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The supply chain of Brazilian maize and soybeans: the effects of segregation on logistics and competitiveness

RESEARCH ARTICLE

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Abstract

Despite the significant advances of Brazilian agriculture, transportation and storage costs still constitute the main barriers to the Brazilian agribusiness. The aim of this article is to analyze the effect of segregation of maize and soybeans in the Brazilian transport and storage logistics, especially genetically modified grains. In the context of the guidelines of the Cartagena Protocol on Biosafety (CPB) as well as of the competitiveness in the international market, we develop a spatial equilibrium model in the form of a mixed complementarity problem. The competitiveness of Brazilian maize and soybeans on the international market is compromised by the inefficient logistics and slow responses to the demands of the CPB. The contribution of the paper is to evaluate how regulatory issues of a segment, in this case biotechnology, may interfere with logistic infrastructure projects.

Keywords: agricultural logistics, partial equilibrium models, international agreements, biotechnology
JEL code: Q13, Q02, Q17

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1. Introduction

Brazilian agribusiness stands out globally for its competitiveness in exporting products such as sugar, coffee, orange juice, ethanol, soybean and derivatives, and beef, pork and chicken meat (FAO, 2014; USDA, 2014). This performance is due mainly to three measures: the management of natural resources, the use of genetic engineering in the development of new varieties, and the adoption of new management practices.

The continued success of Brazilian agriculture depends on successive advances in new technologies that ensure productivity gains and/or added value in the final product. The intensification of the production is associated with a high use of fertilizers and pesticides, with significant increases in labor and land productivity. Genetic engineering, notably the creation of genetically modified organisms (GMOs), and mechanization with intense automation and precision agriculture represent some of the technologies that have significantly increased agricultural productivity (Buainain, 2014). However, despite the gains recorded and potential use of biotechnology in sectors such as agriculture and medicine, this has been one of the most controversial issues of our time. This is due, in large part, to the disagreement among stakeholders concerning the actual or potential benefits and risks of products from agricultural biotechnology.

Some social groups recognize the benefits of GMOs, such as the decreased use of pesticides, smaller agricultural production costs, increased yield per hectare, and lower food prices. However, many others focus on the potential negative effects of GMOs to the well-being of the population, including threat to human health and environmental damage or loss of biodiversity (Oliveira *et al.,* 2012).

Regardless of the opinion on GMOs, two points deserve emphasis. First, stricter rules regarding GMOs have economic implications, particularly in developing countries. The proliferation of biosafety systems and GMO authorization rules related to labeling, identity preservation, segregation, and traceability may complicate the international trade of genetically modified agricultural products and negatively affect the trade of agricultural commodities, especially in Brazil.

Second, segregation affects logistics and increase storage and transportation costs (Schlecht *et al.,* 2004). The full segregation for maize and soybeans requires more compartments in the storage units or lower-capacity silos that allow segregated storage.

The theoretical design of GMO regulations follows the Convention on Biological Diversity through the Cartagena Protocol on Biosafety (CPB) and the World Trade Organization, which are, in turn, based on the standards and guidelines of the *Codex Alimentarius* to address the issues on food security. The process of setting up consensus-approved multilateral protocols is complex. There is little room for collective action in the context of the CPB and specific provisions about GMOs as advancing from thesis towards practice often involves deadlocks.[1]

The CPB is expected to have more intense effects on the soybean and maize markets. Both are products with a significant share in global agricultural production. The economic impact will depend on the costs of the resources needed to comply with the legal requirements of the CPB.

The aim of this paper is to analyze – in the context of the CPB – how the segregation of maize and soybeans affects the logistics of transport and storage in Brazil and impacts the country's international competitiveness. Such analysis demands appropriate analytical tools and scenario simulations. The findings may guide the implementation of more effective policies and support new investments in logistics.

[1] Common sources of disagreement are labeling, transport, liability, and redress.

2. Grain segregation and agroindustrial logistics

Over 369 biotechnology events[2] and 27 biotech crops have passed the regulatory barrier in several countries as of June 2015, and many of them have been marketed during the last fifteen years (ISAAA, 2015).

Farmers around the world adopted biotech crops swiftly. The planted area of biotech crops increased approximately 62-fold since 1996 (James, 2013). Brazil had remained the second largest producer of biotech crops in the world in 2013. The planted area of transgenic crops increased by 3.7 million hectares in one year (the largest absolute increase observed in any country in the world) to 40.3 million hectares in 2013 (James, 2013).

Brazil implemented a faster approval system and approved 18 transgenics events (GM events) between 2010 and 2013. The commercialization of the first soybean variety resistant to insects and tolerant to herbicides was approved in 2012. Notably, Brazilian Agricultural Research Corporation (EMBRAPA) demonstrated its impressive technical capacity to develop and release a new cutting-edge GM crop by developing a virus-resistant locally produced bean entirely with its own resources and receiving approval for marketing it (James, 2013).

The Cartagena Protocol on Biosafety (CPB) governs the regulation on GMOs. Article 18 of the CPB establishes the rules for handling, transportation, packaging, and identification of all loads that contain or may contain GMOs. The analysis in this paper is restricted to loads of genetically modified organisms intended for direct use as food, feed, or for processing (GMOs-FFPs) (Mackenzie *et al.,* 2003).

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.

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 living modified organisms (LMOs). The purpose of this analysis is restricted to loads of LMOs-FFPs, 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 (Brasil, 2006).

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'.

The analytical framework aims to assess the intervention of CPB in Brazilian exports. It borrows from Gruère and Rosegrant (2008) who rated countries to assess the impact of Article 18.2.a. of the CPB. Gruère and Rosegrant (2008) divided the countries into four groups according to the countries' affiliation to the CPB and the production of GMOs:

[2] These biotechnological advances include creating genetically modified products (GM event) or transgenic products.

- Group 1: countries that produce GMOs, but are not parties to the CPB (for example, Argentina, United States, Canada).
- Group 2: countries that do not produce GMOs, but are parties to the CPB (for example, Japan, UK, Peru).
- Group 3: countries that produce GMOs and are parties to the CPB (for example, Brazil, China, South Africa).
- Group 4: countries that do not produce GMOs and are not parties to the CPB (for example, Russia, Israel, Chile).

Important observations may be inferred from a simple depiction of how the imposition of the CPB affects trade flows (Figure 1). First, the trade flows in countries in Group 3 (parties to the Protocol and producers of GMOs) are the most affected. Those countries would have to control the imports from all GMO-producing countries and exports to the other parties to the CPB as well as the exports to all non-member countries. Second, Group 2 countries (parties to the Protocol that do not produce GMOs) would have to control only the imports from countries in Group 1.

The imposition of the CPB impacts Brazil (Group 3) more than the United States and Argentina (both Group 1), the main competitors of Brazil in the soybean market (Figure 1). The soybean export competitiveness of Brazil is thus negatively affected. All flows of the Brazilian exports of grain are similarly affected. The main importers of Brazilian maize and soybeans belong to Groups 2 and 3 (parties to the CPB), hence, Brazil would have to carry out costly qualitative and, in many cases, quantitative tests to identify GMO shipments. These costs may result in loss of trade. According to Gruère and Rosegrant (2008), the identification requirements in Article 18.2.a. of the Cartagena Protocol impose additional marketing costs in maize and soybeans exports and affect the exporting countries' competitiveness.

Oliveira *et al.* (2012) gauged the implementation of the CPB as for the Brazilian soybean to fit the term 'contains GMO.' The study indicated that, considering the cost of tests to identify two transgenic events, segregated logistics, and reduction of international trade, the total competitiveness loss for Brazil in the

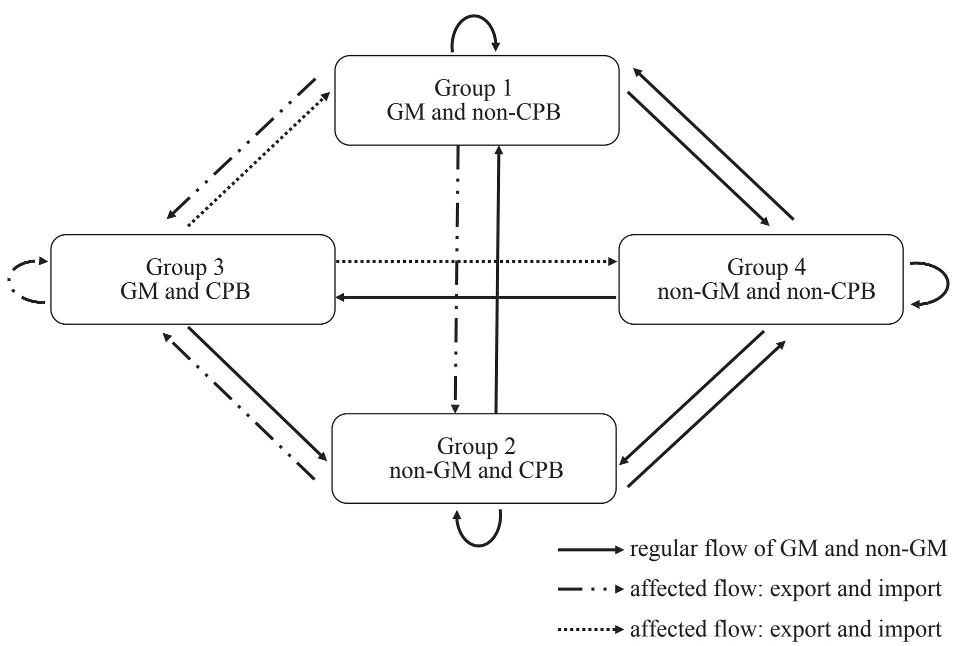

Figure 1. Trade flows affected by the implementation of the Cartagena Protocol on Biosafety (adapted from Gruère and Rosegrant, 2008).

international market reached US$ 1.57 billion. This amount represents 13.8% of the foreign currency generated by Brazilian soybean exports in 2009.

International trade loss may be even more significant for maize, considering that the number of transgenic events requiring evaluation is superior to soybean (six on average). Further, there is more spatial fragmentation in maize production than soybean production. This makes establishing routes very difficult and complicates the calculation of the impact of the full segregation of conventional and transgenic loads.

The movement of homogeneous and standardized products proved to be an important strategy to ensure economies of scale and facilitate logistics. However, the demand for differentiated grains has grown significantly.

The exports of Brazilian agricultural commodities are at a disadvantage compared with commodities produced in other countries due to the high costs of transportation via inadequate roads and costly and inefficient port services.

In addition to the issues with the transportation system, the storage infrastructure in Brazil adds to the logistics. Despite the growing investment in storage in Brazil, it has not accompanied the growth of the agricultural sector. After a small annual growth of 2.1%, the static capacity of warehouses was 145.6 million tons, but did not accommodate the grain production of 186.9 million tons for the 2012/2013 harvest (an annual increase of 12.5%) (CONAB, 2014b). The storage deficit thus amounted to 22.1% (Figure 2).

Adding the challenges of CPB implementation to the critical shortage of warehouses for conventional production exacerbates the already inherent limitations of proper storage for segregated beans. Improvements in transportation should accompany the expansion of farm areas originating a new, larger spatial arrangement for the production sectors. The transportation sector thus constitutes a logistical bottleneck. Harnessing the potential of grain production, however, will be possible only through an efficient road system, integrated intermodal transport corridors, and addressing the storage deficit, especially for the segregated cargo.

3. Methodology

In order to quantify the potential impact of the costs of implementing the CPB for Brazil, with a focus on the organization of the Brazilian logistics of transport and storage, we used a partial equilibrium model formulated as a mixed complementarity problem (MCP). The use of MCP has been proposed by Thore (1991), Rutherford (1995) and Bishop *et al.* (2001), and it has already been used by Oliveira *et al.* (2012) and Alvim and Waquil (2004).

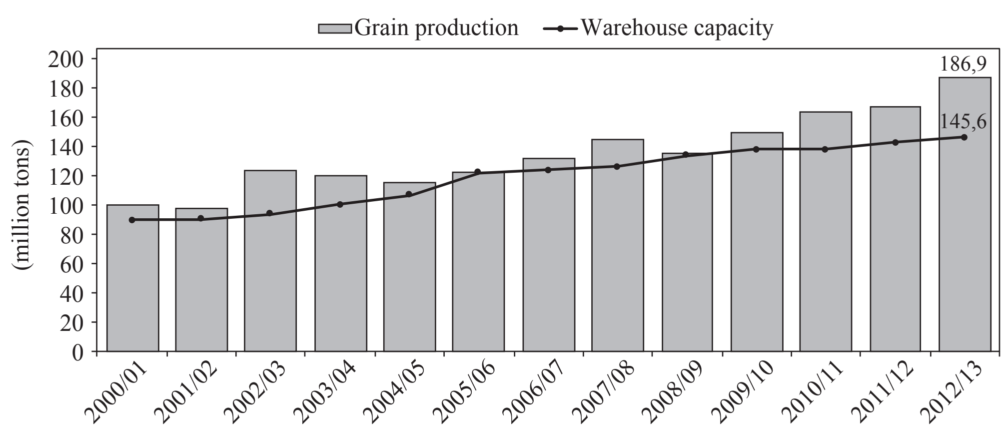

Figure 2. Evolution of the static storage capacity and grain production in Brazil, 2000/2001-2012/2013 harvest (adapted from CONAB, 2014a)

The MCP has the advantage of allowing the easier incorporation of rates, Oliveira *et al.* (2012) analyzed the main effects of segregation of soybean market on the Brazilian logistics systems, included the cost of segregation like additional rate in the MCP. The model allows the simulation of different scenarios, from the most restrictive to the more relaxed.

Alvim and Waquil (2004) has used the MCP to examine possible changes in the rice market through the implementation of some trade policies. The main changes occur in production, consumption, prices, trade flows and consumer and producer surplus when are simulated changes in tariff barriers and subsidies.

The partial equilibrium models elect a sector or product under consideration and examine the effects of a (exogenous) variation of the relative price on the balance of the industry, assuming that the allocation for the rest of the economy remains unchanged (Ahumada and Villalobos, 2009).

We adopt the partial equilibrium approach to analyze the impact of CPB in the Brazilian soybean and maize market. The method allows for a detailed evaluation of the effects of implementing the CPB in the Brazilian commercial flows. Another advantage of this method is an easier incorporation of tariffs, tariff quotas, and grants.

A complementarity problem consists of a system of simultaneous equations (linear or nonlinear inequalities) derived from the functions of supply and demand. The MCP is equivalent to the Kuhn-Tucker conditions, which are necessary and sufficient to maximize the net social payoff function[3] (NSP). Maximizing the NSP function implies achieving equilibrium in all markets and in all regions.[4] It is easier to incorporate rates, quotas, and grants in the MCP (Bishop *et al.,* 2001). The MCP for analyzing the Brazilian grain market is as follows:

$$0 \leq \varphi_i \perp \sum_j^J x_{ij} + \sum_k^K x_{ik} \leq z_i \quad (1),^5$$

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

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

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

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

Where i denotes supply regions (i = 1,…,n), j denotes domestic demand regions (j = 1,…,m), k denotes international demand regions (k = 1,…,g), and r denotes transport routes (r = 1,…,h). p_i stands for observed supply prices, p_j for observed domestic demand prices, and p_k for observed international demand prices. z_i represents the quantity supplied by region i, y_j the quantity consumed in domestic market j, y_k the quantity consumed in international market k, and $x_{i,j}$ total trade from region i to region j. The parameters of the model are transportation cost $t_{i,j}$; shadow price associated with the supply region i, φ_i; shadow price associated with the demand region j, λ_j; and shadow price associated with the demand region k, μ_k.

[3] Samuelson's (1952) formulation shows that maximizing the NSP function, given by the sum of the surplus of producers and consumers minus shipping cost and subject to regional balance equations, generates a framework of optimality conditions. Samuelson warned about problems associated with the use of his model to make inferences about social welfare. Hence, the expression 'net social payoff', which excludes a reference to social welfare (Samuelson, 1952).

[4] The global maximum is the solution to a problem of nonlinear programming with a differentiable and concave objective function and linear differentiable and convex constraints, since the optimal point satisfies the Kuhn-Tucker conditions (Takayama and Judge, 1971).

[5] In the MCP, elasticity coefficients are included in the restrictions (1), (2), and (3) such that the quantities produced and consumed are replaced by the following expressions:

$$z_i = a_i \times \varphi_i^{b_i}$$

$$y_j = c_j \times \lambda_j^{-d_j}$$

$$y_k = e_k \times \mu_k^{-f_k}$$

The '⊥' symbol conveys that at least one of the adjacent inequalities must be satisfied as a strict equality. This is nothing more than a formality of the complementarity in the Kuhn-Tucker conditions. Equations (4) and (5) thus facilitate the inclusion of the *ad valorem* rate or tariff entailed by the cost of the test to identify transgenic events.

The inclusion of the *ad valorem* rate follows Bishop *et al.* (2001). A parameter tax_{ik}, representing an *ad valorem* rate or tariff, may be incorporated in the model in Equation (5), considering the zero net condition. This is because, in this study, the rate has implications only for flows earmarked for the international market. Modifying the zero-net condition results in:

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

The rate tax_{ik} represents the cost of tests for the identification and quantification of GMO events, plus the cost of segregated storage on the international market flows, as the CPB imposes measures on trans-boundary movements.

In equilibrium, 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 GMO tests and segregation, should be equal to the price of the international demand. Otherwise, in the absence of commercial flows, the price in the region of international demand is lower than the price in the region of supply plus transportation costs and tests.

The starting point for our model was to identify and select regions of supply and demand for soybean and maize. The evolution over the last few years of several variables, such as production, average yield, cultivated area, exports, industrial processing, and consumption for pig and poultry production, was analyzed to capture the dynamics in Brazil's prominent agricultural regions with great potential for expansion. Regions of excess of supply are regions where soybean or maize production is greater than the amount processed. Otherwise, they were regions of excess of demand. Regional heterogeneity in the states of Mato Grosso and Paraná implies different trade flows and the use of different transportation routes; hence, different production and processing micro regions[6] were identified in these states.

Source of data

The model employs data from 2011. Production data are from the Brazilian Institute of Geography and Statistics and the United States Department of Agriculture (USDA). The Brazilian Association of Chick Producers and the Brazilian Association of Pork Producers and Exporters were the sources for consumption data. The consulting agency Safras and Mercado (2011) and USDA (2011) were the source for soybean and maize prices for the domestic and international markets, respectively. Studies by Fuller *et al.* (2001, 2003) and FAPRI (2011) were the source of data on price elasticities of supply and demand. The freight from the road, rail, waterway, and maritime transportation modes come from the freight information system, Sifreca (2011).

We conducted personal interviews with semi-structured questionnaires with key industry players (trading companies, shipping companies and certifiers). This exploratory and qualitative research allowed us to understand the operational aspects of segregation of GMO grains and to obtain the segregated storage costs and costs of tests to identify transgenic events. In addition, some trading companies authorized visits to their facilities, which allowed the observation and viewing of all stages of segregation operations, including the boarding of ships.

The interviews were conducted with key players in the grain chain. This methodological approach known as 'rapid assessment' or 'quick appraisal,' as Dunn (1994) in which use data from secondary sources together

[6] Microregions consist of a cluster of cities with similar agricultural, industrial, and economic characteristics.

with non-random samples and semi structured interviews with the key players can be applied in research that is necessary to obtain data and/or more detailed information to understand the dynamics of the sector.

The interview guide was directed to three different groups. In the first group, the agricultural trading companies, agricultural cooperatives and rural producers association have been interviewed. The second group were the railway undertakings, including trading companies who own businesses and/or owns part of logistics operations, such as the Caramuru and Amaggi that control waterway companies like Torque S.A. and Hermasa Amazon Navigation SA, respectively. The third group were the main laboratories and certifiers. The interviews were conducted during the second half of 2009. Respondents were representatives of ADM, Amaggi, Bunge, Caramuru, Cargill, Brazilian Association of Non-Genetically Modified Grain Producers (EXTEND), Cocamar, Cooperative Castrolanda. As for logistics operators were America Latina Logistica (ALL), Companhia Vale do Rio Doce (Vale), S.A. Torque and Hermasa Amazon Navigation S.A. Finally, the laboratories and certifiers: CertID Brazil, Eurofins and SGS Brazil.

The field research helped determine the cost of tests for the identification of transgenic events (GM events) as well as the sampling pattern. There are two methods to analyze GMOs: DNA analysis and protein analysis. The DNA analysis uses a quantitative or qualitative technique named polymerase chain reaction (PCR). The protein analysis employs a simple enzyme-linked immunosorbent assay (the dipstick test) and detects only one event at a time.

The unit cost was US$ 3 for the dipstick test and US$ 300 for the PCR. Two samples are taken from every 40 tons and requiring two dipstick tests with a total cost of US$ 6. The quantitative real-time PCR for maize cost US$ 1,050 per sample and six GM events; three analyses[7] for every 3,000 tons amount to a total of US$ 3,150. The PCR cost for soybean was US$ 900, with only one event tested.

Major companies exporting non-GM maize and non-GM soybean were sources for segregated storage costs. Costs in trans-shipment warehouses were approximately 13 US$/ton and storage at ports of export were, on average, 10 US$/ton.

The costs of tests and storage were estimated for grain labeled as ‘contains GM.’ Considering the descriptor ‘may contain GM’ would not significantly impact marketing costs or the logistics structure (Borges *et al.,* 2009; Gruère and Rosegrant, 2008; Huang *et al.,* 2008; Kalaitzandonakes, 2004; Simões, 2008).

Table 1 describes the supply and demand regions and Table 2 shows the logistical routes considered and analyzed in the research. In Table 1 is shown the main producer and consumer regions in Brazil and also the main importers of corn and soybeans.

In turn Table 2 describes the Brazilian logistical routes obtained from interviews conducted with key players in the grain chain and representing the major transport routes used in Brazil.

Alternative scenarios

We simulated two different scenarios. Scenario 1 is the control, in which there are no expenses with GMO tests and segregated storage; trade flows were based only on transportation costs (i.e. without the CPB rules concerning the term ‘contain’ in place).

Scenario 2 represents a framework of full segregation of grain that ‘contains GM.’ The PCR test was considered when boarding on the ship. The number of dipstick tests varied according to the transport route considered. Each change of transportation mode requires trans-shipment operations to prevent the mixing of cargo and an additional dipstick test. The process also considers segregated storage. Consequently, the

[7] One PCR is performed when boarding, one at the port of export and one on the ship.

Table 1. Description of the supply and demand regions considered in the model.

Regions	Description	Classification
PR-N	north of Paraná State	supply region
PR-W	west of Paraná State	supply region
PR-SE	southeast of Paraná State	domestic demand region
RS	Rio Grande do Sul State	supply region
MG	Minas Gerais State	supply region
SC	Santa Catarina State	domestic demand region
SP	São Paulo State	domestic demand region
GO	Goias State	supply region
MS	Mato Grosso do Sul State	supply region
MT-N	north of Mato Grosso do Sul State	supply region
MT-W	west of Mato Grosso do Sul State	supply region
MT-SE	southeast of Mato Grosso do Sul State	domestic demand region
MT-NE	northeast of Mato Grosso do Sul State	supply region
Europe	European Union (EU 27): Germany, Austria, Belgium, Bulgaria, Cyprus, Denmark, Slovakia, Slovenia, Spain, Estonia, Finland, France, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Poland, Portugal, United Kingdom, Czech Republic, Romania and Sweden.	international demand
China		international demand
Japan		international demand
Taiwan		international demand
Iran		international demand

Table 2. Description of the logistical routes considered in the model.

Route	Description		
	Destination[1]	Transport modals	Transshipment points
R1	SP demand	road	
R2	PR-SE demand	road	
R3	MT-SE demand	road	
R4	port of Santos	road	
R5	port of Santos	road and rail	rail terminal of Alto Araguaia
R6	port of Santos	road and rail	rail terminal of Campo Grande
R7	port of Santos	road and rail	rail terminal of Goiânia
R8	port of Santos	road-hydro-rail	hydroport of São Simão and rail terminal of Pederneiras
R9	port of Paranaguá	road	
R10	port of Paranaguá	road and rail	rail terminal of Londrina
R11	port of Rio Grande	road	
R12	port of Rio Grande	road and rail	rail terminal of Cruz Alta
R13	port of Rio Grande	road and hydro	hydroport of Estrela
R14	port of Vitória	road and rail	rail terminal of Araguari
R15	port of Santarem	road and hydro	hydroport of Porto Velho

[1] SP = São Paulo, PR = Paraná, MT = Mato Grosso.

ad valorem rate calculated was 60% in intermodal flows and 55% in unimodal flows. These data are also the result of interviews conducted with key players in the grain chain.

The study employs the General Algebraic Modeling System software (GAMS Development Corporation, Washington, WA, USA) to process the information for the movement of maize and soybean in Brazil within the MCP framework (Brooke *et al.,* 1995).

4. Results and discussion

Mathematical programming models must be validated by checking the consistency of the results of the problem. In Waquil and Cox (1995), the validation presupposes an adaptation of the coefficients and the structure of the model. How well the model's solution approaches the real situation can validate the model. Many spatial equilibrium models generate results different from the actual data (Thompson, 1981), without invalidating the model. Tables 3 and 4 present the levels of supply and demand estimated by the model (scenarios 1 and 2) for soybean and maize, respectively, as well as the observed quantities in 2011 (observed data).

Scenario 1 corresponds to the control group with no expenses regarding GMO tests and segregated storage; trade flows were based only on transportation costs. This scenario represents business transactions without the imposition of the CPB.

Table 3. Volumes of supply, domestic demand and international demand of soybean.[1]

Regions	Observed data (A) (thousands tons)	Scenario 1 (B) (thousands tons)	Scenario 2 (C) (thousands tons)	Variation B to C (%)
Supply				
Total Mato Grosso (MT)	13,131.2	13,489.0	12,930.9	-4.14
North MT	7,071.4	7,222.4	6,926.5	-4.10
Northeast MT	3,792.0	3,934.1	3,762.7	-4.36
West MT	2,267.9	2,332.5	2,241.8	-3.89
Total Paraná (PR)	6,525.5	6,692.4	6,411.9	-4.19
West PR	3,671.1	3,753.4	3,592.6	-4.28
North PR	2,854.4	2,939.0	2,819.3	-4.07
Rio Grande do Sul	4,853.8	4,924.7	4,801.7	-2.50
Goiás	2,820.4	2,931.1	2,789.9	-4.82
Minas Gerais	1,282.9	1,307.9	1,257.2	-3.87
Mato Grosso do Sul	1,065.9	1,073.4	1,016.8	-5.27
Total supply	29,679.6	30,418.4	29,208.4	-3.98
Domestic demand (D)				
São Paulo	2,028.9	2,023.4	2,046.0	1.12
Southeastern PR	1,225.0	1,221.4	1,234.7	1.09
Southeastern PR	748.5	745.0	754.6	1.30
Subtotal	4,002.4	3,989.7	4,035.4	1.15
International Demand (E)				
China	17,000.0	16,232.7	15,522.0	-4.38
EU-27	10,000.0	9,558.9	9,068.0	-5.14
Japan	700.0	637.2	583.0	-8.50
Subtotal	27,700.0	26,428.7	25,173.0	-4.75
Total demand (D+E)	31,702.4	30,418.4	29,208.4	-3.98

[1] The tabel contains model estimates (scenarios 1 and 2) and observed data from 2011.

Table 4. Volumes of supply, domestic demand and international demand of maize.

Regions	Observed Data (A) (thousands tons)	Scenario 1 (B) (thousands tons)	Scenario 2 (C) (thousands tons)	Variation B to C (%)
Supply				
Total Mato Grosso (MT)	6,610.1	5,084.3	4,826.2	-5.08
North MT	4,957.6	3,827.0	3,627.0	-5.22
Southeast MT	1,652.5	1,257.3	1,199.2	-4.62
Goiás	4,004.0	3,003.3	2,875.9	-4.24
Mato Grosso do Sul	2,747.7	1,962.5	1,848.9	-5.79
Minas Gerais	3,386.0	2,704.3	2,610.6	-3.47
Total Paraná (PR)	5,367.8	4,293.4	4,121.0	-4.02
North PR	3,489.1	2,841.0	2,677.8	-5.74
West PR	1,878.7	1,452.4	1,443.2	-0.64
Total supply	22,115.5	17,047.8	16,282.6	-4.49
Domestic demand (D)				
Santa Catarina	3,028.2	3,179.4	3,210.7	0.99
Rio Grande do Sul	124.7	130.8	130.9	0.13
São Paulo	270.7	288.6	289.1	0.19
Subtotal	3,423.6	3,598.7	3,630.8	0.89
International demand (E)				
Iran	5,000.0	5,329.7	4,796.9	-10.00
Japan	4,000.0	4,016.3	3,983.3	-0.82
Taiwan	4,000.0	4,103.1	3,871.6	-5.64
Subtotal	13,000.0	13,449.1	12,651.9	-5.93
Total demand (D+E)	16,423.6	17,047.8	16,282.6	-4.49

[1] The table contains model estimates (scenarios 1 and 2) and observed data from 2011.

In scenario 2, the system for the identification and quantification decreased soybean production by 3.98%. International flows were the most affected, with losses amounting to 1.25 million tons. The exports to Japan and Europe, the main importers of non-GM soybean, fell by 8.50 and 5.14%, respectively.

Scenario 2 (full segregation) for soybean gives evidence of the loss of competitiveness of the Brazilian soybean in a system of segregation. Adjusting the parameters of the model allows for simulating changes in production performance and consumption in the regions under analysis as an international agreement is simulated.

Due to the expenses with tests and storage (US$ 1.1 billion) and the reduction of international trade (US$ 482.8 million), monetary losses reached US$ 1.57 billion. This amount represents 10% of the foreign currency generated by exports of Brazilian soybean in 2011 (US$ 16.33 billion according to the Ministry of Development, Industry and Foreign Trade (MDIC)).

In scenario 2 for maize, the system for the identification and quantification of transgenic maize events decreased trade by 4.49%. The greatest effect was on international flows and losses were 765,000 tons. The exports to Iran and Taiwan, the main partners of Brazil, fell by 10% and 5.64%, respectively.

The most effect was on regions far from ports of export, as any increase in the costs of logistics is felt more strongly. The most affected states were Mato Grosso do Sul (central-western region of Brazil), 5.79%, followed by the north of Paraná (southern region of Brazil), 5.74%, and the north of Mato Grosso (central-western region of Brazil), 5.22%.

Scenario 2 gives evidence of the loss of competitiveness of the Brazilian maize exports and of the regional impact. The Brazilian production system requires a greater number of transfers, given the long distances to ports of export. Brazil's main competitors – the United States and Argentina – have greater logistical efficiency, thus, the reduction of the Brazilian competitiveness becomes eminent.

Due to the expenses with tests and storage (US$ 506 million) and the decrease in international trade (US$ 212 million), monetary losses regarding maize reached US$ 718 million. This amount represents 26% of the foreign currency generated by Brazilian maize exports in 2011 (US$ 2.72 billion according to MDIC).

The simulation of scenario 2 suggests that the CPB measures may have very different effects in each of the major regions of maize production and exports in Brazil. The losses in this scenario ranged from 0.64 to 5.79%. These differences arise from the different storage and transport infrastructures. Tables 5 and 6 show the trade flows and the logistics routes used for moving soybean in scenarios 1 and 2, respectively.

In scenario 1, the Chinese and Japanese markets were the targets of production for this region, using intermodal transport through the port of Santarém. Soybean was transported by truck to the river port of the city Porto Velho, and from there travelled by waterway to the port of Santarém (Figure 3). In scenario 2, there were changes in the transacted volumes and target markets.

In scenario 1, the exports were made via intermodal options, responsible for 86.9% of movements (26.4 million tons). In scenario 2, only 15% of the soybean for the international market was carried by intermodal options (approximately 3.7 million tons). Only exports from the western region of Mato Grosso used intermodality as a competitive option. Due to the implementation of segregation measures, more than 77% of intermodal routes ceased to be competitive (increased cost). Priority for the road mode was overwhelming and the costs of implementing the CPB had a greater impact on intermodal routes because of the greater number of tests

Table 5. Soybean: trade flow by transportation route, scenario 1.[1,2]

Supply	Demand	Route[3]									
		R1	R2	R3	R5	R8	R9	R10	R13	R14	R15
PR-W	PR-SE		1,221.4								
MT-N	MT-SE			745.0							
GO	SP	2,023.4									
RS	EU-27								4,924.7		
PR-N	China						2,939.0				
PR-W	EU-27							2,532.0			
MT-N	China				6,477.5						
MT-NE	EU-27				2,102.2						
MT-NE	China				230.3						
MT-W	China										3,296.9
MT-W	Japan										637.2
MS	China							1,073.4			
GO	China					907.7					
MG	China									1,307.9	
Total = 30,418.4		2,023.4	1,221.4	745.0	8,810.0	907.7	2,939.0	3,605.4	4,924.7	1,307.9	3,934.1

[1] Road route (unimodal): R1, R2, R3, R9; intermodal route: R5, R8, R10, R13, R14, R15.

[2] PR = Paraná; MT = Mato Grosso; GO = Goiás; SP = São Paulo; RS = Rio Grande do Sul; MS = Mato Grosso do Sul; MG = Minas Gerais.

[3] Values in thousands of tons.

Table 6. Soybean: trade flow by transportation route, scenario 2.[1,2]

Supply	Demand	Route[3]						
		R1	R2	R3	R4	R9	R11	R15
PR-W	SE		1,234.7					
MT-N	MT-SE			754.6				
GO	SP	2,046.0						
RS	EU-27						4,801.7	
PR-N	China					2,819.3		
PR-W	China					2,357.8		
MT-N	China				3,083.2			
MT-N	UE-27				2,505.6			
MT-N	Japan				583.0			
MT-NE	China				2,241.8			
MT-W	China							3,762.7
MS	UE-27					1,016.8		
MG	China				1,257.2			
GO	EU-27				743.9			
Total = 29,208.4		2,046.0	1,234.7	754.6	10,414.7	6,193.9	4,801.7	3,762.7

[1] Road Route (unimodal): R1, R2, R3, R4, R9, R11; intermodal route: R15.

[2] PR = Paraná, SE = Sergipe, MT = Mato Grosso, GO = Goiás, SP = São Paulo, RS = Rio Grande do Sul, MS = Mato Grosso do Sul, MG = Minas Gerais.

[3] Values in thousands of tons.

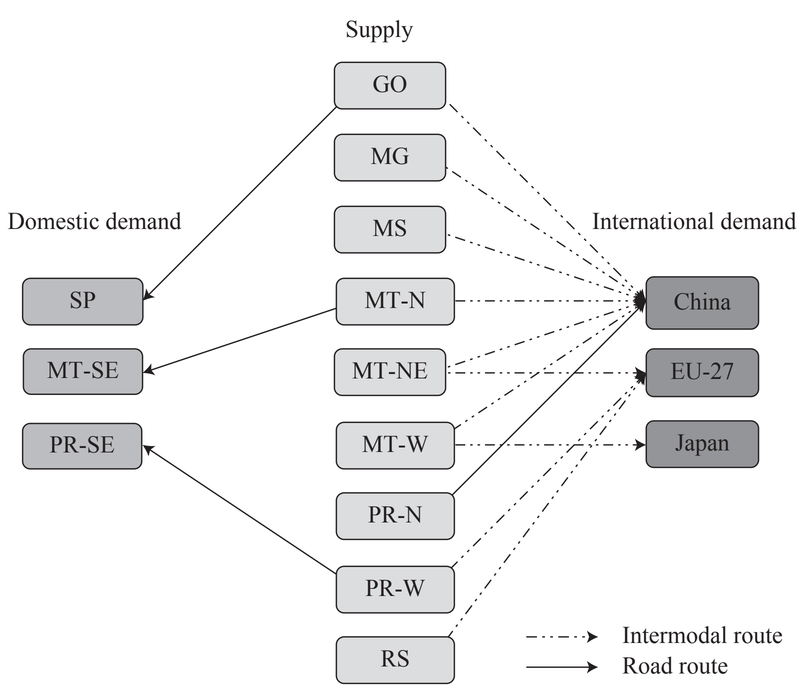

Figure 3. Soybean: trade flow by transportation route, scenario 1. SP = São Paulo; MT = Mato Grosso; PR = Paraná; GO = Goiás; MG = Minas Gerais; MS = Mato Grosso do Sul; RS = Rio Grande do Sul.

and increasing demand for segregated storage. The cost of soybean transport thus increased in comparison with unimodal, railroad-only routes.

The inefficiency of the Brazilian logistics is represented by high transportation costs. Moreover, the limitations of intermodality are evident by the high cost of transshipment. The result is that segregation make the most inefficient Brazilian logistics, especially intermodal flows that are the most affected.

In scenario 1 for maize, a portion of the maize production in Minas Gerais (MG) was destined for the domestic market, supplying Santa Catarina in the southern region of Brazil and using only road transport (route R2). Another portion of the production went to Iran through the port of Vitória. The road and railway routes were used (intermodal route) for this flow. Maize was transported by trucks 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) (Table 7).

An increase in logistics costs due to the CPB rules modified movement of maize in scenario 2 (Table 8).The region of Minas Gerais began providing a greater volume to local markets and started to export maize to Taiwan. In addition, the route for the international market changed (the intermodal route (R14) used before in scenario 1 was no longer competitive). The export was made to the port of Santos via road (route R4).

In scenario 1, the exports of maize were through intermodal options, responsible for 100% of the movements (13.45 million tons). In scenario 2, only 29% of the maize for the international market was carried by intermodal options (approximately 3.6 million tons). Only exports from the northern region of Mato Grosso used intermodality as a competitive option. The increased transportation cost was compared to unimodal railroad-only routes.

The logistics of transport and storage are affected by the requirements of the CPB. Therefore, the more rigid the identification process, the greater the impact on exports. Consequently, the competitiveness of Brazilian maize on the international market suffers due to inefficient logistics, that are unresponsive to the demands of the CPB.

Table 7. Maize: trade flows by transportation route, scenario 1.[1,2]

Supply	Demand	Route[3]						
		R1	**R2**	**R3**	**R8**	**R10**	**R14**	**R15**
PR-W	SC		1,001.3					
PR-W	SP	288.6						
PR-W	RS			130.8				
MS	SC		1,962.5					
MG	SC		215.7					
PR-N	Iran					2,841.0		
PR-W	Japan					31.8		
MT-N	Taiwan							3,827.0
MT-SE	Taiwan				276.1			
MT-SE	Japan				981.2			
MG	Iran						2,488.7	
GO	Japan				3,003.3			
Total = 17,047.7		288.6	3,179.4	130.8	4,260.6	2,872.8	2,488.7	3,827.0

[1] Road Route (unimodal): R1, R2, R3; intermodal route: R8, R10, R14, R15.

[2] PR = Paraná; SC = Santa Catarina; RS = Rio Grande do Sul; MS = Mato Grosso do Sul; MG = Minas Gerais; MT = Mato Grosso; GO = Goiás.

[3] Values in thousands of tons.

Table 8. Maize: trade flows by transportation route, scenario 2.[1,2,]

Supply	Demand	Route[3]					
		R1	R2	R3	R4	R9	R15
PR-W	RS			130.9			
MS	SP	289.1					
MS	SC		1,559.8				
MG	SC		1,650.9				
PR-N	Iran					2,677.8	
PR-W	Iran					1,312.3	
MT-N	Japan						3,627.0
MT-SE	Iran				806.8		
MT-SE	Taiwan				392.4		
MG	Taiwan				959.7		
GO	Taiwan				2,519.6		
GO	Japan				356.3		
Total = 16,282.6		289.1	3,210.7	130.9	5,034.7	3,990.1	3,627.0

[1] Road route (unimodal): R1, R2, R3, R4, R9; intermodal route: R15.

[2] RS = Rio Grande do Sul, MS = Mato Grosso do Sul, SP = São Paulo, SC = Santa Catarina, MG = Minas Gerais, PR = Paraná, MT = Mato Grosso, GO = Goiás.

[3] Values in thousands of tons.

Brazil has a matrix of unbalanced transportation and logistical bottlenecks, hence, the costs of adapting the country's infrastructure to the norms and standards of the CPB are higher in comparison to key competitors, the United States and Argentina, which have better logistics. The soybean and maize produced in Argentina travel shorter distances between production areas and ports of export, and the US prioritizes the waterway mode to distribute agricultural production.

The scenario full segregation for maize clearly showed a negative impact on shipping, this is because approximately 70% of the intermodal route (more efficient in terms of cost, large volumes and long distances) become uncompetitive and are no longer used. In the case of soybeans, the situation is even worse since 77% of intermodal routes are no longer competitive. The implementation of full segregation systems greatly impact the Brazilian logistics making Brazil's transportation matrix even more unbalanced. A full segregation system favors road freight transportation.

However, the impact of the CPB in Brazil depends not only on the level of demand for segregation, but also on the compliance with the Protocol by the main importers. Importers should demand the same requirements from non-signatory countries, such as Argentina and the United States. If countries like Argentina and the United States do not have to follow the norms and standards set out by the CPB, Brazil may become even less competitive.

5. Final remarks

The advances of the Brazilian agribusiness owe to a combination of factors, including more integrated supply chains, intensive capitalization in the various segments of the supply chains, and governmental support to agriculture. On the other hand, the logistics sector has been lagging behind, lacking adequate transportation infrastructure or storage facilities.

The logistics of transport and storage, up until now marked by the movement of standardized products in large volumes, must adapt quickly to cope with the growing demand for differentiated and segregated products.

Our findings suggest that trade flows required performing tests along the chain and resulted in the decreased competitiveness of the Brazilian maize and soybeans exports. The effect was greater in border states such as Mato Grosso. The requirement of segregation can interfere with the production decisions of farmers, without the production constituting a biosafety hazard. In a certain way, the CPB also imposes an increased opportunity cost when adopting a new technology.

The monetary loss for soybean and maize was US$ 2.29 billion. This amount represents 12% of the foreign currency generated by the Brazilian exports of soybean and maize in 2011.

The implementation of Identity Preservation Systems leads to an increase in fixed costs, with no direct connection to the fulfillment of the objectives of the Protocol, and may block the access of farmers to technology. It also negatively affects the competition among companies in the market of hybrid seeds, by delaying the release of cultivars resistant to insects and by limiting the offers available to farmers under the false argument that small farmers prefer local and non-hybrid varieties.

The implementation of the CPB introduces a conflict between importers and exporters of agricultural commodities. On the one hand, importing countries attempt to establish an extremely demanding system on behalf of biosecurity. On the other hand, the large exporters of GMOs are concerned with the costs of implementing the Protocol and with new restrictions on international trade. Bilateral agreements and/or prediction of mechanisms to reduce tariffs imposed by importing countries may represent attempts to reduce the negative impacts of the CPB.

Brazil is the second largest cultivator of biotech agriculture in the world and offers a complete and rigorous regulatory system. In the context of biotechnology activities, the Brazilian legal system is designed to protect consumers and the environment. Today, Brazil faces the challenge of reducing its deficit in transport and storage capacity. The country aims to increase its operational efficiency as well as take advantage of economies of scale and scope. The imposition of Identity Preservation Systems on a large scale would not only divert the necessary resources from agribusiness, but also creates uncertainty in the type of investment needed. Overall, it is critical that discussions on GMO regulation envision investments in infrastructure, so that advantages of agricultural biotechnology become available to more consumers in more countries.

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