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Restructuring of the Corn Supply Chain in Brazil: Facing the Challenges in Logistics or Regulation of Biotechnology

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Abstract

This study aims to analyze the effects of corn segregation on Brazilian transport and storage logistics, and how it impacts global competitiveness.

A partial equilibrium model as a Mixed Complementarity Problem (MCP) was developed to guide the implementation of more effective policies and support new investments. The Cartagena Protocol on Biosafety requirements affects the logistics of transport and storage in Brazil. Intermodal flows were most affected and significant commercial reductions occurred in the regions farthest from export ports. This research is original in its use of a model and forecast scenarios to measure how biotechnology regulatory issues directly affect infrastructure logistics. Establishing stringent identity preservation systems affects these projects, since intermodal flows are most affected by such systems.

Keywords: segregation, partial equilibrium models, transgenic crops, cereal sector and logistics

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Introduction

Biotechnology encompasses a variety of technologies able to introduce and enhance the characteristics of living organisms, allowing the generation of new products, processes and services in many sectors of the economy worldwide. These developments are based on the emergence of Genetic Engineering which occurred about thirty years ago. This new technological standard aims to lead to a substitution of fossil fuels and capital-intensive technologies, beginning the search for new biologically based technologies in food and energy. Unlike most other methods of plant breeding, modern biotechnology and biotech crops are strictly regulated regarding the issues of food and environmental security.

Up to the present moment, over 272 biotechnology events and 25 biotech crops have passed the regulatory barrier in several countries and many of them have been marketed during the last fifteen years (ISAAA 2012).

The adoption of biotech crops by farmers around the world occurred over a short time period. Since 1996, the planted area has increased to 94 times its original area, and in 2011 it reached the milestone of 160 million hectares, an increase of 8% over the previous year (James 2011). In 2011, Brazil maintained and strengthened its position as the second largest producer of biotech crops in the world. According to James (2011), transgenic crops occupied 30.3 million hectares, an increase of 4.9 million hectares in relation to the previous year - the largest absolute increase observed in any other country in the world.

Borges et al. (2009) have shown that the potential benefits of agricultural biotechnology hold as much importance as the perceived benefits regarding the acceptance of Genetically Modified Crops (GM) in Brazil. This means that for a group of experts able to foresee biotechnology benefits, the present generation of GM foreshadows even bigger impacts. Focusing on a few traits - herbicide tolerance (HR), insect resistance (IR) and diffusion in platform crops (soybean, corn, cotton and canola) - GM crops have shown significant impacts on the world's agriculture, mostly in the leading export countries (Oliveira et al. 2012).

The success of the diffusion processes in different countries is clear: the diffusion path, when compared to what happened with hybrid corn in EUA in the late forties and fifties, is impressive: an s-shape pattern reaching levels of adoption by farmers of over 80% in soybean (Brazil); cotton (India, China); and canola (Canada). This revealed growers' preference for GM cultivars, despite the negative role of regulatory pressures, particularly grain importing countries (Oliveira et al. 2012).

Galvão (2012) estimates gains in the gross operational margin of corn (winter harvesting) in Mato Grosso in 2011 in Brazil, ranging from 5.6% for IR traits and 11.8% for stack (IR and HT) varieties. This takes into account that the cost of GM seeds is almost ten times more than that of conventional seeds. Risk reduction, a sharp decrease in pesticide usage (mostly in cotton, reducing, on average, the number of pesticide applications from 18 to 5 per crop cycle) and the reduction of Greenhouse Gas Emissions (GHG´s) are other important determinants of the impacts of the adoption of GM crops. Barrows et al. (2013) add a new argument: these effects generate an extensive margin from the adoption of GM, raising the value of marginal product of complementary inputs. In other words, there are additional impacts to those generated by the direct effects of GM adoption, generating a systemic effect on agriculture.

However, the proliferation of biosecurity systems at the country level, as Phillips (2010) points out, raises the cost of regulation process to amounts near US$ 150 million by new event. Firms after selecting the most promising results (several years before the launching of the new seed), begin to collect information on issues from biosafety experiments to mechanisms of communication to the consumer such as labeling, identity preservation, segregation and traceability processes. It generates barriers to entry to small innovative firms, leading firms to focus on platform crops and the few traits (IR and HT). This process is tougher when legislation imposes bans on doing research, produce and even commercialize products derived from GM crops.

While developed countries have established their rules for dealing with agricultural biotechnology based on their national strategies and priorities, developing countries are doing so in less flexible circumstances. According to Zarilli (2005), instead of enjoying the freedom to assess the risks and benefits that agricultural biotechnology can bring, developing countries increasingly rely on the demands of their trading partners to define their guidelines.

Silveira and Borges (2007) argue that the leading agriculture exporters are prone to implementing a soft biosafety legislation, or at least accepting information that had been generated by similar processes carried out in the recent past. Brazil, up to the year 2005, was an exception, imposing serious restrictions on the registration of GM crops and able to cope with the European countries legislation. However, according to Galvão (2012), after the Decree 5,591 that regulates the Biosafety Law (November, 2005) the average time to approve a new trait has been reduced from 50 to less than 10 months, generating a healthy environment for research, production and commercialization of GMOs.

The international regulations on genetically modified organisms (GMOs) have been, in theory, designed under the rules of the Convention on Biological Diversity (CBD) through the Cartagena Protocol on Biosafety (CPB) and the World Trade Organization (WTO). These rules, in turn, are based on the standards and guidelines of *Codex Alimentarius* to address the issues of food security. From the theory to the practice, there is a distance covered by the complexity of forming multilateral protocols in which the consensus is the rule. The space for collective action causes the constitution of the CPB, with respect to its specific provisions about GMOs, experience several deadlocks.

Immediately, the CPB would affect, more intensively, the markets of soy and corn, products with great participation in the global agricultural production. Regarding economic impacts, these will depend on the compliance costs to the CPB, which correspond to the costs of the resources needed to fulfill the legal requirements established by the parties.

From the viewpoint of handling logistics, segregation implies higher costs for storage and transport (Schlecht et al. 2004). The system of full segregation for grains requires a greater amount of compartments in the storage units or the need for the establishment of silos with lower capacity in order to allow segregated storage.

An evaluation of the implementation of the CPB for the Brazilian soybean in order to fit the term "contain" was carried out by Oliveira et al. (2012). The study indicated a loss in competitiveness for Brazil in the international market; considering the cost of the tests to identify two transgenic events, segregated logistics and reduction of international trade, these losses reached US$ 1.57 billion. This amount represented 13.8% of the foreign currencies generated by exports of soybeans in Brazil in 2009.

In the case of corn, this reduction may be even more significant, as the number of transgenic events to be evaluated is superior to soybean, on an average of six. Another point concerns the spatial production; corn production is much more fragmented in the territory than soybean production, which makes it very difficult to establish routes that make it possible to calculate the impact of measures aimed at full segregation of conventional versus transgenic loads. Differently from soybean, gene flow affects corn plants. In countries when pollen is viable in a short period, such as European countries, adventitious presence can generate serious problems for segregation, regarding the threshold level of 0.5% required by EU authorities. In Brazil, studies (CIB, 2006) suggest a distance of 200 meters between varieties as a measure to avoid gene flow effectively. It is therefore possible to control adventitious presence in the case of Brazil using good practices. However, when low-level standards of adventitious presence has been demanded by CPB, this becomes a new source of concern.

Accordingly, the aim of this paper is to analyze the effects of segregation of corn on the logistics of transport and storage of Brazil and its impacts on competitiveness in the international market, in a context of building new institutions, in this case, from the simulation of resolutions undertaken by the Cartagena Protocol on Biosafety, CPB.

The treatment of the proposed problem requires the search for new analytical tools and simulation scenarios. Thus, the proposal is to develop a partial equilibrium model as a Mixed Complementarity Problem (MCP), which aims to provide guidance for the implementation of more effective policies that support new investments in the sector.

In Brazil, from 2003 to 2006, an intense debate took place on the costs of complying with alternative rules of CPB (main contain versus contain). The importance of the papers prepared for the debate with different stakeholders, as shown in Oliveira (2011), was that the results were very easy to interpret, in spite of the requirement of a certain degree of knowledge on economics to understand the methodology developed. These works have contributed to convincing the majority of public managers to take the issues raised by the Cartagena Protocol in the field of external trade seriously.

On the one hand, these papers have contributed to alerting stakeholders, mostly public managers, to the risks of generating trade diversion when taking the stringent versions of CPB. On the other hand, these studies, including this paper, informs people involved in full segregation that contamination in storage and transportation activities demands particular facilities dedicated to segregation, and as a result, premiums; in other words, to pay attention to the link between logistics and contracts.

In section 2 we examine the key role of regulation in the formation of markets for biotech products and the implications of the Cartagena Protocol (CPB) through Article 18.2 of the logistics of transport and storage of corn in Brazil. Section 3 shows the model adopted - Mixed Complementarity Problem (MCP) - to analyze the issue of genetically modified (GM) corn and the construction of the scenarios used. Section 4 shows the main results obtained with the MCP implementation and the impacts of imposing CPB in the Brazilian corn trade flows. Finally, section 5 shows the main findings and contributions of the research.

Implications of Identity Preservation Systems

Corn production in Brazil, along with soy, contributes to approximately 80% of the grain production in the country (Duarte 2011). Unlike soy which has immediate liquidity, the production of Brazilian corn is focused on domestic supply. Recently, however, exports of this cereal have been held in significant quantities, contributing to greater support for domestic corn prices.

Brazil is third place in the global ranking of corn production, behind the United States and China (USDA 2012). According to Duarte (2011), the economic importance of corn is characterized by various forms of its use - from feeding to the high-tech industry. One of the main uses is in the composition for poultry and pigs; we must mention, however, that nowadays corn is incorporated in the bioethanol chain as the main raw material in the production of clean fuels, such as in the U.S.

Although versatile in its use, corn production has basically followed the growth of production of pigs and poultry, both in Brazil and around the world. An important aspect that should be highlighted is the location of industrial units of pigs and poultry in Brazil. The Southern region still produces the majority of these animals and has shown growth in this activity. More recently, the production of pigs and chickens in the Central-West region is showing strong growth, linked to the increased production of soybean and corn in the region. This trend is fully justified because of the weight of corn and soybean in the final cost of feed, both for poultry and pigs.

A counterpoint, however, of this productive migration to the Central-West region needs to be mentioned. The cost of transport, especially in Brazil, where infrastructure conditions are poor, ends up burdening the good, with direct implications on the cost of production of corn, when transported over long distances. On the one hand, there is a tendency to consume corn as close to production areas as possible, but on the other hand, when considering exports of corn in the Brazilian ports located at distances beyond a thousand miles of the Central-West region, the share of transport cost becomes more evident.

That said, it can be noted that the regulatory aspects regarding the segregation of the load, by implementing full segregation preservation systems, besides the implications on the diffusion of technology, greatly affect the production costs and the logistics configuration of corn transportation.

According to Oliveira (2011), who assessed the implications of a full segregation system for the Brazilian soybean case proposing a scenario in which the costs of testing to identify transgenic events and segregated storage were added to the logistical costs. Strict measures can alter the economic efficiency of infrastructure projects existing in Brazil. This is because a segregation system makes regions far from the port of export become less competitive due to the increase in logistical costs through the identity preservation system, invalidating transportation projects that would probably not have the same load demand for movement.

The mandatory implementation of processes that lead to an increase in fixed costs, with no direct connection to the fulfillment of the objectives of the Cartagena Protocol (CPB) - especially through Article 18.2 - should be viewed as a new component in the process of creating technical barriers to trade, with negative effects on agricultural producers in exporting countries and on consumers in importing countries.

The CPB was created based on the precautionary principle. In situations where the potential risks are unknown for reasons of scientific uncertainty, countries may restrict, and even prevent, the importation of living modified organisms (LMOs) (Mackenzie et al. 2003).

Based on this principle, the CPB establishes, in Article 18, the requirements and necessary steps with regard to handling, transport, packaging and identification of all loads that contain or may contain LMOs. The purpose of this analysis is restricted to loads of LMOs-FFPs (living modified organisms intended for direct use as food or feed, or for processing), whose requirements are set out in paragraph 2.a of Article 18 (Mackenzie et al. 2003):

> 2. Each Party will take measures to require that documentation accompanying:
> (a) living modified organisms intended for direct use as food or feed, or for processing, clearly identifies that these "may contain" LMOs and are not intended for intentional introduction into the environment, as well as a contact point for further information. The Conference of the Parties serving as the meeting of the Parties to this Protocol will take a decision on the detailed requirements for this purpose, including specification on its identity and any unique identification, no later than two years after the entry into force of this Protocol (CTNBIO 2010).

Although in its original text the Protocol uses the expression "may contain", most importers of agricultural products requires the load to be identified with the use of the term “contain”.

According to Vieira Filho et al. (2006), when interfering in contractual and export decisions about the grain export chain, the statement "contain" opens the door to demands aimed at generalizing the requirements of identity preservation systems based on tests. This causes undesirable impacts on the configuration of the trade - encouraging verticalization in producer countries and fostering grain production in less efficient countries from an agricultural point of view.

The implementation of CPB also depends on the definition of "detailed requirements". According to Kalaitzandonakes (2004), these requirements can be separated into three groups. The first one concerns the specification of the accidental mixing of LMOs in export loads, i.e., what is an acceptable level of adventitious presence and when is labeling required. The second group covers the information that must be provided by exporters and how it should be collected, such as labeling with "may contain" or if additional information to identify or quantify the LMOs is necessary. Finally, the third group relates to issues involving decisions about how the importer receives and, in turn, uses the information provided by the exporter.

After the controversial debate at the COP-MOP3, the members of the Cartagena Protocol agreed to consider two options for identifying GMO loads. The choice of the term "may contain" for loads in which events are not precisely identified, can easily be operationalized by including a list of likely events with the load; as a result the impacts on trade flows would be well reduced. The term "contain" requires additional measures, where the identity of GMOs contained in loads must be determined by an Identity Preservation System (IPS) based on tests, including a list of events in it.

Although the benefits of this change are highly debatable, its application would generate highly significant additional costs (Boüet et al. 2010; Kalaitzandonakes 2004). More specifically, under the term "contain", countries that produce and export non-GM products would be exempt from checks and tests, while countries that export GM products would have to test each load to verify the accuracy of the identification of each event.

Despite the assertions of authors like Zarilli (2005) that developing countries have less defined regulatory principles than developed countries, this criticism does not apply to the case of Brazil, which is marked by ambiguity arising from being a major exporter of agriculture and a residual importer - of wheat, barley and a few non-tropical products (Silveira 2010). Brazil also boasts great biodiversity and centers of origin of cultivars (such as Peru, Colombia, Mexico, Costa Rica, Turkey, China and others). Thus, the delay for the definition of the biosafety policy in Brazil is due less to a lack of training in the area than to the conflicts that still exist between different social players involved directly and indirectly in the regulation process (Borges et al. 2009).

The cost structure for the identity of preserved crops differs from the commodity market because it includes the costs plus the segregation and expenses to mitigate the risks specific to the IP markets. The risks stem from one or more factors of pricing (price premium, quality and information) and instruments for the fulfillment of international protocols, among which, the Cartagena Protocol on Biosafety, aspects which are more prevalent in IP grains than in conventional grains (Boüet et al. 2010).

These costs and risks have direct implications not only on trade relations, but also on transportation logistics and storage. According to Boüet et al. (2010), despite advances in biotechnology, aspects such as infrastructure and transportation continue to be factors that limit the potential of modern agriculture.

The issue of the disposal of the Brazilian harvest is a key factor that affects agribusiness at its base, substantially changing the marketing, pricing and competitiveness of the sector. The logistics infrastructure must have the ability to move and store the entire national agricultural production and also provide systems for imported products to satisfactorily meet domestic demand.

As the requirements of Article 18.2.a of the Cartagena Protocol imply additional costs in trading, particularly in transboundary movements, it is necessary to understand the effects of these measures.

The exploitation of the potential expansion of grain production depends on establishing an efficient system of transportation. Such a system will have to store larger volumes at lower costs, thus allowing the grain sector to increase its contribution to the domestic supply of food and maintain its position in the international market.

In general, countries with limited land areas guide their transport in road transportation, while countries with large areas, with the exception of Brazil, prioritize rail and waterway transport, as these modes are more efficient and competitive when transporting long distances.

According to Caixeta-Filho (2010), what has been observed in the Brazilian agricultural economy in recent decades is the real revolution of its spatial arrangement, where agribusiness occupied borders such as the North and Central-West regions, and have advanced to the Northeast, generally through activities that incorporate modern production technologies. This way, introducing a whole chain of support for the main business, i.e., input suppliers, storers and processing industries are clustered around the production areas, in order to minimize transportation costs, while complying with the principles of economic rationality.

According to Caixeta-Filho (2001), the average distance covered by these loads becomes greater than 1600 km, on the other hand, considering the total of loads moved by rail, the average distance is less than 500 km. This is due certain factors such as lack of infrastructure logistics, problems with storage, relatively low cost of land, growing distances between producers and consumers poles.

In this context, the change in the direction of flow of agricultural production is due to a reduction in transportation costs caused by multimodality and a reduction in the distance to the exporting port.

However, the reality in Brazil shows an inefficient transport system (Figure 1). According to the data from ANTT (2006), the mode of road transport has absorbed more than half of the cargo transportation in Brazil. This predominance of road transport can be explained by the difficulties facing other modes of transport to efficiently cater to rising demand in the more remote areas of the country, which are not provided with railways or waterways.

According to Oliveira et al. (2012), the compliance costs to the CPB correspond to the costs of the resources needed to fulfill the legal requirements established by the parties. They depend on three factors:

- the nature of identification of the LMOs required;
- the country's position in the global market of agricultural commodities (if the country is an exporter or importer, and a producer of GM crops);
- the internal conditions of each country, such as logistics conditions and expertise to safely and inexpensively perform tests.

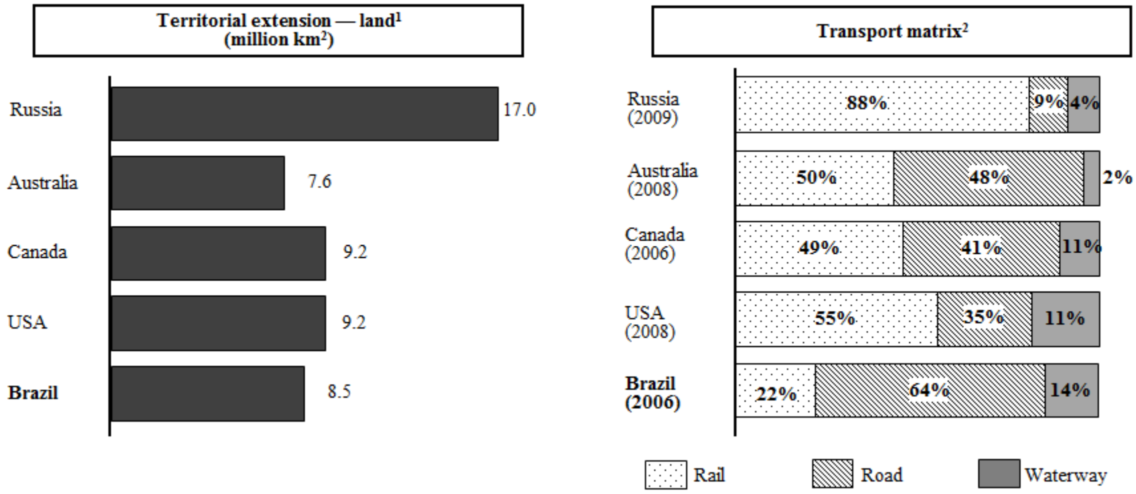

Figure 1. Territorial extension and load transport, selected countries.
Notes. 1) Total territorial extension minus areas covered by water. 2) Does not consider air and pipeline transportation.
Source. CIA World Factbook (2010) for territorial extension; Bureau of Transportation Statistics (2010), International Transport Forum (2010) and ANTT (2006) for transport matrix (as cited in Oliveira 2011).

Studies carried out in the United States, Argentina and Brazil show that the cost of testing LMOs vary according to: a) the number of samples to be analyzed; the type of testing required by the Protocol (simple identification, using the protein test, qualitative assessment, quantitative assessment); b) the number of events that will be tested; and c) the number of crops that will be evaluated (Silveira 2006; Kalaitzandonakes 2004). Thus, evaluating the determinations of Brazil on the CPB and technical measures that may arise from it is an important tool to analyze the impacts of the adoption of the Protocol, taking into account the specific logistics of each signatory country.

Methodology

In order to quantify the potential impacts of the costs of implementing the CPB for Brazil, with a focus on the organization of the Brazilian logistics of transport and storage, we use a partial equilibrium model formulated as a Mixed Complementarity Problem (MCP).

The partial equilibrium models elects a sector or product under consideration and examines the effects of a variation (exogenous) of the relative price on the balance of the industry, assuming that the allocation for the rest of the economy remains unchanged (Alvim 2003; Cavalcante and Mercenier 1999).

The most frequent use of partial equilibrium models with endogenous prices has been observed in problems related to competition for interregional markets (Yavuz et al. 1996). They have also been applied to simulate the impact of trade policies in different markets (McCarl and Spreen 2001). Furthermore, it is important to note that the theoretical structure of this model can be expanded, to include multi-exporter and importer regions, multimodal transport and multicommodity. In addition, they can be used to simulate the impact on markets that occurred through the application of trade policies, such as quotas, subsidies, tariffs, among other (Oliveira et al. 2012).

As the present study comprises an analysis of the impact of CPB on the Brazilian corn market, the partial equilibrium approach was adopted. The choice of this method provides a detailed review of the effects of implementing the CPB in Brazilian commercial flows, as well as the advantage of allowing the easier incorporation of tariffs, tariff quotas and grants.

Another approach to partial equilibrium models is the one shown in the form of a Mixed Complementarity Problem (MCP). The use of the MCP has been proposed by Thore (1992), Rutheford (1995) and Bishop et al. (2001), and is already used by Alvim (2003) and Alvim and Waquil (2004).

A complementarity problem consists of a system of simultaneous equations (linear or nonlinear), which are described as inequalities, from the functions of supply and demand. The PCM is equivalent to the Kuhn-Tucker conditions, which are necessary and sufficient to maximize the Social Net Payoff function (NSP), which in turn, implies achieving balance in all markets and regions.

Samuelson's formulation shows that maximizing the NSP function, given by the sum of the surplus of producers and consumers, minus shipping costs, and subject to regional balance equations, generates a framework of optimality conditions. It is however noteworthy that Samuelson warned of the problems associated with the use of his model to make inferences about social welfare, hence the expression "Social Net Payoff" which excludes a reference to the social welfare (Samuelson 1952). For a problem of nonlinear programming in which the objective function is differentiable and concave, with linear constraints (differentiable and convex), the result is the global maximum, since the optimal point satisfies the Kuhn-Tucker conditions (Takayama and Judge 1971).

Furthermore, the MCP has the advantage of allowing the easier incorporation of rates, quotas and grants to the model (Bishop et al. 2001).

The MCP proposed to analyze the Brazilian corn market is given below:

Indexes:

$i = \text{supply regions} \ (i = 1,...,7)$

$j = \text{domestic demand regions} \ (j = 1,...,3)$

$k = \text{international demand regions} \ (k = 1,...,3)$

$r = \text{transport routes} \ (r = 1,...,15)$

Variables:

$p_i = \text{supply price}$

$p_j = \text{domestic demand price}$

p_k = international demand price
z_i = quantity supplied
y_j = quantity consumed by domestic demand
y_k = quantity consumed by international demand
$x_{..}$ = quantity transacted

Parameters:
t_{IJ} = cost of transport
φ_i = shadow price associated with the supply region i
λ_j = shadow price associated with the domestic demand region j
μ_k = shadow price associated with the international demand region k

(1) $$0 \le \varphi_i \perp \sum_j^J x_{ij} + \sum_k^K x_{ik} \le z_i$$

(2) $$0 \le \lambda_j \perp y_j \le \sum_i^I x_{ij}$$

(3) $$0 \le \mu_k \perp y_k \le \sum_i^I x_{ik}$$

(4) $$0 \le x_{ij} \perp p_i + t_{ij} \ge p_j \quad \forall_{i,j}$$

(5) $$0 \le x_{ik} \perp p_i + t_{ik} \ge p_k \quad \forall_{i,k}$$

For the "⊥" symbol, it is understood that at least one of the adjacent inequalities must be satisfied as strict equality. This is nothing more than a formality of the complementarity that we saw earlier, when describing the Kuhn-Tucker conditions. Equations (4) and (5) are thus submitted to facilitate the inclusion of the *ad-valorem* rate or tariff entailed by the cost of testing to identify transgenic events. In the MCP, elasticity coefficients are included in the restrictions (1), (2) and (3), replacing the quantities produced and consumed by the following expressions:

$$z_i = a_i \cdot \varphi_i^{b_i}$$
$$y_j = c_j \cdot \lambda_j^{-d_j}$$
$$y_k = e_k \cdot \mu_k^{-f_k}$$

The inclusion of the *ad-valorem* rate was based on the work of Bishop et al. (2001). Considering the condition of zero net (5), the inclusion of a parameter tax_{ik}, representing an *ad-valorem* rate or tariff, occurs by incorporation in the model in equation (5). This is because, in this study, the rate has implications only on flows earmarked for the international market. Modifying the condition of zero net, as follows, we have:

(6) $$(p_i + t_{ik}) \cdot (1 + tax_{ik}) \ge p_k \quad \forall_{i,k}$$

In this case, the rate is a result of the imposition of tests for identification and quantification of LMO events, plus the cost of segregated storage on the flows for the international market, as the CPB imposes measures on transboundary movements.

When equilibrium is attained, if there is a trade flow between producing regions and international demand, the price of the product in the region of supply, plus the cost of transport, after the imposition of the LMO tests and segregation, should be equal to the price of international demand. Otherwise, if there is no commercial flow, the price in the region of international demand would be smaller than the price in the region of supply plus transportation costs and tests.

In the model, we initially identified and selected regions of supply and demand for corn. The selected states are part of the Southeast, Central-West and Southern regions. We analyzed the behavior, in recent years, of the variables: corn production, average yield, cultivated area, exports and consumption of corn in the pig and poultry production. The choice of states that comprised the model was based on the expressiveness of these regions in the participation of the variables analyzed. The aim was to characterize the dynamics of these regions, which hold prominent national expression and great potential for expansion based on agricultural frontiers.

The states selected are: Paraná, Mato Grosso, Mato Grosso do Sul, Goiás and Minas Gerais as regions of corn supply, due to their expressiveness in the production and/or export; São Paulo, Santa Catarina and Rio Grande do Sul as regions of demand. The corn importing countries considered are Iran, China and Japan.

To characterize the regions of excess supply and demand, we started from the following premise: if soy production is greater than the amount processed, this region is characterized as a region of excess supply, otherwise, this region is characterized as a region of excess demand. For the State of Mato Grosso and Paraná, we identified different microregions (consisting of a cluster of cities with characteristics similar to agricultural production, industrial and economic activities), both with respect to production and processing, due to the regional heterogeneity that implies different trade flows and the use of different transport routes.

The data that make up the model (production, consumption, marketing prices of the domestic and international market, price elasticities of supply and demand, freight of different modes and costs of LMO tests) were based on the year 2011. Production data were from the Brazilian Institute of Geography and Statistics (IBGE) and the Department of Agriculture of the United States (USDA). The consumption data were based on the Brazilian Association of Chicken Producers (APINCO) and the Brazilian Pork Industry and Exporter Association (ABIPECS), and the price of corn for domestic and international markets were based on the advisor Safras & Mercado (2011) and USDA (2012), respectively. The data of price elasticities of supply and demand were based on studies developed by Fuller et al. (2001 and 2003) and FAPRI (2011). The freight from the road, rail, waterway and maritime modes were based on the Freight Information System (“Sistema de Informações de Fretes” - SIFRECA 2011).

Aiming to understand the operational aspects of segregation of LMO grains and calculate the costs related to tests to identify transgenic events and segregated storage costs, we conducted interviews with key industry players (trading companies, shipping companies and certifiers). This was an exploratory and qualitative research, with semi-structured questionnaires used to assist personal interviews. Some trading companies also authorized visits to facilities, which allowed the observation and viewing of all stages of segregation operations, including boarding ships.

In order to anticipate the cost analysis of implementing potential decisions made in the CPB regarding transboundary flows of a LMO load, we emphasize that the impact of CPB on the trade of corn can be determined by the type of information that must accompany a load containing LMOs. This information may be achieved by one of the three following alternatives:

a) a simple indication that the load "may contain" LMOs;
b) identification for the specific LMO in the load; and,
c) identification and quantification of a specific LMO.

Each of the alternatives required will demand a particular analytical procedure, also resulting in different risks and costs for each.

Based on field research, we determined the cost of tests for the identification of transgenic events, as well as the sampling pattern. There are two methods of LMO analysis: one carried out by analysis of DNA and another by the analysis of proteins. In the first case, the technique used is the PCR (Polymerase Chain Reaction), of a quantitative or qualitative nature. For the protein analysis, the simple ELISA (Enzyme-linked immunosorbent assay) test or the dipstick test can be used. In this test, only one event at a time was detected.

The unit cost was US$ 3.00 for the dipstick tests and US$ 300.00 for the PCR. Every 40 tons, 2 samples are taken, which requires 2 dipsticks, giving a total cost of US$ 6.00. In the case of PCR, we considered the PCR Quantitative Real Time with a cost of US$ 1,050.00 (US$ /sample/6events), which performs 3 analyses for every 3,000 tons, amounting to US$ 3,150.00, including 1 PCR when boarding, 1 PCR at the port of export and 1 PCR on the ship.

Segregated storage costs were incurred by the major companies exporting non-GM corn. Costs in transshipment warehouses were approximately US$ 13.00/ton and storage at ports of export were, on average, US$ 10.00/ton.

Thus, the estimated costs of tests and storage were calculated based on the use of the term "contain", i.e., comprising both the identification and the quantification of GM corn. This consideration was made as the option for the term "may contain" would have almost no effect on marketing costs and cause minimal triggers on the logistics structure (Huang et al. 2008; Borges et al. 2009; Kalaitzandonakes 2004; Gruère and Rosegrant 2008; Simões 2008).

We simulated two different scenarios. Scenario 1 was the control, where there were no expenses from LMO tests and segregated storage; trade flows were based only on transport costs, i.e., without the imposition of the CPB in relation to the term "contain".

In Scenario 2, we propose a framework of full segregation in relation to the term "contain". The PCR test was considered when boarding, at the port of export and the ship. The number of dipstick tests varied according to the transport route considered. With each change of mode of transport - which requires transshipment operations, since mixing of cargo can occur - an additional dipstick test was performed. The segregated storage was also considered during the process. Based on these considerations, the *ad valorem* rate calculated was 60% in intermodal flows and 55% in the unimodal flows.

The processing of the information for the MCP developed for the movement of corn in Brazil was carried out using the computer program General Algebraic Modeling System - GAMS (Brooke et al. 1995).

Transportation costs of the road and rail modes in the model were estimated by linear equations based on the distances between the loading and receiving points (source/destination). The behavior of the mode cost (variable of response) was analyzed using a multiple linear regression model. We used monthly data on types of freight used throughout Brazil in 2011, employing data from the Freight Information System (SIFRECA) as a source. For the waterway mode, we used freight practiced in the waterway routes in 2011 and the source was also SIFRECA. We did not perform a regression test, as there were only three waterway routes considered in the model.

Results and Discussion

According to Alvim (2003), mathematical programming models must be validated by checking the consistency of the results of the problem. For Waquil and Cox (1995), the validation presupposes an adaptation of the coefficients and the model structure. The model can be validated by checking how well the solution suggested by the model approximates the real situation. According to Thompson (1981) (as cited in Waquil and Cox 1995), much of the spatial equilibrium models do not generate results identical to the actual data.

Thus, some differences can occur between the results estimated by the model and the data observed, without invalidating the model. In Table 1, we can verify the levels of supply and demand estimated by the model. The volumes committed in 2011 ("Observed Data") and the data estimated from the model ("Scenarios 1 and 2") are also shown.

Scenario 1 corresponds to the control group. In this group there were no expenses with LMO tests and segregated storage; trade flows were based only on transport costs. This scenario represents business transactions without the imposition of the CPB. With the focus of analyzing the impacts under the CPB through Article 18.2.a and considering the use of the term "contain", the segregation test costs were incurred in Scenario 2.

In Scenario 2, the identification and quantification system of transgenic corn events generated a negative impact of 4.49% on trade. International flows were the most affected, with losses of 765,000 tons. The exports to Iran and to Taiwan, which are Brazil's main partners, fell by 10.0% and 5.64%, respectively.

Table 1. Supply volumes, domestic demand and international demand, model estimates (scenarios 1 and 2) and observed data, 2011.

Regions	**Scenario 1 (A)**	**Scenario 2 (B)**	**Observed Data (C)**	**Variation (B)/(A) (%)**
		(thousand tons)		
Supply				
Total Mato Grosso (MT)	*5,084.25*	*4,826.21*	*6,610.10*	*-5.08*
North MT	3,826.99	3,627.04	4,957.57	-5.22
Southeast MT	1,257.27	1,199.17	1,652.52	-4.62
Goiás (GO)	3,003.32	2,875.85	4,003.96	-4.24
	1,962.46	1,848.92	2,747.65	-5.79
Minas Gerais (MG)	2,704.33	2,610.61	3,385.99	-3.47
Total Paraná (PR)	*4,293.42*	*4,121.02*	*5,367.82*	*-4.02*
North PR	2,840.98	2,677.80	3,489.08	-5.74
West PR	1,452.44	1,443.22	1,878.74	-0.64
TOTAL SUPPLY	**17,047.78**	**16,282.62**	**22,115.52**	**-4.49**
Domestic Demand (D)				
Santa Catarina (SC)	3,179.39	3,210.72	3,028.19	0.99
	130.76	130.94	124.65	0.13
São Paulo (SP)	288.57	289.11	270.71	0.19
Subtotal	*3,598.72*	*3,630.77*	*3,423.55*	*0.89*
International Demand (E)				
Iran	5,329.65	4,796.90	5,000.00	-10.00
Japan	4,016.32	3,983.33	4,000.00	-0.82
Taiwan	4,103.10	3,871.61	4,000.00	-5.64
Subtotal	*13,449.06*	*12,651.85*	*13,000.00*	*-5.93*
TOTAL DEMAND (D+E)	**17,047.78**	**16,282.62**	**16,423.55**	**-4.49**

Source. Research Data (2011)

The most significant commercial reductions occurred in the Brazilian regions farthest from ports of export, where the increase in cost impacting the logistics network is more strongly perceived. The main decreases were in the state of Mato Grosso do Sul (Central-West region of Brazil), 5.79%, followed by the North of the state of Paraná (Southern region of Brazil), 5.74%, and North of the state of Mato Grosso (Central-West region of Brazil), 5.22%.

Scenario 2 provides evidence for the loss of competitiveness of Brazilian corn and as well as the regional impacts. Through the parameters supplied, it is possible to identify how production performance and consumption in the regions analyzed are modified when an international agreement is simulated. To drain the Brazilian production, it is necessary to perform a greater number of transfers, given the long distances to ports of export, as the main competitors - the United States and Argentina - have greater logistical efficiency, thus the reduction in Brazilian competitiveness becomes eminent.

With respect to monetary losses, considering the expenses with tests and storage (US$ 506 million) and the reduction of international trade (US$ 212 million), losses reach US$ 718 million. This amount represents 27.4% of the foreign currencies generated by exports of corn grain by Brazil in 2011, which amounted, according to the Ministry of Development, Industry and Foreign Trade (MDIC), to US$2.62 billion.

From the simulation of Scenario 2, it is possible to verify that the triggers of the CPB have different reflexes in major producing regions of Brazil. The losses in this scenario ranged from 0.64% to 5.79%. The impact of the measures of the CPB can vary considerably among Brazilian states exporting corn. These differences occur due to conditions of transport infrastructure and storage; logistical options available and their ability to make quick adjustments to meet the segregated movements; laboratory infrastructure and weight of the grain exports for the trade balance of the states. Charts 1 and 2 show the trade flows and the logistics routes used for moving corns in Scenarios 1 and 2, respectively.

Chart 1. Trade flows by transport route, Scenario 1 (thousand tons).

Supply	Demand	Route						
		R1	**R2**	**R3**	**R8**	**R10**	**R14**	**R15**
PR-W	SC		1,001.27					
PR-W	SP	288.57						
PR-W	RS			130.76				
MS	SC		1,962.46					
MG	SC		215.66					
PR-N	Iran					2,840.98		
PR-W	Japan					31.84		
MT-N	Taiwan							3,826.99
MT-SE	Taiwan				276.11			
MT-SE	Japan				981.16			
MG	Iran						2,488.67	
GO	Japan				3,003.32			

Scenario 1. There were no expenses with LMO tests.
Road Route (unimodal). R1; R2; R3; Intermodal route: R8; R10; R14; R15.
Source. Research Data (2011).

In Scenario 1, a portion of corn production in Minas Gerais (MG) was destined for the domestic market, supplying Santa Catarina (SC) in the Southern Region of Brazil, using only road transport (route R2). Another portion of the production was directed to Iran, exported through the port of Vitória (state of Espírito Santo). For this flow, the roads and railways routes were used (intermodal route). Corn was transported by truck up to the rail terminal located in the city of Araguari (MG), and from there it was transported by rail up to the port of Vitória (route R14).

The movement of corn from this region in Scenario 2, where there was an increase in logistic costs by imposing the CPB, changed. The region began providing a greater volume to local markets and started to export corn to Taiwan. In addition to this modification, the route to the international market changed (the intermodal route (R14) used before in Scenario 1 is no longer competitive). The corn was exported through the Santos port via road route (route R4).

Chart 2. Trade flows by transport route, Scenario 2 (thousand tons).

Supply	Demand	Route					
		R1	R2	R3	R4	R9	R15
PR-W	RS			130.94			
MS	SP	289.11					
MS	SC		1,559.81				
MG	SC		1,650.91				
PR-N	Iran					2,677.80	
PR-W	Iran					1,312.28	
MT-N	Japan						3,627.04
MT-SE	Iran				806.82		
MT-SE	Taiwan				392.35		
MG	Taiwan				959.70		
GO	Taiwan				2,519.56		
GO	Japan				356.29		

Scenario 2. includes testing costs for 1 event and segregation. *ad-valorem* rate: road routes: 55%; intermodal routes: 60%.
Road Route (unimodal). R1; R2; R3; R4; R9. Intermodal route: R15.
Source. Research Data, 2011.

Another analysis that can be made concerns the routes used. In Scenario 1, the exports were made via intermodal options, responsible for 100% of movements (13.45 million tons). In Scenario 2, only 29% of corn destined for the international market was done so by intermodal options (approximately 3.6 million tons). Only exports from the northern region of Mato Grosso used intermodality as competitive option. The implementation of measures of segregation resulted in 71% of intermodal routes being no longer competitive due to the increased cost, and road mode was prioritized and overwhelmed. Thus, the costs of implementing the CPB had a larger impact on intermodal routes due to the greater number of tests required and the increased demand for segregated storage; these factors contributed to the increased cost of transport compared to unimodal routes using only the railroads for transporting corn.

Thus, the logistics of transport and storage is affected by the requirements of the Cartagena Protocol on Biosafety; therefore, the more rigid the identification process, the greater the impact on exports. As a result, the competitiveness of Brazilian corn on the international market is compromised by inefficient logistics in terms of responding to the demands of the CPB at the same speed.

Although the study aims to analyze Brazilian trade flows, as the country has a matrix of unbalanced transportation and logistical bottlenecks, the costs of adapting the infrastructure in the face of norms and standards set by the CPB are higher when compared to key competitors,

United States and Argentina, who have better logistics. The corn produced in Argentina travels shorter distances between production areas and ports of export; the Americans prioritize the waterway mode - at a lower cost compared to other modes - to distribute their production.
However, the impacts of the CPB for Brazil not only depend on the level of demand for segregation, but also on the fulfillment of the measures of the Protocol by the main importers that must demand the same requirements for non-signatory countries, Argentina and the United States. Therefore, if the United States and Argentina do not have to follow the norms and standards set out by the CPB, Brazil may become even less competitive.

A further evaluation was made of Scenario 2 through sensitivity analysis of two parameters used in the model: the price elasticity of supply and the price elasticity of demand. According to Law and Kelton (1991), sensitivity analysis can be defined as a technique that allows, in a controlled way, the conduction of experiments and research by means of a simulation model. This type of analysis is an important tool to observe trends and evaluate the impacts associated with: (a) changes in the values of input variables and system parameters, and (b) structural changes in a model. These impacts are determined by analysis of the output variables.

Thus, a number of simulations are carried out to evaluate the international trade of Brazilian corn (already considering the imposition of the CPB and its impact), from the positive and negative variation of these parameters. The parameter price elasticity of supply is associated with producing regions in Brazil, and the parameter price elasticity of demand is associated with regions of domestic and international consumption.

According to Alvim (2003), the price elasticity of demand measures the response of consumers to changes in price, while the price elasticity of supply measures the reaction of sellers to changes in price. When a change occurs in market prices, there may be changes in the volumes consumed and produced that are more or less intense, depending on the inclinations of the curves of supply and demand of the product evaluated. In this study, the price elasticities of supply and demand are different depending on the region, and therefore certain changes in prices may imply more or less intense variations in each region.

When simulations regarding the behavior of price elasticity of supply are carried out, it must be considered that this variable may vary if there are alterations such as technological changes in the production and/or marketing or new alternatives in production. As for the price elasticity of demand, this may vary in the countries analyzed in relation to the base scenario, if there are changes in income, substitutes, or simply consumer preferences.

Thus, for Scenario 2 we simulated a 50% increase in price elasticities of supply and demand, C2S+50 and C2D+50, respectively, and a 50% decrease in the price elasticities of supply and demand, C2S-50 and C2D-50, respectively.

- C2D+50: the price elasticity of demand became more negative. For example, for São Paulo the price elasticity of demand was Scenario 2 = -0.10 and went to Scenario 2D+50 = -0.15.

- C2D-50: the price elasticity of demand became less negative. For example, for São Paulo the price elasticity of demand was Scenario 2 = -0.10 and went to Scenario 2D-50 = -0.05.

In the scenario with the imposition of the CPB (Scenario 2), all trade flows show losses when the price elasticity of supply in producer regions increases (CS +50) (Figure 2), i.e., consumers respond negatively to this change. This picture has a good approach with the implications of the CPB, as, besides the increase observed in transportation costs for segregation (simulated in Scenario 2), other expenses can be generated with the adoption of the Protocol, involving additional costs of marketing and operation of a Identity Preserved (IP) system, which can result in price changes, leading to a decrease in total sales volume.

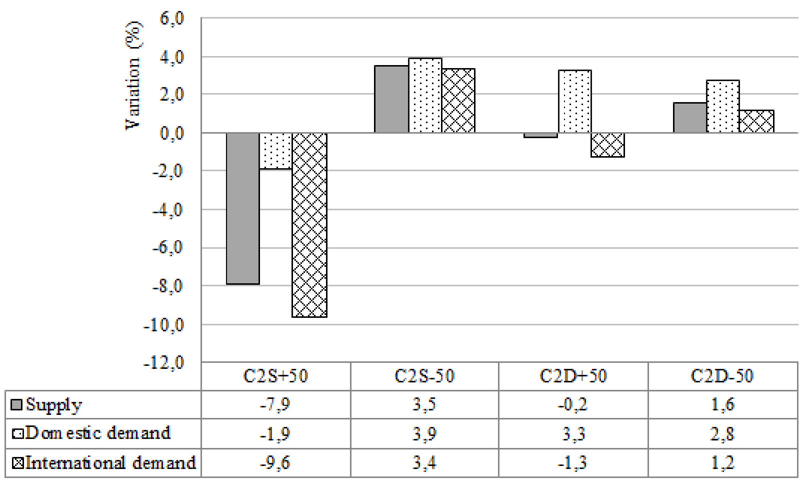

Figure 2. Sensitivity analysis of the marketing of corn to changes in price elasticities of supply and demand, Scenario 2.
Source. Research Data (2011).

In Scenario 2, the trades amounted to 16,282.62 thousand tons, but with the simulation of the CS+50 framework the volume transacted went to 14,995.08 thousand tons (down 7.9%), greater loss observed (Chart 3).

The biggest gain in volume was observed in the simulation C2S-50, with an increase of 3.5%. In this configuration, consumers responded positively to this change, in which it was possible to reduce the negative impacts of the CPB.

Chart 3. Volumes of marketing of corn obtained from the changes in price elasticities of supply and demand, Scenario 2 (thousand tons).

Variables	**Scenario 2**	**C2S+50**	**C2S-50**	**C2D+50**	**C2D-50**
Supply	16,282.62	14,995.08	16,856.32	16,242.58	16,537.30
Domestic demand	3,630.77	3,563.19	3,773.67	3,751.86	3,731.22
International demand	12,651.85	11,431.89	13,082.65	12,490.72	12,806.09

Source. Research Data (2011).

Finally, in a scenario of imposition of the CPB, other impacts may occur (positive or negative), according to the perception of the agents involved in the marketing of corn, regarding the benefits of GM corn and the costs associated with segregation. This perception may be reflected in the price level that will interfere in the sales volume, causing an increase or decrease.

Final Considerations

Advances in Brazilian agribusiness can be explained by the success of the combination of factors ranging from more integrated supply chains, intensive use of capital in the various segments that comprise it and government programs to support agriculture. On the other hand, the logistics sector has not been reaching the same level of development and has revealed several weaknesses, either in terms of lack of infrastructure to transport the production, or the inability to adequately store the national harvest.

The logistics of transport and storage, which until now has tried to adjust to the movement of standardized products and in large volumes, must adapt quickly to cope with the growing demand for differentiated products, which must be segregated and will require adjustments in the current logistics system.

From the proposed model we found that trade flows required testing along the chain, which reflected in a decrease in competitiveness of Brazilian corn. The effect is greater in border states, such as Mato Grosso; thus, the requirement of segregation can interfere with the production decisions of farmers just to meet the criteria that are not necessary from the point of view of biosafety. The CPB also results in an increase in opportunity cost when adopting a new technology.

From a competitiveness point of view the implementation of Identity Preservation Systems leading to an increase in fixed costs, with no direct connection with the fulfillment of the objectives of the Protocol, may block the access of farmers to technology, which is easily done by purchasing seed. It also prevents the competition among companies in the market of hybrid seeds being fully exercised. This happens by delaying the release of cultivars resistant to insects and by limiting the offers at the choice of farmers, under the false argument that small farmers prefer local and non-hybrid varieties.

Thus, what we see is a conflict between importers and exporters of agricultural commodities. On the one hand the efforts of importing countries to establish an extremely demanding system on behalf of biosecurity. On the other hand, the large exporters of LMOs are concerned about the costs of implementing the Protocol and the possibility of creating new restrictions on international trade. An important contribution to try to equate these diversions is the implementation of bilateral agreements and/or prediction of mechanisms to reduce tariffs imposed by importing countries in an attempt to reduce the negative impacts of the CPB.

It is worth noting that Brazil is the second largest cultivator of biotech agriculture in the world and offers a complete and rigorous regulatory system. Thus, the protection of consumers and environment with respect to biotechnology activities is duly guaranteed by the Brazilian legal system.

Today, Brazil faces the challenge of reducing its deficit in transport and storage capacity, a process based on increasing operational efficiency, as well as taking advantage of economies of scale and scope. The imposition of Identity Preservation Systems on a large scale would not only divert the resources needed from agribusiness to accompany the growth rate of Brazil, but would also create uncertainty as to the type of investment that must be made.

Either way, it is critical that discussions regarding the regulation of LMOs envisage investments in infrastructure, so that the positive effects of agricultural biotechnology can be made clear to consumers as well as countries whose talent is manifested in the competitiveness of agribusiness.

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