would like capture minimal premiums for supplying the EU market as they would still have to compete for it. This scenario, therefore would only exist if the innovator would impose it by introducing its new RRII technology only in the US market.

It is interesting to note that in the past the intellectual property rights (IPRs) of biotech innovations have been difficult to protect in Brazil and Argentina (Goldsmith et al 2003) and capturing value from new biotechnologies has been challenging for the innovators. Hence, it is likely that the developer of RRII could capture maximum benefits from its technology by introducing it only in the US market thereby maximizing the gains of the US producers and hence the value it could share in as IPRs are well protected in that market (compare tables 5d, 6d, and 7d). Under this scenario the EU would also benefit the most from the new technology, especially if the innovation had secured regulatory approval insuring uninterrupted trade. At this time, the innovator had confirmed its intentions to commercialize the technology only in the US. Similarly, the EU is vigorously pursuing regulatory approval of RRII. Both would seem to be reasonable behaviors in the light of the present analysis.

VI. Summary and Concluding Comments

In this essay I have examined the potential economic impacts from the adoption of a new soybean biotechnology, RRII, in the US, Argentina and Brazil –the three countries that represent the bulk of the global soybean production and export capacity. I have also examined the implications of the introduction of this new technology in the absence of regulatory approval in the EU. Such asynchronous approval would effectively impose an import ban on RRII soybeans in the key EU market and would segment the global market into two separate ones – a market for soybeans and value added products that could include RRII and a market that could not.

The preceding analysis indicates that depending on the supply and demand conditions of the commodity and value added products in key exporting and importing countries as well as the relevant adoption paths of the new technology, the implied market segmentation may or may not be easily accommodated. Import countries lacking regulatory approval would need to compensate one or more producing countries to refrain from adoption in order to supply their markets. Alternatively, the innovator can impose market segmentation through asymmetric introduction of the new technology. My analysis suggests that the distributional impacts of these alternative paths to market segmentation would be quite different.

The size of the innovation rents from the adoption of RRII derived in this study hint at the levels of compensation that might be necessary to convince certain producers to forego adoption. However, full and accurate valuation of such compensation schemes would require a spatial equilibrium model where restrictions on directional trade flows can be explicitly imposed and the resulting prices can reflect the implied market segmentation. Such spatial equilibrium models would need to account not only for the location of production and associated directional trade flows but also for the location of processing activities and the trade flows of value added products.

It is worth noting, that as the number of new biotech innovations and the degree of regulatory asynchronicity increase the resulting market segmentation becomes more complex, both to achieve and to analyze. This is not a hypothetical situation. There is currently another new biotech innovation (Liberty Link soybeans) which is being considered for commercialization. It has received regulatory approval for food and feed use in the US, Canada, Japan, and the EU but not in China. Obviously, introduction of both RRII and Liberty Link soybeans at this time would greatly complicate trade in the global soybean complex. Given that the soybean biotech pipeline is currently quite full and that regulatory agencies around the world continue to approve new biotech products at very different pace, considerations of trade disruptions and associated economic impacts from regulatory asynchronicity are likely to surface repeatedly in the coming years.

In this analysis I have assumed that redistribution of trade under regulatory asynchronicity can occur without cost when adequate supplies exist to facilitate shifts in trade flows. While this is a convenient simplifying assumption, it is likely not realistic as significant displacement of trade from one country to another would likely imply significant search and other transaction costs, incremental transport costs, quality differentials that may or may not be possible to accommodate, difficulties in the alignment of existing supply chains and other non-trivial issues. These are likely to make relevant trade adjustments more complex and costly and, in some cases, not possible.

Finally, it is important to note that all the figures I have presented in this study on the changes in acreage, production, prices and trade as well as the innovation rents and their distribution resulting from the introduction of RRII are most appropriately understood in a relative rather than in an absolute sense. Year-to-year variations in weather (e.g. drought), pest pressure and other factors would tend to shift the levels of all the changes I discussed in earlier sections. The distribution of innovation rents would also change accordingly. The figures I presented earlier do not account for potential structural changes either. Structural shifts in the demand for soybeans and value added products (e.g. through changes in various biofuels policies) or in their supply (e.g. through new environmental regulation) could shift both the levels of changes I described and their distribution. Irrespectively, the direction and the relative size of the economic impacts and their distribution I presented in this study allow a solid description of the relevant incentive structure in the market place and provide insights on the potential behavior of stakeholders. These findings are robust and can be generalized over other biotechnologies and markets.

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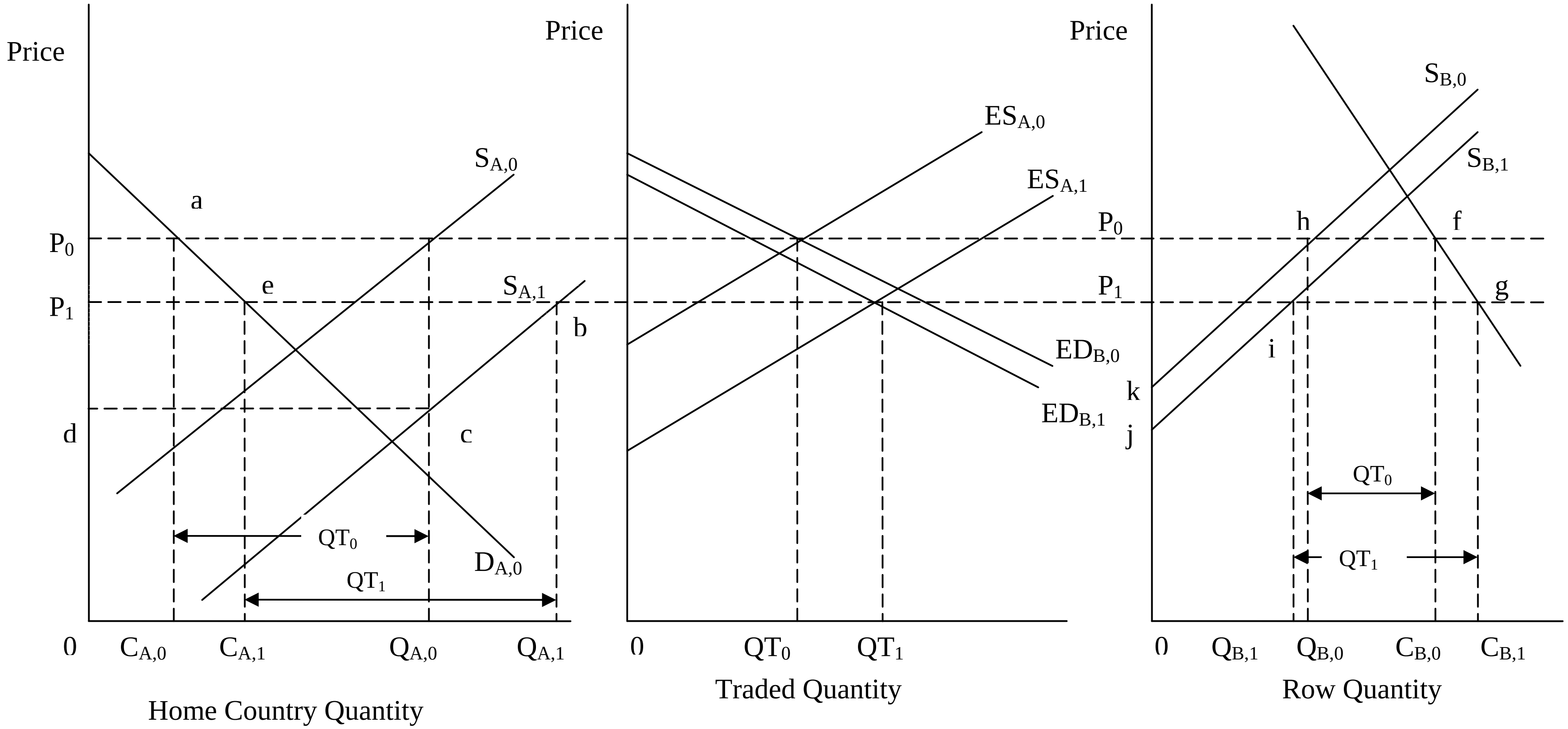
Figure 1: Size and Distribution of RRII Benefits



(A) Home Country Production, Consumption & Trade

(B) Excess Supply, Demand, & Trade

(C) ROW Production, Consumption & Trade

Figure 2

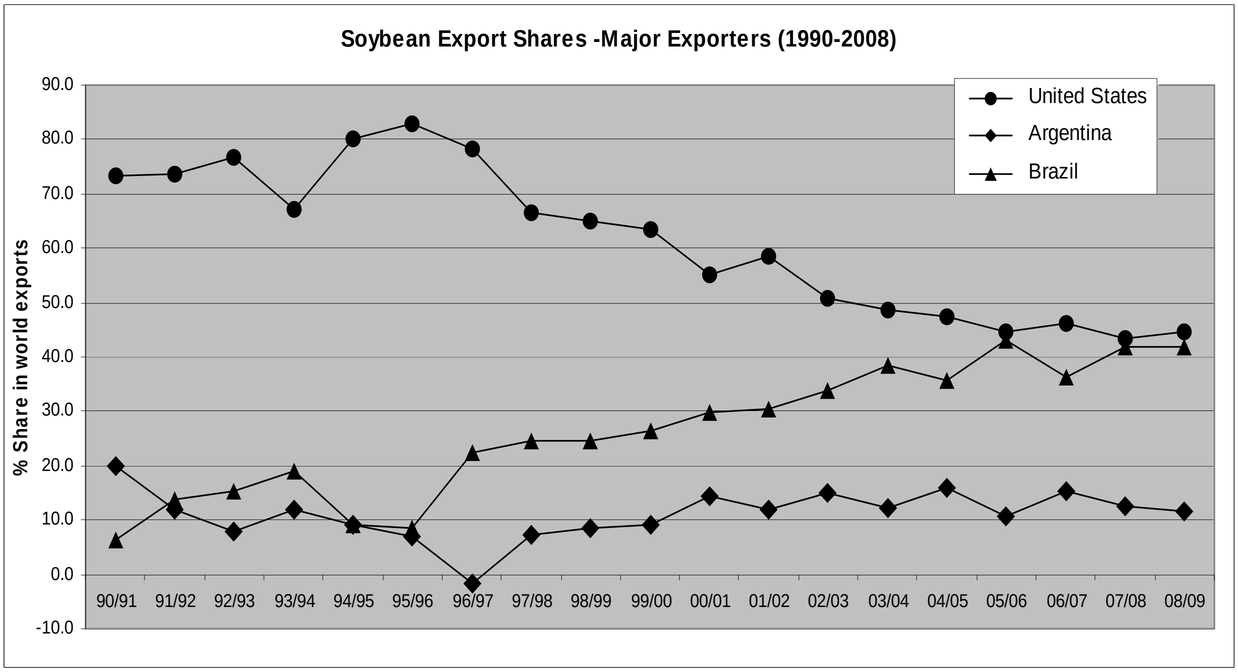


Figure 3

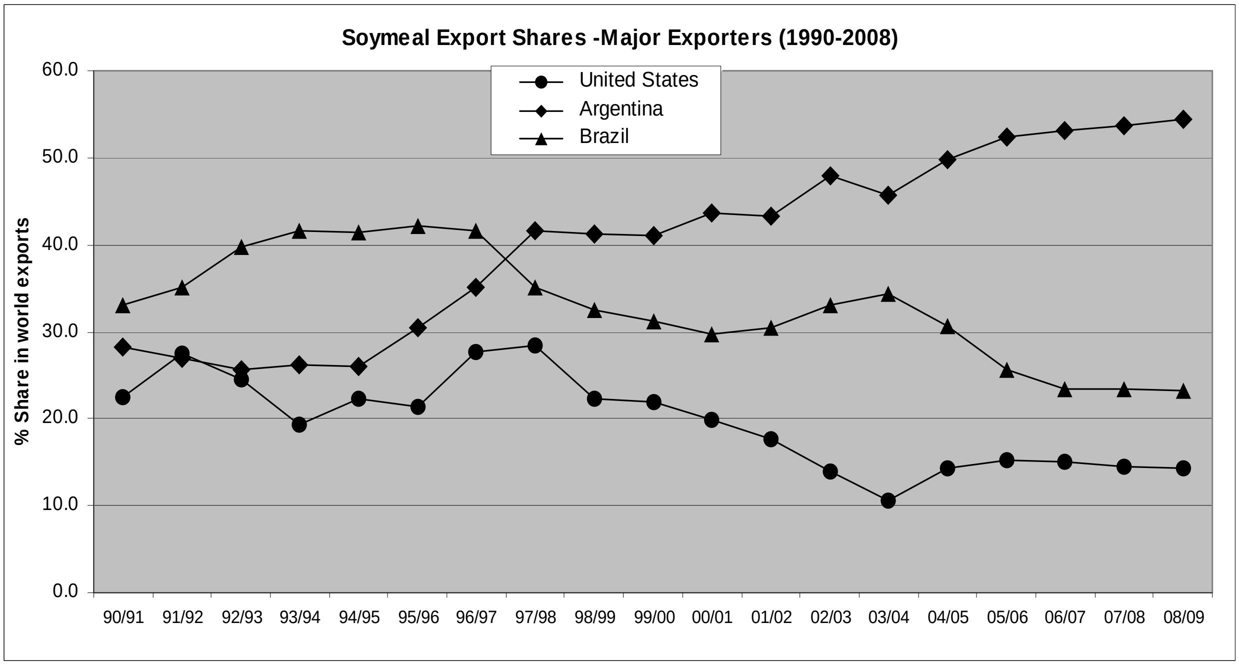


Figure 4

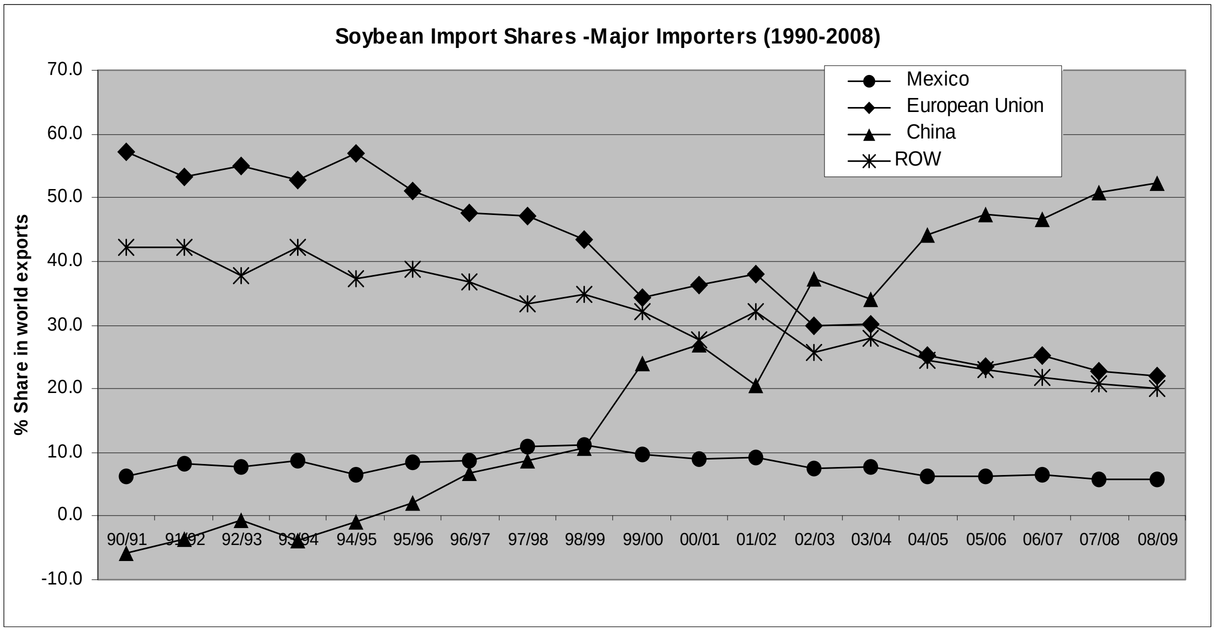


Figure 5

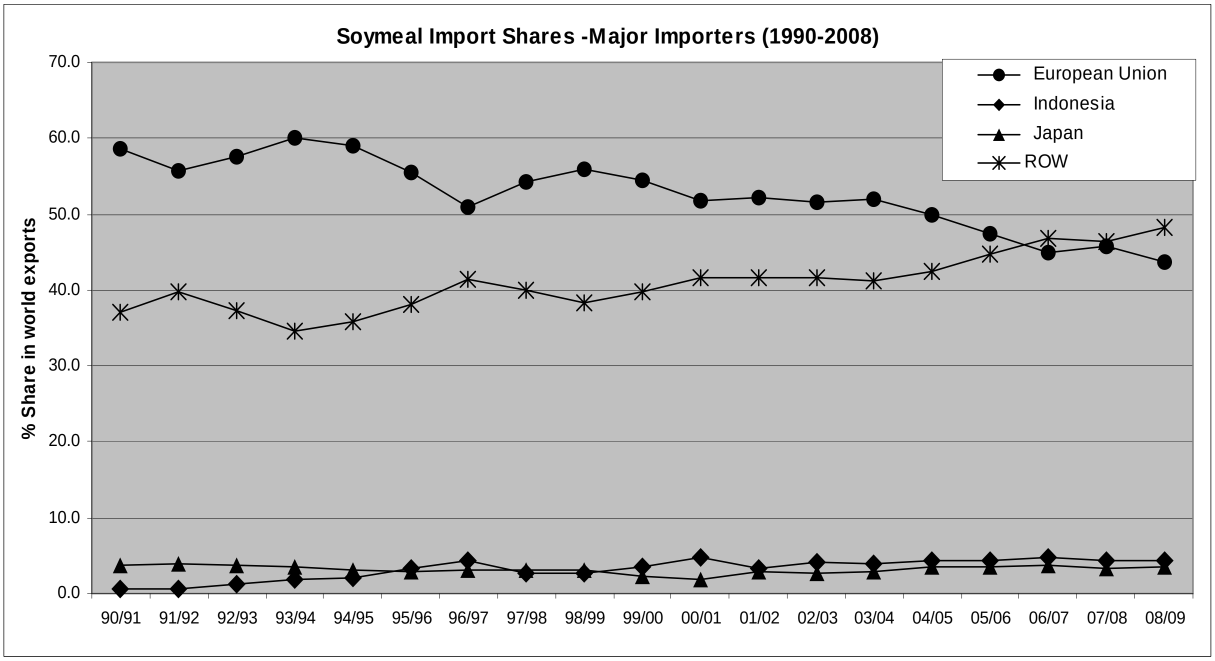


TABLE 1: Assumptions of Yield advantage for RRII soybeans and adoption rates in various countries

	2009	2010	2011	2012	2013
Yield Advantage (%)	8	8	8	8	8
Adoption Rates of RRII					
Scenario I - Only US(in million acres)	2	10	30	50	73
Scenario I - Only US (%)	3	14	41	68	100
Scenario II - US (%)	3	14	41	68	100
Argentina (%)	0	3	14	41	68
Scenario III - US (%)	3	14	41	68	100
Brazil (%)	0	3	14	41	68
Scenario IV - US (%)	3	14	41	68	100
Brazil (%)	0	3	14	41	68
Argentina (%)	0	3	14	41	68

TABLE 2: BASELINE STATISTICS

ACREAGES ('000 Hectares)

	2008	2009	2010	2011	2012	2013
Soybeans						
US	30012	29613	28947	29179	29268	28985
Argentina	17308	17578	17939	18351	18831	19350
Brazil	22245	23293	24237	25076	25757	26353
World	97307	99546	100594	102501	104055	105084
Sunflower- World	23673	23581	23526	23500	23492	23469
Rapeseed - World	28377	29388	29965	30293	30466	30700
Palmoil -World	12805	13065	13291	13583	13878	14190
PRODUCTION (000 Metric Tons)						
Soybeans						
World	243125	250122	254938	262332	268846	274059
Argentina	49482	50607	52010	53574	55355	57268
Brazil	64340	68037	71485	74674	77436	79977
China	15029	16287	16362	16579	16747	16809
EU	1036	1093	1092	1082	1057	1033
US	85753	85435	84401	85968	87072	87146
Soymeal						
World	166802	171177	174976	179827	184282	187965
Argentina	31217	32366	33486	34680	35840	36941
Brazil	25587	26020	26409	26933	27428	27827
China	31546	33114	34695	36305	37903	39471
EU	11480	11538	11503	11607	11671	11626
US	40331	41005	41449	42492	43283	43692
Soyoil						
World	39528	40559	41454	42601	43654	44522
Argentina	7657	7938	8213	8506	8791	9061
Brazil	6337	6444	6541	6671	6793	6892
China	7112	7466	7822	8185	8545	8899
EU	2624	2637	2629	2653	2668	2657
US	9774	9938	10045	10298	10490	10589

TABLE 3: BASELINE STATISTICS

PRICES (US $/Metric ton)

	2008	2009	2010	2011	2012	2013
Soybeans, FOB, Argentina	514.5	497.1	503.1	490.7	481.1	476.5
Soybeans, FOB, Rio Grande Brazil	503.2	487.2	492.8	481.3	472.5	468.3
Soybeans, CIF Rotterdam, U.S.	558.9	541.4	547.5	535.0	525.3	520.6
Soybean Oil, FOB(All Dest.),Argentina	1174.8	1214.8	1268.1	1289.6	1267.2	1245.4
Soyoil, FOB (All Desti.) Rio Grande Brazil	1132.1	1169.5	1219.5	1239.5	1218.6	1198.2
Soyoil, FOB, Decatur	1161.5	1200.4	1252.4	1273.3	1251.5	1230.3
Soyoil, FOB, Dutch, Rotterdam	1266.3	1306.7	1360.6	1382.3	1359.7	1337.7
Soymeal Pellets, FOB (All Dest) Argentina	319.8	290.5	282.1	267.0	263.1	258.7
Soymeal, FOB (All Dest), 45% Protein, Brazil	311.4	281.5	272.9	257.6	253.6	249.0
Soymeal, Decatur, 48% Protein	316.1	286.7	278.2	263.1	259.3	254.7
Soymeal, Hamburg, 44% Protein	450.3	419.9	411.2	395.6	391.6	386.9
Sunflowers, FOB, Argentina	450.0	459.2	478.4	483.5	473.8	464.2
Sunflower Oil, FOB (All Dest) Argentina	1364.7	1402.8	1453.6	1474.0	1452.7	1432.0
Sunflower Meal, FOB(All Dest) Argentina	205.4	190.2	185.9	178.1	176.0	173.7
Rapeseed, CIF, Hamburg	660.9	664.6	679.0	681.4	671.7	661.8
Rapeseed Meal, FOB Rotterdam, 34% Protein	317.2	296.5	289.8	279.5	273.3	265.7
Rapeseed Oil, FOB, ex Mill	1525.8	1564.8	1617.9	1638.9	1613.8	1588.7
Palm Oil, FOB, Malaysia	1215.7	1256.2	1310.2	1331.9	1309.2	1287.2

TABLE 4: BASELINE STATISTICS

DOMESTIC USE (FOOD & FEED) (000 Metric Tons)

Soybeans	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
World	30802	31721	32374	33198	33945	34576
Argentina	1561	1598	1615	1640	1669	1703
Brazil	2978	3031	3069	3136	3196	3241
China	10364	10865	11173	11431	11686	11904
EU 25	1251	1280	1280	1296	1316	1334
US	4746	4779	4815	4957	5044	5094
Soymeal						
World	164721	169019	172874	177705	182198	185882
Argentina	680	719	754	791	825	859
Brazil	12579	13059	13439	13859	14262	14662
China	31515	32579	34140	35880	37314	38400
EU 25	35061	35225	35364	35578	36222	36990
US	32342	33263	33661	34613	35408	35798
Soyoil						
World	39561	40055	40946	42052	43039	43904
Argentina	1256	1369	1449	1469	1499	1527
Brazil	4032	4107	4123	4170	4246	4323
China	9791	10000	10232	10486	10764	11086
EU 25	3459	3521	3559	3581	3617	3655
US	9152	8983	9367	9937	10176	10258
TRADE (000 Metric Tons)						
Soybeans						
Argentina (Exports)	7764	7325	7293	7286	7546	8018
Brazil(Exports)	28337	31422	34330	36776	38838	40820
US(Exports)	30159	28544	27543	27286	27208	26809
China (Imports)	35168	36391	38620	40694	42799	44935
EU (Imports)	14788	14841	14795	14962	15090	15074
Soymeal						
Argentina(Exports)	30520	31624	32724	33879	35012	36080
Brazil(Exports)	13002	12956	12970	13071	13166	13163
US(Exports)	7983	7729	7783	7871	7871	7892
EU (Imports)	23594	23701	23867	23985	24560	25379
Soyoil						
Argentina(Exports)	6400	6569	6764	7037	7292	7533
Brazil(Exports)	2301	2347	2427	2503	2544	2567
US(Exports)	1227	1011	728	382	286	305
China (Imports)	2729	2585	2460	2351	2268	2237

TABLE 5a: SCENARIO I – US is the only adopter						
% CHANGE IN ACREAGES						
	2009	**2010**	**2011**	**2012**	**2013**	**Average**
Soybeans						
US	0.0	-0.2	-0.5	-0.9	-1.0	-0.5
Argentina	-0.1	-0.2	-0.6	-1.0	-1.5	-0.7
Brazil	0.0	-0.2	-0.6	-1.1	-1.8	-0.7
World	0.0	-0.2	-0.5	-0.9	-1.3	-0.6
Sunflower- World	0.0	0.0	0.0	0.0	0.0	0.0
Rapeseed - World	0.0	0.0	-0.1	-0.1	-0.2	-0.1
Palmoil -World	0.0	0.0	0.0	0.0	0.0	0.0
% CHANGE IN PRODUCTION						
Soybeans						
World	0.0	0.2	0.6	0.8	1.2	0.5
Argentina	-0.1	-0.2	-0.6	-1.0	-1.5	-0.7
Brazil	0.0	-0.2	-0.6	-1.1	-1.8	-0.7
China	0.0	-0.1	-0.4	-1.0	-1.5	-0.6
EU	0.0	-0.1	-0.4	-0.9	-1.5	-0.6
US	0.2	0.9	2.8	4.5	6.9	3.1
Soymeal						
World	0.1	0.2	0.5	0.7	1.0	0.5
Argentina	0.0	0.1	0.1	0.1	0.2	0.1
Brazil	0.0	0.1	0.3	0.3	0.4	0.2
China	0.0	0.0	0.1	0.1	0.1	0.1
EU	0.1	0.4	0.8	1.1	1.3	0.7
US	0.1	0.5	1.4	2.2	3.1	1.5
Soyoil						
World	0.1	0.2	0.5	0.7	1.0	0.5
Argentina	0.0	0.1	0.1	0.1	0.2	0.1
Brazil	0.0	0.1	0.3	0.3	0.4	0.2
China	0.0	0.0	0.1	0.1	0.1	0.1
EU	0.1	0.4	0.8	1.1	1.3	0.7
US	0.1	0.5	1.4	2.2	3.1	1.5

TABLE 5b: SCENARIO I – US is the only adopter

% CHANGE IN PRICES

	2009	2010	2011	2012	2013	Average
Soybeans, FOB, Argentina	-0.4	-1.5	-3.9	-5.8	-7.9	-3.9
Soybeans, FOB, Rio Grande Brazil	-0.4	-1.5	-3.7	-5.4	-7.4	-3.7
Soybeans, CIF Rotterdam, U.S.	-0.4	-1.4	-3.6	-5.4	-7.3	-3.6
Soybean Oil, FOB(All Dest.),Argentina	-0.1	-0.6	-1.6	-2.4	-3.4	-1.6
Soyoil, FOB (All Desti.) Rio Grande Brazil	-0.1	-0.6	-1.5	-2.4	-3.3	-1.6
Soyoil, FOB, Decatur	-0.1	-0.6	-1.6	-2.4	-3.4	-1.6
Soyoil, FOB, Dutch, Rotterdam	-0.1	-0.6	-1.5	-2.3	-3.2	-1.5
Soymeal Pellets, FOB (All Dest) Argentina	-0.4	-1.8	-4.9	-7.5	-10.4	-5.0
Soymeal, FOB (All Dest), 45% Protein, Brazil	-0.5	-1.9	-5.2	-7.9	-11.0	-5.3
Soymeal, Decatur, 48% Protein	-0.5	-1.9	-5.0	-7.6	-10.6	-5.1
Soymeal, Hamburg, 44% Protein	-0.3	-1.3	-3.4	-5.2	-7.2	-3.5
Sunflowers, FOB, Argentina	0.0	0.0	0.0	0.0	0.0	0.0
Sunflower Oil, FOB (All Dest) Argentina	-0.2	-0.7	-1.9	-2.9	-4.0	-1.9
Sunflower Meal, FOB(All Dest) Argentina	-0.1	-0.3	-0.8	-1.3	-1.9	-0.9
Rapeseed, CIF, Hamburg	0.0	0.0	0.0	0.0	0.0	0.0
Rapeseed Meal, FOB Rotterdam, 34% Protein	-0.1	-0.4	-1.0	-1.4	-2.1	-1.0
Rapeseed Oil, FOB, ex Mill	-0.3	-1.3	-3.4	-5.4	-7.7	-3.6
Palm Oil, FOB, Malaysia	0.0	-0.2	-0.5	-0.7	-1.0	-0.5

TABLE 5c: SCENARIO I – US is the only adopter						
% CHANGE IN DOMESTIC USE (FOOD & FEED)						
Soybeans	**2009**	**2010**	**2011**	**2012**	**2013**	**Average**
World	0.1	0.3	0.8	1.2	1.6	0.8
Argentina	0.0	-0.1	-0.2	-0.6	-0.9	-0.4
Brazil	0.1	0.3	0.7	0.8	0.9	0.6
China	0.1	0.3	0.6	0.9	1.1	0.6
EU 25	0.2	1.0	2.4	3.3	4.1	2.2
US	0.1	0.6	1.8	2.9	4.2	1.9
Soymeal						
World	0.0	0.2	0.5	0.7	1.0	0.5
Argentina	0.0	0.2	0.4	0.6	0.9	0.4
Brazil	0.0	0.1	0.3	0.5	0.7	0.3
China	0.0	0.1	0.4	0.6	0.8	0.4
EU 25	0.0	0.2	0.5	0.7	0.9	0.5
US	0.1	0.4	1.1	1.6	2.1	1.1
Soyoil						
World	0.0	0.2	0.5	0.7	1.0	0.5
Argentina	0.0	0.1	0.4	0.6	0.8	0.4
Brazil	0.0	0.1	0.3	0.4	0.6	0.3
China	0.0	0.1	0.3	0.5	0.7	0.3
EU 25	0.0	0.1	0.3	0.4	0.6	0.3
US	0.0	0.2	0.5	0.7	1.0	0.5
% CHANGE IN TRADE						
Soybeans						
Argentina (Exports)	-0.5	-2.2	-5.7	-8.7	-11.6	-5.7
Brazil(Exports)	-0.1	-0.5	-1.4	-2.6	-3.9	-1.7
US(Exports)	0.5	2.1	5.7	9.7	14.3	6.4
China (Imports)	0.0	0.2	0.4	0.8	1.0	0.5
EU (Imports)	0.1	0.5	1.1	1.4	1.8	1.0
Soymeal						
Argentina(Exports)	0.0	0.1	0.1	0.1	0.1	0.1
Brazil(Exports)	0.0	0.1	0.2	0.2	0.1	0.1
US(Exports)	0.2	0.8	2.7	4.8	7.3	3.2
EU (Imports)	0.0	0.1	0.3	0.5	0.7	0.3
Soyoil						
Argentina(Exports)	0.0	0.0	0.1	0.0	0.0	0.0
Brazil(Exports)	0.0	0.1	0.2	0.2	0.1	0.1
US(Exports)	0.4	3.3	20.7	49.2	71.9	29.1
China (Imports)	0.1	0.4	1.2	2.0	3.0	1.3

TABLE 5d: SCENARIO I – US is the only adopter

(A) CHANGE IN CONSUMER SPENDING (Million US $)

	2009	2010	2011	2012	2013
Soybeans					
US	-7	-22	-51	-70	-91
China	-17	-71	-184	-278	-388
EU-25	-1	-3	-9	-16	-24
ROW	-24	-98	-255	-392	-553
Total	-48	-194	-499	-756	-1056
Soyoil					
US	-10	-47	-136	-214	-307
China	-14	-61	-167	-255	-369
EU-25	-5	-22	-60	-91	-129
ROW	-19	-85	-230	-356	-515
Total	-49	-215	-593	-916	-1320
Soymeal					
US	-32	-135	-361	-565	-794
China	-39	-166	-438	-684	-967
EU-25	-40	-163	-417	-646	-918
ROW	-116	-481	-1259	-1947	-2727
Total	-195	-811	-2115	-3277	-4612
Sunflower Complex - World	-21	-90	-241	-371	-528
Rapeseed Complex - World	-45	-194	-524	-809	-1156
Palmoil - World	-34	-150	-416	-663	-991

(B) GAIN TO ADOPTERS (Million US $)

	2009	2010	2011	2012	2013
US (Due to Increased Yield)	107	422	776	685	43
US (Due to Reduction in Acreage)	3	13	34	69	76

(C) LOSS TO NON-ADOPTERS (Million US $)

	2009	2010	2011	2012	2013
Argentina	-109	-453	-1152	-1745	-2438
Brazil	-130	-560	-1467	-2284	-3237
US	-177	-633	-1092	-897	0

TABLE 6a: SCENARIO II – US and Argentina are adopters						
% CHANGE IN ACREAGES						
	2009	**2010**	**2011**	**2012**	**2013**	**Average**
Soybeans						
US	0.0	-0.2	-0.7	-1.7	-3.2	-1.2
Argentina	-0.1	-0.2	-0.6	-0.8	-0.9	-0.5
Brazil	0.0	-0.2	-0.6	-1.4	-2.3	-0.9
World	0.0	-0.2	-0.6	-1.2	-2.0	-0.8
Sunflower- World	0.0	0.0	0.1	0.1	0.0	0.0
Rapeseed – World	0.0	0.0	-0.1	-0.2	-0.2	-0.1
Palmoil –World	0.0	0.0	0.0	0.0	0.0	0.0
% CHANGE IN PRODUCTION						
Soybeans						
World	0.0	0.2	0.7	1.1	1.5	0.7
Argentina	-0.1	0.0	0.5	2.5	4.5	1.5
Brazil	0.0	-0.2	-0.6	-1.4	-2.3	-0.9
China	0.0	-0.1	-0.5	-1.2	-2.0	-0.8
EU	0.0	-0.1	-0.4	-1.1	-2.0	-0.7
US	0.2	0.9	2.6	3.6	4.6	2.4
Soymeal						
World	0.1	0.2	0.6	0.9	1.2	0.6
Argentina	0.0	0.1	0.2	0.2	0.3	0.2
Brazil	0.0	0.1	0.3	0.6	0.7	0.4
China	0.0	0.0	0.1	0.2	0.2	0.1
EU	0.1	0.4	1.1	1.7	2.2	1.1
US	0.1	0.6	1.5	2.5	3.4	1.6
Soyoil						
World	0.1	0.2	0.6	1.0	1.2	0.6
Argentina	0.0	0.1	0.2	0.2	0.3	0.2
Brazil	0.0	0.1	0.3	0.6	0.7	0.4
China	0.0	0.0	0.1	0.2	0.2	0.1
EU	0.1	0.4	1.1	1.7	2.2	1.1
US	0.1	0.6	1.5	2.5	3.4	1.6

TABLE 6b: SCENARIO II – US and Argentina are adopters

% CHANGE IN PRICES

	2009	**2010**	**2011**	**2012**	**2013**	**Average**
Soybeans, FOB, Argentina	-0.4	-1.7	-4.7	-8.1	-10.9	-5.2
Soybeans, FOB, Rio Grande Brazil	-0.4	-1.6	-4.4	-7.6	-10.2	-4.8
Soybeans, CIF Rotterdam, U.S.	-0.4	-1.6	-4.4	-7.4	-10.0	-4.8
Soybean Oil, FOB(All Dest.),Argentina	-0.1	-0.7	-1.9	-3.2	-4.4	-2.1
Soyoil, FOB (All Desti.) Rio Grande Brazil	-0.1	-0.7	-1.8	-3.1	-4.3	-2.0
Soyoil, FOB, Decatur	-0.1	-0.7	-1.9	-3.2	-4.3	-2.0
Soyoil, FOB, Dutch, Rotterdam	-0.1	-0.6	-1.8	-3.0	-4.1	-1.9
Soymeal Pellets, FOB (All Dest) Argentina	-0.4	-2.1	-5.8	-9.9	-13.6	-6.4
Soymeal, FOB (All Dest), 45% Protein, Brazil	-0.5	-2.2	-6.1	-10.5	-14.4	-6.7
Soymeal, Decatur, 48% Protein	-0.5	-2.1	-5.9	-10.1	-13.9	-6.5
Soymeal, Hamburg, 44% Protein	-0.3	-1.5	-4.1	-6.9	-9.5	-4.4
Sunflowers, FOB, Argentina	-0.2	-0.8	-2.3	-4.1	-5.6	-2.6
Sunflower Oil, FOB (All Dest) Argentina	-0.1	-0.4	-1.0	-1.8	-2.5	-1.1
Sunflower Meal, FOB(All Dest) Argentina	-0.4	-1.7	-4.9	-8.4	-11.7	-5.4
Rapeseed, CIF, Hamburg	-0.1	-0.5	-1.2	-2.0	-2.7	-1.3
Rapeseed Meal, FOB Rotterdam, 34% Protein	-0.3	-1.4	-4.1	-7.2	-10.2	-4.6
Rapeseed Oil, FOB, ex Mill	0.0	-0.2	-0.6	-0.9	-1.3	-0.6
Palm Oil, FOB, Malaysia	-0.1	-0.3	-0.8	-1.4	-2.0	-0.9

TABLE 6c: SCENARIO II – US and Argentina are adopters

% CHANGE IN DOMESTIC USE (FOOD & FEED)

Soybeans	**2009**	**2010**	**2011**	**2012**	**2013**	**Average**
World	0.1	0.4	0.9	1.4	1.8	0.9
Argentina	0.0	-0.1	-0.2	-0.5	-0.7	-0.3
Brazil	0.1	0.3	0.8	1.2	1.3	0.7
China	0.1	0.3	0.8	1.2	1.6	0.8
EU 25	0.2	1.1	2.9	4.6	5.7	2.9
US	0.1	0.5	1.5	2.0	2.8	1.4
SOYMEAL						
World	0.0	0.2	0.6	0.9	1.2	0.6
Argentina	0.0	0.2	0.5	0.8	1.1	0.5
Brazil	0.0	0.1	0.4	0.6	0.8	0.4
China	0.0	0.1	0.4	0.7	1.1	0.5
EU 25	0.0	0.2	0.6	0.9	1.1	0.6
US	0.1	0.5	1.2	2.0	2.6	1.3
SOYOIL						
World	0.0	0.2	0.6	0.9	1.2	0.6
Argentina	0.0	0.2	0.5	0.8	1.0	0.5
Brazil	0.0	0.1	0.3	0.6	0.7	0.4
China	0.0	0.1	0.4	0.7	0.9	0.4
EU 25	0.0	0.1	0.3	0.6	0.8	0.4
US	0.0	0.2	0.6	1.0	1.3	0.6

% CHANGE IN TRADE

Soybeans						
Argentina (Exports)	-0.5	-0.7	2.6	16.3	30.3	9.6
Brazil(Exports)	-0.1	-0.6	-1.7	-3.4	-5.2	-2.2
US(Exports)	0.5	1.9	4.3	5.2	5.9	3.6
China (Imports)	0.0	0.2	0.5	1.0	1.4	0.6
EU (Imports)	0.1	0.5	1.4	2.2	2.8	1.4
Soymeal						
Argentina(Exports)	0.0	0.1	0.1	0.2	0.3	0.1
Brazil(Exports)	0.0	0.1	0.3	0.5	0.6	0.3
US(Exports)	0.2	0.8	2.7	4.8	6.9	3.1
EU (Imports)	0.0	0.1	0.4	0.6	0.7	0.3
Soyoil						
Argentina(Exports)	0.0	0.0	0.1	0.1	0.1	0.1
Brazil(Exports)	0.0	0.1	0.3	0.5	0.6	0.3
US(Exports)	0.4	3.6	22.5	55.2	75.6	31.5
China (Imports)	0.1	0.4	1.3	2.5	3.6	1.6

TABLE 6d: SCENARIO II – US and Argentina are adopters

(A) CHANGE IN CONSUMER SPENDING (Million US $)

	2009	2010	2011	2012	2013
Soybeans					
US	-7	-29	-79	-148	-199
China	-17	-79	-222	-387	-534
EU-25	-1	-4	-11	-22	-34
ROW	-24	-110	-308	-541	-753
Total	-48	-222	-620	-1099	-1521
Soyoil					
US	-10	-52	-162	-286	-394
China	-14	-69	-198	-341	-471
EU-25	-5	-25	-71	-121	-165
ROW	-19	-96	-274	-477	-662
Total	-48	-242	-705	-1225	-1693
Soymeal					
US	-32	-150	-431	-762	-1060
China	-39	-185	-520	-913	-1271
EU-25	-40	-182	-495	-863	-1209
ROW	-116	-536	-1495	-2605	-3605
Total	-195	-902	-2509	-4381	-6085
Sunflower Complex - World	-21	-101	-288	-501	-694
Rapeseed Complex - World	-45	-217	-622	-1082	-1509
Palmoil - World	-33	-169	-496	-892	-1284

(B) GAIN TO ADOPTERS (Million US $)

	2009	2010	2011	2012	2013
US (Due to Increased Yield)	107	409	621	-14	-1257
US (Due to Reduction in Acreage)	3	14	50	130	233
Argentina (Due to Increased Yield)	0	48	106	-77	-685
Argentina (Due to Reduction in Acreage)	0	11	26	38	44

(C) LOSS TO NON-ADOPTERS (Million US $)

	2009	2010	2011	2012	2013
Argentina	-109	-487	-1162	-1353	-999
Brazil	-130	-627	-1761	-3115	-4378
US	-176	-708	-1340	-1288	0

TABLE 7a: SCENARIO III – US and Brazil are adopters

% CHANGE IN ACREAGES

	2009	**2010**	**2011**	**2012**	**2013**	**Average**
Soybeans						
US	0.0	-0.2	-0.7	-1.9	-3.5	-1.3
Argentina	-0.1	-0.3	-0.8	-1.4	-2.0	-0.9
Brazil	0.0	-0.2	-0.7	-1.4	-2.4	-0.9
World	0.0	-0.2	-0.6	-1.4	-2.4	-0.9
Sunflower- World	0.0	0.0	0.1	0.1	0.0	0.0
Rapeseed - World	0.0	0.0	-0.1	-0.2	-0.3	-0.1
Palmoil -World	0.0	0.0	0.0	0.0	0.0	0.0

% CHANGE IN PRODUCTION

	2009	**2010**	**2011**	**2012**	**2013**	**Average**
Soybeans						
World	0.0	0.2	0.7	1.2	1.5	0.7
Argentina	-0.1	-0.3	-0.8	-1.4	-2.0	-0.9
Brazil	0.0	0.0	0.4	1.8	2.9	1.0
China	0.0	-0.1	-0.5	-1.3	-2.1	-0.8
EU	0.0	-0.1	-0.4	-1.2	-2.1	-0.8
US	0.2	0.9	2.5	3.5	4.2	2.3
Soymeal						
World	0.1	0.2	0.6	1.0	1.3	0.6
Argentina	0.0	0.1	0.2	0.3	0.3	0.2
Brazil	0.0	0.1	0.4	0.6	0.7	0.4
China	0.0	0.0	0.1	0.2	0.2	0.1
EU	0.1	0.4	1.1	1.8	2.3	1.1
US	0.1	0.6	1.6	2.6	3.5	1.7
Soyoil						
World	0.1	0.2	0.6	1.0	1.3	0.6
Argentina	0.0	0.1	0.2	0.3	0.3	0.2
Brazil	0.0	0.1	0.4	0.6	0.7	0.4
China	0.0	0.0	0.1	0.2	0.2	0.1
EU	0.1	0.4	1.1	1.8	2.3	1.1
US	0.1	0.6	1.6	2.6	3.5	1.7

TABLE 7b: SCENARIO III – US and Brazil are adopters

% CHANGE IN PRICES

	2009	2010	2011	2012	2013	Average
Soybeans, FOB, Argentina	-0.4	-1.8	-4.9	-8.5	-11.2	-5.4
Soybeans, FOB, Rio Grande Brazil	-0.4	-1.7	-4.6	-7.9	-10.5	-5.0
Soybeans, CIF Rotterdam, U.S.	-0.4	-1.6	-4.5	-7.8	-10.4	-4.9
Soybean Oil, FOB(All Dest.),Argentina	-0.1	-0.7	-1.9	-3.4	-4.5	-2.1
Soyoil, FOB (All Desti.) Rio Grande Brazil	-0.1	-0.7	-1.9	-3.3	-4.4	-2.1
Soyoil, FOB, Decatur	-0.1	-0.7	-1.9	-3.3	-4.4	-2.1
Soyoil, FOB, Dutch, Rotterdam	-0.1	-0.7	-1.8	-3.2	-4.2	-2.0
Soymeal Pellets, FOB (All Dest) Argentina	-0.4	-2.1	-6.0	-10.4	-14.1	-6.6
Soymeal, FOB (All Dest), 45% Protein, Brazil	-0.5	-2.2	-6.3	-11.0	-14.9	-7.0
Soymeal, Decatur, 48% Protein	-0.4	-2.1	-6.1	-10.6	-14.3	-6.7
Soymeal, Hamburg, 44% Protein	-0.3	-1.5	-4.2	-7.2	-9.7	-4.6
Sunflowers, FOB, Argentina	-0.2	-0.8	-2.4	-4.2	-5.7	-2.7
Sunflower Oil, FOB (All Dest) Argentina	-0.1	-0.4	-1.0	-1.8	-2.5	-1.2
Sunflower Meal, FOB(All Dest) Argentina	-0.4	-1.7	-5.0	-8.8	-12.0	-5.6
Rapeseed, CIF, Hamburg	-0.1	-0.5	-1.3	-2.1	-2.8	-1.3
Rapeseed Meal, FOB Rotterdam, 34% Protein	-0.3	-1.4	-4.2	-7.5	-10.5	-4.8
Rapeseed Oil, FOB, ex Mill	0.0	-0.2	-0.6	-1.0	-1.3	-0.6
Palm Oil, FOB, Malaysia	-0.1	-0.3	-0.8	-1.5	-2.1	-0.9

TABLE 7c: SCENARIO III – US and Brazil are adopters

% CHANGE IN DOMESTIC USE (FOOD & FEED)

Soybeans	**2009**	**2010**	**2011**	**2012**	**2013**	**Average**
World	0.1	0.4	0.9	1.4	1.7	0.9
Argentina	0.0	-0.1	-0.3	-0.7	-1.3	-0.5
Brazil	0.1	0.3	0.8	1.3	1.4	0.8
China	0.1	0.3	0.8	1.3	1.6	0.8
EU 25	0.2	1.1	2.9	4.8	5.9	3.0
US	0.1	0.5	1.4	1.8	2.6	1.3
SOYMEAL						
World	0.0	0.2	0.6	1.0	1.3	0.6
Argentina	0.0	0.2	0.5	0.8	1.1	0.5
Brazil	0.0	0.2	0.4	0.6	0.8	0.4
China	0.0	0.1	0.4	0.8	1.1	0.5
EU 25	0.0	0.2	0.6	0.9	1.1	0.6
US	0.1	0.5	1.3	2.1	2.7	1.3
SOYOIL						
World	0.0	0.2	0.6	1.0	1.3	0.6
Argentina	0.0	0.2	0.5	0.8	1.0	0.5
Brazil	0.0	0.1	0.3	0.6	0.8	0.4
China	0.0	0.1	0.4	0.7	0.9	0.4
EU 25	0.0	0.1	0.4	0.6	0.8	0.4
US	0.0	0.2	0.6	1.0	1.3	0.6
% CHANGE IN TRADE						
Soybeans						
Argentina (Exports)	-0.5	-2.5	-7.0	-12.3	-16.2	-7.7
Brazil(Exports)	-0.1	-0.1	0.5	2.9	5.0	1.6
US(Exports)	0.5	1.8	4.0	4.4	4.6	3.1
China (Imports)	0.0	0.2	0.5	1.1	1.5	0.7
EU (Imports)	0.1	0.5	1.4	2.3	2.9	1.5
Soymeal						
Argentina(Exports)	0.0	0.1	0.1	0.2	0.3	0.1
Brazil(Exports)	0.0	0.1	0.3	0.5	0.6	0.3
US(Exports)	0.2	0.8	2.7	4.8	6.8	3.1
EU (Imports)	0.0	0.1	0.4	0.6	0.7	0.4
Soyoil						
Argentina(Exports)	0.0	0.0	0.1	0.1	0.2	0.1
Brazil(Exports)	0.0	0.2	0.3	0.5	0.6	0.3
US(Exports)	0.4	3.6	22.8	56.3	76.0	31.8
China (Imports)	0.1	0.4	1.4	2.6	3.7	1.6

TABLE 7d: SCENARIO III – US and Brazil are adopters

(A) CHANGE IN CONSUMER SPENDING (Million US $)

	2009	2010	2011	2012	2013
Soybeans					
US	-7	-30	-85	-162	-213
China	-17	-81	-229	-407	-554
EU-25	-1	-4	-12	-24	-35
ROW	-24	-112	-318	-570	-784
Total	-48	-227	-644	-1163	-1587
Soyoil					
US	-10	-53	-166	-298	-404
China	-14	-70	-204	-356	-482
EU-25	-5	-26	-73	-126	-169
ROW	-19	-98	-282	-497	-677
Total	-48	-247	-725	-1277	-1732
Soymeal					
US	-32	-153	-444	-798	-1096
China	-39	-188	-535	-955	-1311
EU-25	-40	-185	-510	-902	-1247
ROW	-116	-546	-1540	-2724	-3720
Total	-195	-919	-2585	-4581	-6278
Sunflower Complex - World	-21	-103	-295	-521	-710
Rapeseed Complex - World	-45	-221	-640	-1130	-1551
Palmoil - World	-33	-172	-510	-928	-1308

(B) GAIN TO ADOPTERS (Million US $)

	2009	2010	2011	2012	2013
US (Due to Increased Yield)	107	407	591	-140	-1421
US (Due to Reduction in Acreage)	3	14	53	141	261
US Total Gain	110	421	644	1	-1160
Brazil (Due to Increased Yield)	0	65	153	-84	-836
Brazil (Due to Reduction in Acreage)	0	12	42	94	161
Brazil Total Gain	0	78	194	10	-675

(C) LOSS TO NON-ADOPTERS (Million US $)

	2009	2010	2011	2012	2013
Argentina	-109	-519	-1431	-2513	-3422
Brazil	-130	-620	-1563	-1927	-1450
US	-176	-721	-1388	-1359	0

TABLE 8a: SCENARIO IV – US, Argentina and Brazil are adopters						
% CHANGE IN ACREAGES						
	2009	**2010**	**2011**	**2012**	**2013**	**Average**
Soybeans						
US	0.0	-0.2	-0.9	-2.8	-5.6	-1.9
Argentina	-0.1	-0.3	-0.7	-1.2	-1.4	-0.7
Brazil	0.0	-0.2	-0.7	-1.7	-2.9	-1.1
World	0.0	-0.2	-0.7	-1.7	-3.1	-1.1
Sunflower- World	0.0	0.0	0.1	0.1	0.0	0.1
Rapeseed - World	0.0	0.0	-0.1	-0.2	-0.3	-0.1
Palmoil -World	0.0	0.0	0.0	0.0	0.0	0.0
% CHANGE IN PRODUCTION						
Soybeans						
World	0.0	0.3	0.9	1.5	1.8	0.9
Argentina	-0.1	-0.1	0.4	2.1	3.9	1.3
Brazil	0.0	0.0	0.4	1.5	2.4	0.8
China	0.0	-0.1	-0.5	-1.5	-2.7	-1.0
EU	0.0	-0.1	-0.4	-1.3	-2.7	-0.9
US	0.2	0.9	2.3	2.6	2.0	1.6
Soymeal						
World	0.1	0.3	0.7	1.2	1.5	0.7
Argentina	0.0	0.1	0.2	0.3	0.4	0.2
Brazil	0.0	0.2	0.4	0.8	1.0	0.5
China	0.0	0.0	0.1	0.2	0.3	0.1
EU	0.1	0.5	1.3	2.4	3.1	1.5
US	0.1	0.6	1.7	2.9	3.8	1.8
Soyoil						
World	0.1	0.3	0.7	1.2	1.5	0.7
Argentina	0.0	0.1	0.2	0.3	0.4	0.2
Brazil	0.0	0.2	0.4	0.8	1.0	0.5
China	0.0	0.0	0.1	0.2	0.3	0.1
EU	0.1	0.5	1.3	2.4	3.1	1.5
US	0.1	0.6	1.7	2.9	3.8	1.8

TABLE 8b: SCENARIO IV – US, Argentina and Brazil are adopters

% CHANGE IN PRICES

	2009	**2010**	**2011**	**2012**	**2013**	**Average**
Soybeans, FOB, Argentina	-0.4	-2.0	-5.7	-10.6	-14.2	-6.6
Soybeans, FOB, Rio Grande Brazil	-0.4	-1.8	-5.3	-10.0	-13.3	-6.2
Soybeans, CIF Rotterdam, U.S.	-0.4	-1.8	-5.3	-9.8	-13.1	-6.1
Soybean Oil, FOB(All Dest.),Argentina	-0.1	-0.8	-2.2	-4.1	-5.4	-2.5
Soyoil, FOB (All Desti.) Rio Grande Brazil	-0.1	-0.8	-2.2	-4.0	-5.3	-2.5
Soyoil, FOB, Decatur	-0.1	-0.8	-2.2	-4.1	-5.4	-2.5
Soyoil, FOB, Dutch, Rotterdam	-0.1	-0.7	-2.1	-3.9	-5.1	-2.4
Soymeal Pellets, FOB (All Dest) Argentina	-0.4	-2.3	-6.9	-12.7	-17.3	-7.9
Soymeal, FOB (All Dest), 45% Protein, Brazil	-0.5	-2.4	-7.2	-13.5	-18.3	-8.4
Soymeal, Decatur, 48% Protein	-0.4	-2.3	-7.0	-13.0	-17.6	-8.1
Soymeal, Hamburg, 44% Protein	-0.3	-1.6	-4.8	-8.9	-12.0	-5.5
Sunflowers, FOB, Argentina	-0.2	-0.9	-2.8	-5.4	-7.3	-3.3
Sunflower Oil, FOB (All Dest) Argentina	-0.1	-0.4	-1.2	-2.3	-3.2	-1.4
Sunflower Meal, FOB(All Dest) Argentina	-0.4	-1.9	-5.8	-10.9	-14.9	-6.8
Rapeseed, CIF, Hamburg	-0.1	-0.5	-1.5	-2.6	-3.4	-1.6
Rapeseed Meal, FOB Rotterdam, 34% Protein	-0.3	-1.6	-4.8	-9.3	-13.0	-5.8
Rapeseed Oil, FOB, ex Mill	0.0	-0.2	-0.7	-1.2	-1.6	-0.7
Palm Oil, FOB, Malaysia	-0.1	-0.3	-1.0	-1.8	-2.5	-1.1

TABLE 8c: SCENARIO IV – US, Argentina and Brazil are adopters

% CHANGE IN DOMESTIC USE (FOOD & FEED)						
Soybeans	**2009**	**2010**	**2011**	**2012**	**2013**	**Average**
World	0.1	0.4	1.0	1.6	1.9	1.0
Argentina	0.0	-0.1	-0.2	-0.6	-1.1	-0.4
Brazil	0.1	0.4	1.0	1.6	1.8	1.0
China	0.1	0.4	0.9	1.6	2.0	1.0
EU 25	0.2	1.2	3.4	6.0	7.4	3.7
US	0.1	0.4	1.1	1.0	1.2	0.8
SOYMEAL						
World	0.0	0.2	0.7	1.2	1.5	0.7
Argentina	0.0	0.2	0.5	1.0	1.3	0.6
Brazil	0.0	0.2	0.4	0.8	1.0	0.5
China	0.0	0.2	0.5	1.0	1.3	0.6
EU 25	0.0	0.2	0.7	1.1	1.4	0.7
US	0.1	0.6	1.5	2.5	3.2	1.6
SOYOIL						
World	0.0	0.2	0.7	1.2	1.5	0.7
Argentina	0.0	0.2	0.5	1.0	1.2	0.6
Brazil	0.0	0.1	0.4	0.7	0.9	0.4
China	0.0	0.2	0.5	0.8	1.1	0.5
EU 25	0.0	0.1	0.4	0.7	1.0	0.5
US	0.0	0.3	0.7	1.2	1.5	0.8
% CHANGE IN TRADE						
Soybeans						
Argentina (Exports)	-0.5	-1.0	1.3	12.6	25.2	7.5
Brazil(Exports)	-0.1	-0.2	0.2	2.2	3.6	1.1
US(Exports)	0.5	1.6	2.6	0.0	-3.6	0.2
China (Imports)	0.0	0.2	0.6	1.3	1.9	0.8
EU (Imports)	0.1	0.6	1.7	3.0	3.9	1.9
Soymeal						
Argentina(Exports)	0.0	0.1	0.2	0.3	0.4	0.2
Brazil(Exports)	0.0	0.1	0.4	0.8	1.1	0.5
US(Exports)	0.2	0.9	2.7	4.8	6.4	3.0
EU (Imports)	0.0	0.1	0.4	0.6	0.7	0.4
Soyoil						
Argentina(Exports)	0.0	0.1	0.1	0.2	0.3	0.1
Brazil(Exports)	0.0	0.2	0.4	0.8	1.1	0.5
US(Exports)	0.4	3.9	24.6	61.9	80.3	34.2
China (Imports)	0.1	0.5	1.6	3.1	4.3	1.9

TABLE 8d: SCENARIO IV – US, Argentina and Brazil are adopters

(A) CHANGE IN CONSUMER SPENDING (Million US $)

	2009	2010	2011	2012	2013
Soybeans					
US	-7	-37	-113	-237	-318
China	-17	-90	-268	-513	-701
EU-25	-1	-4	-14	-30	-46
ROW	-23	-124	-371	-714	-986
Total	-48	-255	-765	-1494	-2052
Soyoil					
US	-10	-59	-192	-368	-493
China	-14	-78	-235	-438	-587
EU-25	-5	-28	-84	-155	-205
ROW	-19	-108	-325	-613	-827
Total	-48	-274	-837	-1574	-2112
Soymeal					
US	-32	-168	-513	-989	-1366
China	-39	-207	-616	-1175	-1615
EU-25	-40	-203	-587	-1112	-1541
ROW	-115	-600	-1774	-3360	-4600
Total	-194	-1010	-2977	-5647	-7756
Sunflower Complex - World	-21	-114	-341	-646	-880
Rapeseed Complex - World	-45	-244	-737	-1394	-1908
Palmoil - World	-33	-191	-589	-1148	-1606

(B) GAIN TO ADOPTERS (Million US $)

	2009	2010	2011	2012	2013
US (Due to Increased Yield)	107	394	438	-798	-2657
US (Due to Reduction in Acreage)	3	15	68	204	411
Brazil (Due to Increased Yield)	0	63	112	-406	-1563
Brazil (Due to Reduction in Acreage)	0	13	47	112	196
Argentina (Due to Increased Yield)	0	46	68	-376	-1335
Argentina (Due to Reduction in Acreage)	0	12	33	56	71

(C): LOSS TO NON-ADOPTERS (Million US $)

	2009	2010	2011	2012	2013
Argentina	-109	-550	-1400	-1792	-1315
Brazil	-129	-685	-1813	-2395	-1810
US	-176	-795	-1633	-1736	0

TABLE 9: Soybean and Soymeal Trade Matrix (thousand metric tons)

	2009	2010	2011	2012	2013
SCENARIO I					
Soybeans					
Brazil+ Argentina Net Exports	38669	41278	43118	44718	46314
EU Net Imports	14858	14864	15123	15306	15345
Difference	23811	26413	27995	29411	30969
Difference (in meal equivalent)	18479	20499	21726	22825	24034
Soymeal					
Brazil+ Argentina Net Exports	44588	45723	47007	48241	49306
EU Net Imports	23708	23897	24066	24686	25550
Difference	20880	21826	22941	23555	23756
SCENARIO II					
Soybeans					
Brazil Net Exports	31384	34130	36150	37525	38680
EU Net Imports	14858	14874	15164	15420	15494
Difference	16526	19256	20986	22105	23186
Difference (in meal equivalent)	12804	14919	16259	17126	17964
Soymeal					
Brazil Net Exports	12960	12985	13108	13226	13238
EU Net Imports	23708	23899	24072	24695	25549
Difference	-10749	-10913	-10964	-11469	-12311
SCENARIO III					
Soybeans					
Argentina Net Exports	7285	7107	6775	6620	6716
EU Net Imports	14858	14876	15172	15441	15514
Difference	-7573	-7769	-8398	-8820	-8798
Difference (in meal equivalent)	-5887	-6039	-6528	-6857	-6839
Soymeal					
Argentina Net Exports	31628	32744	33927	35091	36177
EU Net Imports	23708	23899	24073	24697	25548
Difference	7920	8845	9854	10394	10629

VITA

Srinivasa Konduru was born in Tirupati, India. He grew up in Tirupati where he attended primary and secondary school. After graduating from high school, he went o Andhra Loyola College, Vijayawada to pursue Intermediate education. After wards, he joined Acharya N.G. Ranga Agricultural University, Tirupati Campus from which he received B.S (Agriculture). Later he pursued Post Graduate Program in Agri-Business Management at National Institute of Agricultural Extension Management (MANAGE), Hyderabad. During his stint at MANAGE, he did an internship with Pioneer Hybrid Corporation (formerly SPIC-PHI in India) where he researched and presented a report entitled “A Study of Hybrid Rice Market in Andhra Pradesh, India”. After graduating from MANAGE in 2000, he joined Wockhardt Life Sciences, India as a Management Trainee in their Mumbai office. He was made in-charge of operations in four districts in the state of Maharastra. In August 2001, Srini enrolled in the M.S. program at University of Missouri, Columbia and worked with Dr. Bruce Bjornson for his thesis entitled “Factor Income Shares in Agri-Food Industries”. During this time, he also worked with Dr. Corinne Valdivia on sustainable livelihood strategies and on a project about agroforestry practices and their adoption in Missouri. He received his M.S in 2004 and continued into the doctorate program at the same university. He worked under the guidance of Dr. Nicholas Kalaitzandonakes as a graduate research assistant along with pursuing the doctorate program. During this time, Srini worked on diversified topics like economics of soybean biotechnology, coverage of globalization in media and impact of third-party vaccinations in cattle auctions. In August 2007, he joined as a lecturer in the department of agricultural economics, California State University, Fresno. Srini's current responsibilities include teaching undergraduate students about agricultural marketing, international agricultural trade and export marketing.