Improving Transportation Infrastructure in Brazil: An Analysis Using Spatial Equilibrium Model on the World Soybean Market♣

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Introduction

According to the Foreign Agricultural Service – FAS/USDA (2007a), since the beginning of the 1990s, the United States have been the leading soybean producer and exporter. However, production and export shares for the United States have been decreasing from over 50 percent and 60 percent in 1990/91 market years (MYs) to approximately 38 percent and 40 percent in 2006/07 MYs, respectively. This loss of production and export share is due to soybean sector expansion in Brazil and Argentina. Brazil's soybean production has been expanding towards the Center-West, North, and Northeast regions in the past three decades. Even though a rapid growth in the last two decades, these regions are still in progress of development in their transportation infrastructure. In some places, the only transportation method is by truck through unpaved and heavily congested roads. Moreover, the most important exporting ports are located in Southern Brazil, which means for farmers in the leading state producer, Mato Grosso, nearly 1,500 kilometers (938 miles) trip from farm to the port.

Brazil has relatively high domestic transportation costs compared to the United States, which reduces the competitiveness of Brazilian soybean producers. The Agricultural Marketing Service – AMS/USDA (2007a) points out that Brazil's internal transportation costs account for nearly 30 percent of the total export cost at the importing port, while for the U.S. this same number is only eight percent. It is generally accepted that the improvement in transportation infrastructure would consequently reduce the transportation costs and make Brazil a stronger soybean export competitor. Along with the infrastructure improvement, Brazil's soybean production is expected to increase and this, in turn, would impact on the world soybean market.

This article focuses on improvements to Brazil's transportation infrastructure and evaluates the effect of these improvements on export quantities, producer revenues, and prices in the United States, Brazil, Argentina, and Canada. In the background section, an analysis is performed about Brazil's soybean industry and its transportation network and associated improvements. This is followed by a section that describes the methodology and the use of a spatial model. In the same section, the model data are discussed with emphasis on projected soybean production and consumption, estimated excess demand and supply. Finally, sections on results and conclusions are presented.

Background

Soybeans in Brazil

Starting from 1930, Brazil has been focusing on the industrial sector as the main source of economic growth and neglecting the agricultural sector, which was perceived to supply the domestic market only. In 1964, the year that Brazil became a military dictatorship, the support to the industrial sector was stronger than ever. Such support benefited some agricultural commodities and soybeans were one of them. Two benefited industrial sectors were: the crushing industry and machinery (tractors, harvesters, etc.). Thereafter, the soybean complex in Brazil was introduced in the states of Rio Grande do Sul and Paraná, which are called the traditional soybean producing states (Sampaio, 2004).

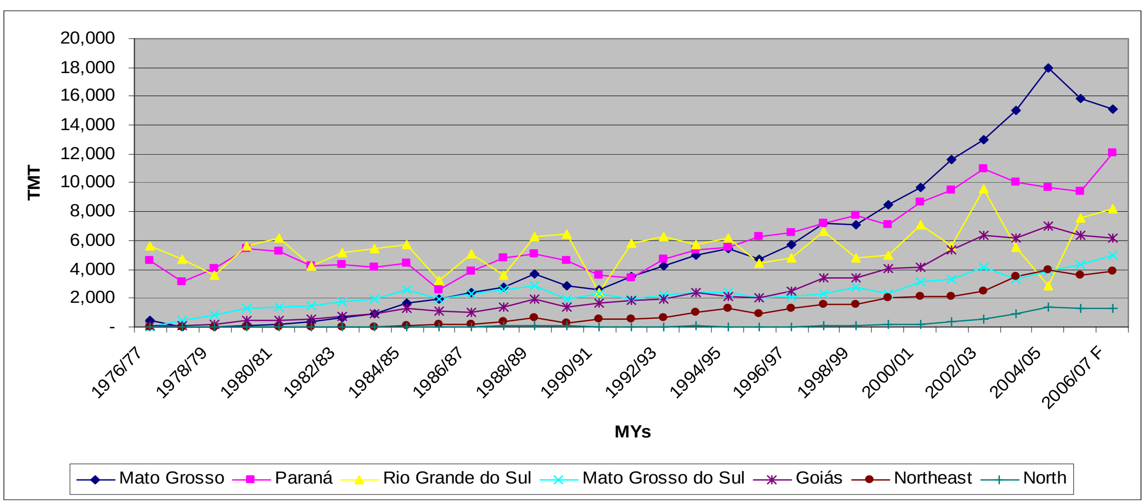
Beginning of the 80's, soybean production in Brazil started to develop in the Central-West of Brazil, with attention to Mato Grosso. Soybeans were brought to the Central-West region to be planted in the *cerrado* area[1]. The expansion of soybean production in the *Cerrado* was strongly affected by an increasing domestic and

[1] The *Cerrado* area comprises a large heterogeneous tropical savanna which occupies more than 2 million hectares, approximately 20 percent of the area of Brazil. It includes areas from the Amazon complex, most of the Central-West of Brazil, and part of the Southeast and Northeast of Brazil.

international demand. On the supply side, three factors were decisive: the natural conditions of these areas; technological development which made feasible the cultivation of soybeans in formerly inhospitable agro-ecosystems; and, although limited, investments in transportation infrastructure in these portions of the *Cerrado* (Mueller, 2003).

Between 1976/77 and 2006/07 (forecast) MYs, the production of soybean in the traditional states (RS and PR states) remained its importance, but the crop had moved deep into the *Cerrado* (Figure 1). In 1976/77 MYs, the traditional states were responsible for 84.4 percent of the total production (a little over 10.25 MMT); the remaining 15.4 percent (1.895 MMT) were divided almost evenly among the states of São Paulo, Mato Grosso and Goiás. In 1999/00 MYs, Rio Grande do Sul and Paraná states remained the two significant producers (third and second largest producers, respectively), but the cultivation of soybean in the savannas of Mato Grosso made it the largest producer in history, with 8.456 MMT.

Figure 1. Historical series of soybean production by state and region, 1976/77 – 2006/07



Source*:* Companhia Nacional de Abastecimento (CONAB/MAPA, 2007a).

Concerning the Brazilian soybean exports value, according to the CONAB/MAPA (2007b), the soybean complex accounted for $9.31 billion, which represented 6.8 percent of Brazil's total export sales ($137.4 billion) in 2006. From the $9.31 billion, 60 percent ($5.67 billion) was the soybean oilseed exports. According to the SECEX/MDIC (2007), the EU and China are large importers of Brazilian soybean oilseed and joint products. In 2006, China and EU imported 10.77 and 9.93 MMT soybeans, respectively, representing 83 percent of the Brazilian total soybean exports (24.96 MMT).

Based on the data from SECEX/MDIC (2007), Brazil's soybean exports are disaggregated to state and region levels (Table 1). From 1997 to 2006, the South region was always a large exporting region, representing on the average 52 percent of Brazil's total quantity exported. However, with the soybean production expansion in the states in the *Cerrado* region, the South region lost its ground to these states as its average export share fell to 27 percent in the past three years (2004 to 2006). Furthermore, Mato Grosso became the leading soybean exporting state/region in 2005.

Table 1. Soybean Exports by State/Region in Brazil (MMT), 1989 - 2006

Year	State/Region					
	Mato Grosso	Goiás	Mato Grosso do Sul	South*	ROB**	Brazil
1997	1.48	0.44	0.31	4.34	1.79	8.34
1998	1.37	0.42	0.07	4.87	2.57	9.29
1999	1.73	0.42	0.25	3.94	2.57	8.92
2000	2.89	0.93	0.08	4.98	2.64	11.52
2001	4.50	0.79	0.45	6.82	3.11	15.68
2002	5.24	0.92	0.13	6.32	3.36	15.97
2003	4.85	2.18	0.23	8.95	3.68	19.89
2004	5.04	1.84	0.35	6.79	5.23	19.25
2005	9.09	3.07	0.98	4.58	4.72	22.44
2006	9.92	2.80	1.18	6.38	4.68	24.96

*South = Paraná + Santa Catarina + Rio Grande do Sul ** ROB = Rest of Brazil
Source: SECEX/MDIC (2007)

The consumption/use of soybeans is investigated by breaking down the crushing capacity by state. Table 2 presents the crushing capacity by state/region in Brazil, from 2002 to 2006. As the production shifted to the Central-West in the subsequent years, Brazil's crushing capacity expanded to new regions.

Table 2. Crushing Capacity by State/Region (MT/day), 1989 - 2006

Year	State/Region						
	Mato Grosso	Goiás	Mato Grosso do Sul	South*	São Paulo	ROB**	Brazil
2002	14,500	9,060	6,630	52,850	12,950	14,570	110,560
2003	14,500	10,320	6,980	53,050	14,450	15,970	115,270
2004	20,600	16,920	7,295	55,499	14,950	16,504	131,768
2005	21,000	18,150	8,295	57,349	15,600	16,704	137,098
2006	23,600	18,800	9,360	58,384	16,400	16,960	143,504

*South = PR + SC + RS ** ROB = Rest of Brazil
Source: ABIOVE (2007)

The Export Cost Competitiveness between the United States, Brazil, and Argentina

To compare the internal transportation system among the United States, Brazil, and Argentina in value, an export cost competitiveness analysis is performed. It examines the components and distribution of farm-level production costs, the costs of internal marketing and transportation, and shipping costs to a common export destination (Schnepf et al, 2001).

Table 3 illustrates that total per-bushel soybean production costs in Brazil's Mato Grosso ($3.87/bushel) and Argentina ($4.22/bushel) were 27 and 21 percent lower than the United States ($5.11/bushel). Production costs are 24 percent lower in the state of Paraná. Likewise, total per-acre soybean production costs were highest in the United States ($244.84), about $78 more than in Brazil and $33.73 higher than in Argentina.

The higher production costs in the United States compared to its counterparts can be attributed heavily to its high fixed costs. Compared to Brazil, the United States is far behind. One of the reasons for such low fixed costs in Brazil's Mato Grosso is the abundant availability of *Cerrado* soils to be converted into agricultural land. However, based only on variable costs, the United States has advantage compared to Brazil. According to Schnepf et al (2001), this might be explained by high fertilizer and chemicals costs in Mato Grosso and great fertilizer and labor costs in Parana.

Table 3. Soybean production costs and export cost competitiveness: United States, Brazil, and Argentina, 2003/04 MYs.

Cost Item	U.S. Heartland[1]	Brazil		Argentina
		MT[2]	PR[3]	
Variable costs:	*US $ per acre*			
Seed	28.67	12.79	10.54	18.57
Fertilizers and Chemicals	24.83	82.47	60.83	23.82
Machine Operation Repair	22.13	18.02	22.82	21.36
Hired Labor, harvest & misc	2.26	15.93	21.15	28.44
Total variable costs	**77.88**	**129.21**	**115.35**	**92.21**
Fixed Costs:	*US $ per acre*			
Depreciation of machinery	51.36	16.83	18.96	22.14
Land costs (rental rate)	97.45	15.46	25.91	72.78
Taxes, insurance & overhead	18.15	5.35	6.54	23.98
Total fixed Costs	**166.96**	**37.63**	**51.40**	**118.90**
Total production costs	**244.84**	**166.84**	**166.75**	**211.11**
Costs per bushel:	*US$ per bushel (% of U.S. cost)*			
Yield (bushels/acre)	46.00	43.07	41.38	50.00
Total costs per bushel	**5.32**	**3.87 (73)**	**4.03 (76)**	**4.22 (79)**
Internal transport (US$/bu.)[4]	0.48	1.80	0.81	0.72
Cost at border	**5.81**	**5.67 (98)**	**4.84 (83)**	**4.94 (85)**
Freight costs to Rotterdam[5]	0.39	1.25	1.25	1.03
Price at Rotterdam	**6.20**	**6.92 (112)**	**6.09 (98)**	**5.97 (96)**

[1] Illinois, Indiana, Iowa, Michigan, Minnesota, Ohio, Wisconsin.[2] Mato Grosso. [3]Paraná.
Source: Costa et al. (2007).

Nevertheless, internal transportation costs for soybeans narrow the gap between the South American countries and the United States. Table 3 indicates that, in the 2003/04 MYs, internal marketing and transportation costs averaged two to three times higher in Brazil and Argentina than in the United States, dampening farmgate prices. These costs averaged $1.80/bushel for Mato Grosso, $0.81/bushel for Paraná, and $0.72/bushel for Argentina. In the United States, these costs totaled $0.48/bushel.

With respect to shipping charges to Rotterdam, table 3 illustrates that the United States has a considerable advantage over both Brazil and Argentina. In the cases of Paraná state and Argentina, this further narrows the export cost differentials when the combined production and transportation costs are compared at the importing port. For Mato Grosso, transport costs are higher; going from the most efficient producer to the most expensive supplier at the importing port.

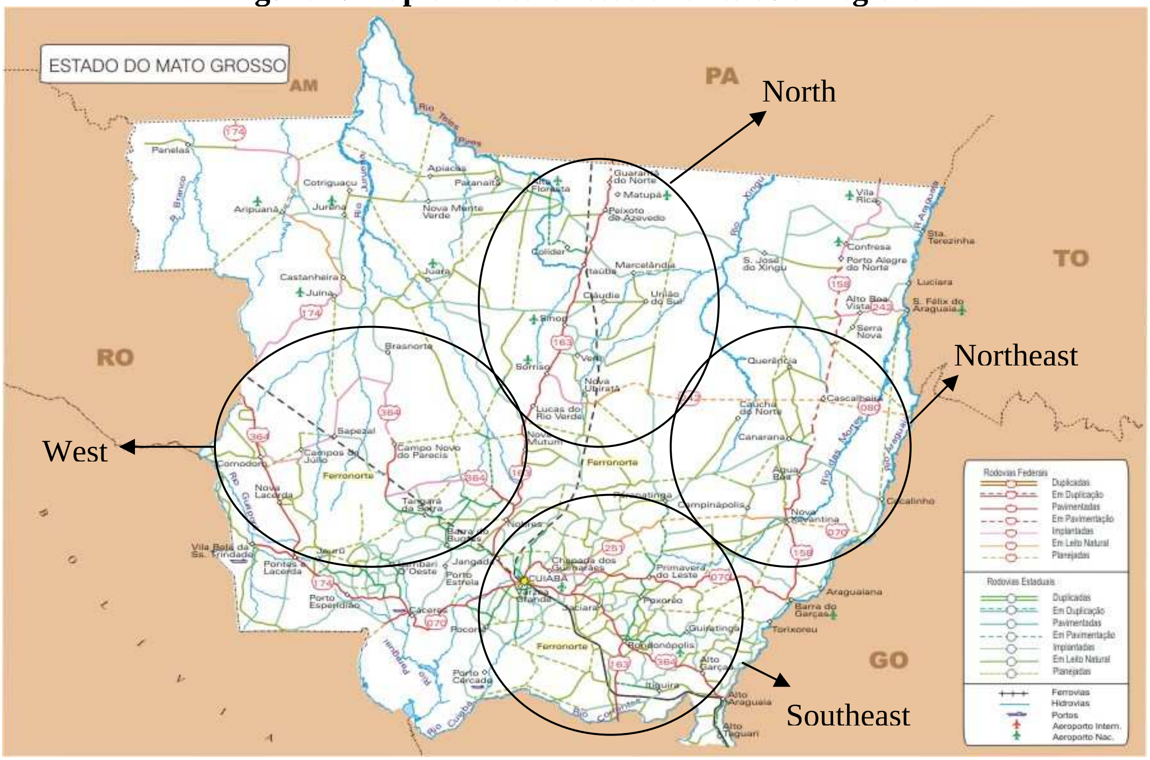
To summarize, the underlying cost structures for producing, transporting, and marketing soybeans from Brazil's two principal regions and Argentina allow them to ship soybeans to Rotterdam at prices slightly below the United States, except for Mato Grosso. These cost advantages partially explain the fast expansion of soybean production and exports by Brazil and Argentina during the past decades.

Analyzed Brazil Soybean Producing Regions and Their Transportation Network

Mato Grosso

The state of Mato Grosso is the third largest state in Brazil with approximately 903,357 km^2 (564,599 $miles^2$) and is located in the Central-West of Brazil (Figure 2). Mato Grosso is also the leading soybean producer and exporter in Brazil. The production in Mato Grosso is distributed throughout the state and improvements in transportation infrastructure will have different impacts in different sub-regions within the state. Therefore, dividing the state into sub-regions is appropriate to analyze the impacts of future improvements.

Figure 2. Map of Mato Grosso and Its Sub-Regions



Source: Ministério dos Transportes (2007)

The West sub-region has two main producing cities, Sapezal and Campo Novo dos Parecis and they were the second and third largest within Mato Grosso, respectively. In 2005, the farmers located in both cities harvested 2.24 MMT soybeans which accounted for 30.9 percent (5.49 MMT) of total soybean production in Mato Grosso in 2005 (IBGE/MPOG, 2007). Campo Novo dos Parecis will represent the sub-region in accordance to the study done by Empresa Brasileira de Planejamento de Transportes from Ministério dos Transportes (GEIPOT/MT, 2001).

With respect to transportation infrastructure improvements for the West sub-region, the construction of the Tapajós-Teles Pires waterway is expected to improve the soybean transportation the most. This waterway would link the soybean production in the West sub-region to the Santarém port located on the Amazon river. First, the soybeans would travel by truck from Campo Novo dos Parecis to Cachoeira Rasteira, on the border of Mato Grosso and Pará states, where soybeans would be loaded into barges. These soybeans would travel through Teles Pires and Tapajós rivers to the exporting port of Santarém. If this waterway is constructed, estimates are that transportation costs would be around $31.65/MT, which represents a reduction of $11.65/MT when compared to the less costly one (Madeira-Amazon waterway).

According to the Departamento Nacional de Infra-Estrutura de Transportes from Ministério dos Transprotes (DNIT/MT, 2007), in the newly released Brazilian government Programa de Aceleração do Crescimento (PAC) – 2007/2010[2], the Tapajós – Teles Pires waterway will not receive government investments for this period.

The North of Mato Grosso is the leading soybean producing sub-region with 6.42 MMT production in 2005, which accounted for 36 percent (6.42 MMT) of the total state's production. Sorriso was the largest soybean producing city not only in Mato Grosso, but also in Brazil (1.8 MMT) (IBGE/MPOG, 2007).

The most important projected transportation route for the North of Mato Grosso is the completion of the BR-163 highway connecting Sorriso to Santarém port. This north-south route will be extended from Cuiabá, the capital of Mato Grosso, to central Mato Grosso and the state of Pará. It is estimated that this highway will reduce transportation costs compared to the current routes around $20/MT. According to the DNIT/MT (2007), the PAC – 2007/10 will dedicate $714 million to complete the construction of highway BR-163.

[2] Such program is a Multiyear plan proposed by the current re-elected government to support Brazil's economic development for at least the next four years. The government along with private sector via PPPs is expected to invest R$ 503.9 billion ($240 billion) in infrastructure, which R$ 58.2 billion ($27.7 billion) will be allocated for transportation infrastructure.

For the Northeast of Mato Grosso, the city of Nova Xavantina is the representative origin for transportation routes. The soybean production of Nova Xavantina was 0.09 MMT in 2005. The main producing cities for this sub-region are Querência and Canarana with the production of 0.33 and 0.31 MMT, respectively (IBGE/MPOG, 2007).

Regarding transportation infrastructure improvement, the expansion of the Mortes – Araguaia waterway through the Tocantins river is extremely important. The Araguaia river and Tocantins river meet before they reach the Tucuruí dam, upon where are called Tocantins. The original project of the Mortes – Araguaia waterway was to make the river navigable to the north Brazil port at Belém, Para, but environmental concerns derived from construction of necessary locks has prevented the complete development of this route[3]. The waterway would link Nova Xavantina river port to the Belém exporting port, Pará. The transportation cost is estimated at $25.85/MT, which represents a decrease of approximately $11/MT compared to shipping by truck. The DNIT/MT (2007) indicated that $260 million will be invested for the improvement of Mortes – Araguaia (Tocantins) waterway through the Brazilian government PAC for the years from 2007 to 2010.

In 2005, the largest soybean producing cities in the Southeast of Mato Grosso were Primavera do Leste (0.68 MMT) and Itiquira (0.46 MMT). Following the GEIPOT/MT (2001) analysis, the city of Rondonópolis will be the origin for transportation analysis in the Southeast of Mato Grosso.

The expansion of the Ferronorte railroad to Rondonópolis will be an improvement in transporting soybeans to Santos port. At Rondonópolis, railcars would be loaded and

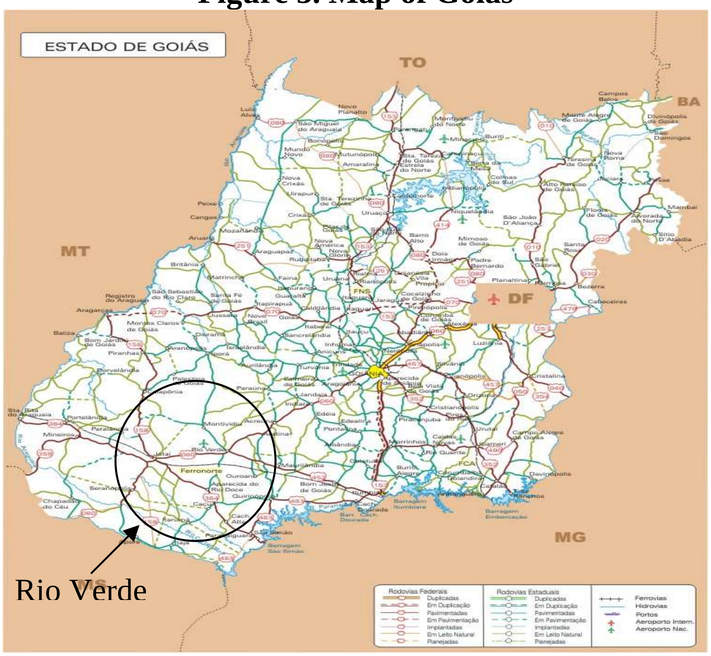
[3] This also explains why the Mortes – Araguaia river waterway currently is having environmental legal issues.

travel to the exporting port of Santos. According to our estimates, total transportation cost for this rail trip would be equal to $35/MT, which represents a reduction of only $1.00/MT. According to DNIT/MT (2007), the PAC 2007/10, has set apart $334 million for the next four years for this improvement.

<u>Goiás</u>

The state of Goiás is located in the Central-West of Brazil and is the seventh largest state with 341,289 km^2 (213,305 miles^2) (Figure 3). The major producing cities are Rio Verde, Jataí, and Mineiros. Altogether they produced 1.64 MMT soybeans in 2005, accounting for a little over 23 percent of the state's production (IBGE/MPOG, 2007). Consequently, the city of Rio Verde is chosen to represent the state of Goiás regarding transportation infrastructure routes and future improvements.

Figure 3. Map of Goiás



Source: Ministério dos Transportes (2007).

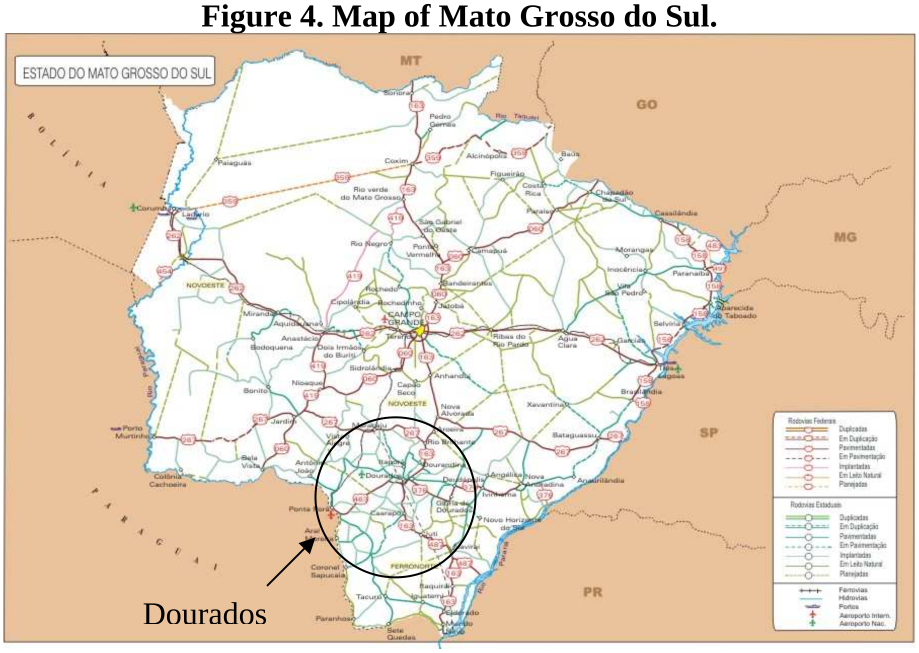
The expansion of the Ferronorte Railroad, connecting Alto Araguaia, Mato Grosso, to Uberlândia, Minas Gerais, will be an attractive soybean transportation route.

At Rio Verde, soybeans would be loaded into railcars and transported to Uberlândia, Minas Gerais, where the Ferronorte railroad interlines with the Ferroban railroad, and then headed to the final destination of Santos port. The total railroad transportation cost is calculated to be \$18.25/MT, which represents a reduction of \$8.11/MT. However, in the Brazilian government PAC 2007/2010, investments for such expansion were not included in the budget (DNIT/MT, 2007).

Mato Grosso do Sul

The state of Mato Grosso do Sul is the seventh largest state in Brazil with 358,158 km^2 (223,848 $miles^2$) (Figure 4). Maracajú and Dourados ranked number one and two with total production of 0.34 and 0.29 MMT, respectively. The production of the southeast of Mato Grosso do Sul, where Maracajú and Dourados are located, accounted for over 61 percent of the state's production (IBGE/MPOG, 2007).

Figure 4. Map of Mato Grosso do Sul.



Source: Ministério dos Transportes (2007).

Due to its significance to the state, the city of Dourados is the representative origin. The improvement in transportation infrastructure is by expanding the Ferropar rail track to the city of Dourados. Such expansion will connect the Dourados all the way to the exporting port of Paranaguá at the Atlantic Ocean. The total rail trip is approximately 1,155 kms (721 miles). In the Brazilian government Programa de Aceleração do Crescimento (PAC) 2007/2010, investments for such expansion were not intended in the budget (DNIT/MT, 2007). This expansion will reduce transportation costs around $1.50/MT, which is not a relevant improvement compared to current routes.

After reviewing implemented and probable improvements to Brazilian Central-West's transportation infrastructure, table 4 below shows the most noteworthy regarding their potential impact on competitiveness.

Table 4. Evaluated Transportation Improvements, Regions Affected by Improvements, and Estimated Savings of Improvements.

Proposed Improvement	Impacted Region	Cost Savings ($/MT)
Tapajós-Teles Pires Waterway	West Mato Grosso	$11.65
BR-163 Highway	North Mato Grosso	$20.00
Mortes-Araguaia Waterway	Northeast Mato Grosso	$11.00
Ferronorte Expansion to Rondonópolis	Southeast Mato Grosso	$1.00
Ferronorte Expansion to Uberlândia	Goiás	$8.11
Ferropar Expansion to Dourados	Mato Grosso do Sul	$1.50

Source: Author's estimation. Data from Sistema de Informações de Fretes (SIFRECA, 2007).

Methodology

International spatial, intertemporal model for soybeans was developed on the basis of quadratic programming model. The model is formed by spatial and temporal dimensions which allow soybeans to move from Brazil producing areas to domestic demand regions and importing countries for each quarter. Initially, base models are formulated that feature transportation and marketing costs *ex ante* improvements: the solution to the model is a benchmark or a measure of conditions prior to the introduction of the featured improvements to the transportation system. The effects of the improvements to the transportation system are measured by introducing their lower costs into the model's transportation network, solving these modified models, and then contrasting their solutions with those of the base model. By contrasting Brazil and other exporting countries soybean prices, revenues, and exports *ex ante* and *ex post* the improvements in Brazil's transportation infrastructure, the effects on international competitiveness are evaluated.

Spatial Models

The spatial equilibrium model was first developed by Samuelson (1952) and later was improved by Takayama and Judge (1971). The spatial equilibrium model is a quadratic programming model that features regional excess supply and excess demand regions relationships. The solution to such model generates interregional flows and prices that result from maximizing producer plus consumer surplus minus transportation and marketing costs. Spatial equilibrium models have been previously developed to analyze transportation improvements on international agricultural commodities trade (Fellin, 1993; Fuller et al, 1998; Fuller et al, 2000; and Fuller et al, 2001).

The Quadratic Programming Model

The model is formed by spatial and temporal dimensions that allow soybeans to move from Brazil producing areas to domestic demand regions and importing countries for each quarter. The United States, Argentina, and Canada were included in the model as soybean exporting region/countries. The importing countries were China, the European Union (25), and Southeast Asia.

Brazil’s domestic producing regions/states were linked to local demand locations and to Brazil’s exporting ports through internal transportation modes (road, railroad, waterway). Likewise, import demand equations in each import country were incorporated and linked to Brazil’s ports and other exporting countries through ocean transportation costs.

The soybean model was established by seven excess supply sub-regions/states and one excess demand region in Brazil. The seven soybean excess supply sub-regions/state in Brazil were North, West, Northeast, and Southeast of the state of Mato Grosso, the state of Goiás, the state of Mato Grosso do Sul, and the rest of Brazil. The only excess demand region in Brazil was represented by the Southeast region, which was composed by the states of São Paulo, Rio de Janeiro, and Espírito Santo.

Development of the Basic Spatial, Intertemporal Equilibrium Model

The spatial, intertemporal equilibrium model was designed to illustrate the soybeans transported through Brazil’s internal transportation modes (road, railroad, and waterway). The model took into account the soybeans movements from excess supply regions to excess demand regions and possible flows to Brazil’s port facilities and the consequent transhipment to the importing countries. The model incorporated major Brazil excess supply states/regions, domestic excess demand states/regions, internal transportation modes, exporting port facilities, ocean ship transportation, and estimated import demand.

A quadratic programming was specified to represent soybean world trade, production, and consumption for 2015. Projections of soybean world trade, production, and consumption for Brazil’s excess supply sub-regions/states in 2015 were performed based on the data collected from IBGE/MPOG (2007), CONAB/MAPA (2007), ABIOVE

(2007), and Food and Agricultural Policy Research Institute (FAPRI, 2007a). As for the other exporting excess supply countries and importing excess demand regions, data were obtained from FAPRI (2007a).

The Model

Given linear supply and demand equations for all regions, objective function and balance restrictions are expressed as

$$
\begin{aligned}
(1)\ Max\ \ NW\ = & \{\sum_q \{-\sum_i (\alpha_{iq} + 0.5\beta_{iq} S_{iq}) S_{iq} - \sum_f (\alpha_{fq} + 0.5\beta_{fq} S_{fq}) S_{fq} \\
& + \sum_j (\alpha_{jq} - 0.5\beta_{jq} D_{jq}) D_{jq} + \sum_d (\alpha_{dq} - 0.5\beta_{dq} D_{dq}) D_{dq}\} \\
& - \{\sum_m (\sum_i (\sum_j C_{ijm} T_{ijqm} + \sum_b C_{ibm} T_{ibqm} + \sum_r C_{irm} T_{irqm} \\
& + \sum_p C_{ipm} T_{ipqm})) + \sum_u \sum_p C_{upm} T_{upm})\} \\
& - \{\sum_b (\sum_u C_{bu} T_{buq} + \sum_p C_{bp} T_{bpq}) \\
& - \sum_r (\sum_p C_{rp} T_{rpq}) \\
& - \sum_d (\sum_p C_{pd} T_{pd} + \sum_f C_{fd} T_{fdq})\}\}
\end{aligned}
$$

subject to:

(2) $\sum_m (\sum_j T_{ijqm} + \sum_b T_{ibqm} + \sum_r T_{irqm} + \sum_p T_{ipqm}) + G_{qq+1} \le S_{iq} + G_{q-1q}$ for all i and q;

(3) $\sum_p T_{bpq} + \sum_u \sum_m T_{buq} \le \sum_i \sum_m T_{ibqm}$ for all b and q;

(4) $\sum_{\mathrm{p}} T_{rpq} \le \sum_i \sum_m T_{irqm}$ for all r and q;

(5) $\sum_{\mathrm{d}} T_{pdq} \le \sum_m \sum_i T_{ipmq} + \sum_b T_{bpq} + \sum_r T_{rpq} + \sum_u T_{upq}$ for all p and q;

(6) $\sum_{\mathrm{m}} \sum_u T_{ujmq} \ge D_{jq}$ for all j and q;

(7) $\sum_{\mathrm{p}} T_{pdq} + \sum_f T_{fdq} \ge D_{dq}$ for all d and q;

(8) $\sum_{\mathrm{d}} T_{fdq} + R_{qq+1} \le S_{fq} + R_{qq-1}$ for all f and q;

(9) $T, S, D \ge 0$ for all i, j, f, q, d, b, and r

where equation (1) is the net welfare interpreted as consumer surplus plus producer surplus minus transportation costs. From (2) to (5), all equations are supply balance constraints. Equation (2) constrains the soybean flow from i excess supply region to all receiving and transhipment points that is less than or equal to the quantity supplied at location i for all four quarters of the year. Equation (3) limits transhipments at barge-loading location so that the quantity shipped from each location is less than or equal to total quantities received for every quarter. Equation (4) constrains transhipments at rail-loading terminals so that the quantity shipped from each location is less than or equal to total quantities received for every quarter. Equation (5) constrains soybean shipments at each Brazil port to be less than or equal to quantity received at the ports by different inland transportation modes for every quarter.

From equation (6) to (8), all equations are demand balance constraints. Equation (6) limits quantity shipped by different inland modes to each demand location to be at least equal to or greater than the quantity demanded at each demand location for every quarter of the year. Equation (7) constrains quantity imported by each importing country to be at least equal to or greater than the quantity demanded for each quarter. Equation (8) limits quantity shipped from exporters f to all importing countries to be less than or equal to the quantity supplied at f for all quarters of the year. Equation (9) represents the non-negativity conditions.

Table 5 below shows the subscripts, parameters, and variables included in the formulated model.

Table 5. Subscripts, Parameters and Variables Included in Formulated Model

Subscripts	***Definition (quantity)***
Q	quarter (1,2,3,4)
I	Brazil excess supply locations (1,2,3…7)
F	foreign exporting regions (1,2,3)
j	Brazil excess demand locations (1)
d	Foreign importing countries (1,2)
m	Inland modes of transportation (1,2,3)
b	Barge loading locations (1)
u	Barge unloading locations (1,2,3)
r	Rail-loading terminal (1,2,3…7)
p	Brazil ports (1,2,3,4,5)
Parameters	***Definition***
C	Transportation costs per MT by the various modes
Variables	***Definition***
S_i	Brazil excess supply regions
S_f	Foreign excess supply regions
D_j	Brazil excess demand regions
D_d	Foreign excess demand regions
T	Soybean flow in MT between nodes
G	Quarterly quantities stored in Brazil
R	Quarterly quantities stored in other major exporting countries

Source: Author's construction.

Estimation of the Excess Supply (Demand) Equations

The following equation was used to estimate excess supply elasticity for exporting regions (Shei and Thompson, 1977):

(12) $E_{es} = E_s(Q_p/Q_e) – E_d(Q_d/Q_e)$

where, E_{es} is the excess supply elasticity of a region, E_s is the own-price supply elasticity of a region, Q_p is the quantity produced in a region, Q_e is the quantity exported from a region, E_d is the own-price demand elasticity of a region, and Q_d is the quantity demanded or consumed in a region.

The soybean own-price supply elasticities (E_s) for all the sub-regions/states in Brazil were estimated by taking the natural log (ln) of the planted soybean area (hectares) supply response equations. All equations were specified as follows:

(13) $PlHect_t = f\ (PlHect_{t-1}, Price_{t-1})$

where $PlHect_t$ is planted hectares in time period t, $PlHect_{t-1}$ is planted hectares in time period t-1, and $Price_{t-1}$ is soybean real export price in Brazil's currency (Real) in period t-1. By taking the natural log (ln) of both sides of the above equation, it gives

(14) $\ln(PlHect_t) = \alpha_0 + \alpha_1 \ln(PlHect_{t-1}) + \alpha_2 \ln(Price_{t-1}) + \varepsilon_t$

where α_0 is the intercept and ε_t is the residual term. The own-price supply elasticities (E_s) were obtained from the estimated coefficients on the lag price variable in each equation (α_2).

Table B-1 in Appendix B presents the estimated soybean hectare supply response equations for sub-regions/states in Brazil. All signs for the $\ln(Price_{t-1})$ variables were positive as they were expected. Also, the coefficients for the price variables were significant at the 0.05 level for all equations except for one which was significant at the 0.10 level. Adjusted R-squares for the equations varied from 0.83 to 0.95. The estimated Brazilian supply elasticities ranged from 0.27 for the rest of Brazil to 1.22 for the Northeast of Mato Grosso.

As for other exporting countries, the own-price supply elasticities for Argentina and the United States and Canada were based on the Elasticity Database from FAPRI (2007b). The own-price supply elasticities for the United States and Argentina were 0.24 and 0.32, respectively. Canada own-price supply elasticity was 0.32.

Similar to the excess supply elasticity equation, the excess demand elasticity equation is represented as (Shei and Thompson, 1977):

(15) $E_{ed} = E_s(Q_p/Q_i) + E_d(Q_d/Q_i)$

where, E_{ed} is the excess demand elasticity of a region, E_s is the own-price supply elasticity of a region, Q_p is the quantity produced in a region, Q_i is the quantity imported into a region, E_d is the own-price demand elasticity of a region, and Q_d is the quantity demanded or consumed in a region.

The soybean own-price demand elasticity for each sub-region/state was assumed to be equal to Brazil's own-price demand elasticity. The equation used to estimate Brazil's own-price soybean demand elasticity is the following (Piggott and Wohlgenant, 2002):

$$(16)\ \eta_b = s^d \left[\frac{P_b}{\frac{\alpha P_m}{\eta_m} + \frac{\beta P_o}{\eta_o}} \right] + (1 - s^d)\eta_{xb}\varepsilon_{fb}$$

where η_b is the elasticity of total demand for soybeans, s^d is the average share of domestic disappearance of soybeans for the period in analysis[4], P_b is the average soybean export price for the period in analysis, α is the yield of soymeal, P_m is the average soymeal export price for the period in analysis, η_m is the elasticity of meal demand, β is the yield soyoil, P_o is the average soyoil export price for the period in analysis, η_o is the elasticity of soyoil demand, η_{xb} is the elasticity of export demand for soybeans, and ε_{fb} is the elasticity of price transmission. By substituting the estimated values (Appendix B) into the equation (16), the soybean own-price demand elasticity for Brazil is -0.20.

[4] $S^d = (B^d/B^s)$ where B^d is the total soybean supply minus total soybean exported and B^s is total soybean supply.

The soybean own-price demand elasticity for the United States, Argentina, and Canada was adopted from several sources. For the United States, the soybean own-price elasticity was -0.38 (Piggott and Wohlgenant, 2002). The soybean own-price demand elasticity for Argentina was assumed to be -0.25 (FAPRI, 2007b). As for Canada, the own-price demand elasticity was -0.25 (FAPRI, 2007b). With respect to the importing countries, the soybean own-price demand elasticities were -0.20 and -0.245 for China and European Union, respectively, according to FAPRI (2007b). For the Southeast Asia, it was assumed the same elasticities as China.

Projecting Production and Consumption in 2015

In order to project production and consumption of soybeans in excess supply (demand) regions in Brazil for 2015, several efforts were carried out based on data from IBGE/MPOG, SECEX/MDIC, and ABIOVE. The table 6 below presents the production, consumption, and exports for each excess supply (demand) region in Brazil for 2015.

Table 6. Estimated soybean production, consumption, and exports for excess supply (demand) regions in Brazil in 2015 (Million Metric Tons)

Region/State	Production	Consumption*	Surplus/Exports
North - Mato Grosso	11.66	0.00	11.66
West - Mato Grosso	9.98	0.00	9.98
Northeast - Mato Grosso	3.09	0.00	3.09
Southeast - Mato Grosso	7.52	6.86	0.66
Goias	12.69	5.46	5.20
Mato Grosso do Sul	6.75	2.72	2.19
Southeast	3.09	4.77	-3.41**
Rest of Brazil	38.21	21.92	11.81
Total - Estimated	92.99	41.73	46.35***
Total - FAPRI	92.99	41.73	46.35

* Consumption = Crush. **Imports from other states.
*** Southeast of Brazil also exports.
Source: Author’s calculation and FAPRI (2007a).

As for the exporting and importing countries, the projections for production, crush, and exports (imports) estimated by FAPRI (2007a) were used. In 2015, the production in the United States, Argentina, and Canada will be 82.52 MMT, 55.71 MMT, and 3.41 MMT, respectively. The consumption (crush) for those countries/regions is expected to be 66.29 MMT, 62.24 MMT, and 1.97 MMT, respectively. With respect to exports, the United States' total exports will be 24.45 MMT. The total exports for Argentina are estimated to be approximately 13.33 MMT. The total exports of the Canada are estimated at 0.801 MMT.

By using FAPRI (2007a) projections, the production, consumption, and imports for China in 2015 are estimated at 17.72 MMT, 70.27 MMT, and 47.59 MMT, respectively. For the European Union, the estimates are 0.82 MMT, 15.83 MMT, and 13.82 MMT. As for Southeast Asia, The production, consumption, and imports are 21.89 MMT, 34.87 MMT, and 23.77 MMT, respectively.

Transportation, Intermodal Transfer, and Port Costs

<u>Truck Cost</u>

The truck costs in this study were calculated based on the monthly data from SIFRECA (2007) for the years 2003/2004. Such costs were estimated with linear equation based on the distance between shipping points and receiving locations. The following equation was estimated and served as a tool to measure new truck transportation routes for 2015:

$$US\$/MT = 5.54 + 0.0207Kms - 1.73DQ1 + 1.36DQ2 - 1.12DQ3$$

where the intercept represented the fixed cost (loading and unloading costs) in dollars per MT and the slope accounted for the variable cost per MT/kilometer (transportation costs).

DQ1, DQ2, and DQ3 are dummy variables that represent seasonality. The sign for the dummy variables were as expected. The harvest quarter, DQ2, had a positive coefficient which means a higher truck cost is charged to transport soybeans. The R-square for this equation was 0.7936. The intercept and the coefficient for the Kms were significant at the 0.01 level. The dummy variable DQ1 and DQ2 were significant at the 0.05 level and DQ3 was significant at the 0.10 level.

Rail Cost

The rail costs were also estimated using the monthly data from SIFRECA (2007) for the years 2003/2004. Two rail cost equations were estimated to represent travel distances less than or greater than 700 kms for eight routes. The rail cost equation for travel distance under 700 kms was the following:

$$US\$/MT = 3.80 + 0.014Kms - 0.003DCasParDist + 0.006DATSanDist - 0.005DPFSaoDist$$

where the intercept was the fixed cost (terminal cost) in dollars per MT, the slope was the variable cost per MT/kilometer (transportation costs). Each dummy variable in the equation represented a different origin-destination travel distance over 700 kms. DCasPar was a dummy for the origin-destination Cascável-Paranaguá multiplied by the distance (736 kms), DATSan was a dummy for the origin-destination Alto Taquari-Santos times distance (1,295 kms), and DPFSao was a dummy for the origin-destination Porto Franco-São Luís times distance (713 kms). Also, the origin-destination for Uberlândia-Vitória (1,313 kms) was represented in the intercept. The coefficient for the dummy variables was the change in magnitude in the slope for the specific route. In other words, it represents the variable cost per MT/kilometers for the mentioned route. The R-square for this equation was 0.786. The intercept and all variables had the coefficient significant at the 0.01 level.

In order to estimate the equation for travel distance greater than 700 kms, the same procedure was adopted for distance less than 700 kms. Dummy variables represented origin-destination routes that had travel distance under 700 kms. The rail cost equation for travel distance greater than 700 kms was the following:

$$\begin{aligned} US\$/MT = \; & -11.62 + 0.031Kms + 0.003DCasAraDist + 0.017DCasPGDist \\ & + 0.028DCamParDist + 0.021DMarParDist + 0.018DPedSanDist \end{aligned}$$

where the slope was the variable cost per MT/kilometer, DCasAra was a dummy for the origin-destination Cascável-Araucária times distance (606 kms), DCasPG was a dummy for the origin-destination Cascável-Ponta Gross times distance (387 kms), DCamPar was a dummy for the origin-destination Cambé-Paranaguá multiplied by the distance (459 kms), DMarPar was a dummy for the origin-destination Maringá-Paranaguá times distance (497 kms), DPedSan was a dummy for the origin-destination Pederneiras-Santos multiplied by the distance (490 kms). The coefficients for the dummy variables represented the variable cost per MT/kilometer for a specific route. The R-square for this equation was 0.912. Once again, the intercept and all variables had coefficients significant at the 0.01 level.

Barge Cost

The barge cost equation was also estimated using the monthly data from SIFRECA (2007) for the years 2003/2004. The following equation represents the barge costs in Brazil:

$$US\$/MT = -0.91 + 0.014\ Kms$$

where the slope was the variable cost per MT/kilometer. The R-square for this equation was 0.86 and the coefficient for the Kms variable was significant at the 0.01 level.

<u>*Ocean Freight Cost*</u>

The ocean freight rates for Brazilian soybean export ports to Hamburg (or Rotterdam) and Shanghai importing ports were based on the AMS/USDA (2007a). Due to lack of data, all exporting ports were assumed to have the same ocean freight cost to the ports of Hamburg and Shanghai as Santos port, with exception to Paranaguá port (Table 7).

Table 7. Quarterly Ocean Freight Chargers for Brazil Soybean Export Ports in 2006, US$/Metric ton

Exporting ports	Importing ports	
Santos, São Paulo	Hamburg, Germany	Shanghai, China
Quarter 1	39.51	50.13
Quarter 2	36.91	44.80
Quarter 3	50.24	60.98
Quarter 4	60.40	73.32
Average	46.77	57.31
Paranaguá, Paraná	Hamburg, Germany	Shanghai, China
Quarter 1	38.51	49.13
Quarter 2	35.91	43.80
Quarter 3	49.24	59.98
Quarter 4	59.40	72.32
Average	45.77	56.31

Source: AMS/USDA (2007a).

Olowolayemo (2007) supplied the data for ocean freight chargers from US Gulf ports to importing ports at Europe (Rotterdam) and Japan (Yokohama). The Yokohama port in Japan was used as proxy to Shanghai port, China. Additionally, due to lack of data a proxy was also used for Argentina. The Rosario port, Argentina, was assumed to have the same ocean freight charges as Santos port in Brazil. In 2006, the quarterly ocean freight charges for US Gulf port to Rotterdam, Netherlands, were for the first and second quarter $19.53/MT and $20.13/MT, respectively. For the other two quarters, charges were $26.87/MT and $29.60/MT. The quarterly charges from US Gulf port to Yokohama were $35.71/MT and $35.52/MT for the first and second quarters, respectively. For the same ocean route, the third and fourth quarters' freight charges were $44.88/MT and $50.24/MT, respectively.

Port and Intermodal Tranfer Costs

The port charges for the Brazilian export ports and intermodal transfer costs were both based on a study done by Martins and Lemos (2006). The port charges estimated by the authors the exporting ports of Santos and Paranaguá, were $13.2/MT and $10.8/MT, respectively. As for the Madeira-Amazon waterway river ports, Porto Velho, Itacoatiara, and Santarém, port charges were $6.00/MT. The port charges for Vitória and Itaqui exporting ports were estimated at $7.2/MT and $6.00/MT, respectively. For every single transhipment point, intermodal transfer costs were estimated at US$ 1.50/MT (Martins and Lemos, 2006).

Model Validation

Model Validation is a necessary procedure when mathematical models are applied to project various outcomes. The validation procedure provides insight into the behavior of the mathematical models and the interpretation of the model results. In this article, the validation procedure involves a comparison of the model results with the actual outcomes of the modeled system. Although the model uses data from 2015, the model will be validated using 2006 historical events and outcomes. Therefore, assumptions of equal price in 2006 and 2015 were required. Since no transportation improvement will happen in Brazil for the base model, it is assumed that the same soybean transportation routes will be utilized for 2015.

Due to lack of data and our analysis only takes into account the transportation network of few excess supply region in Brazil, it is only possible to validate the model-estimated exports (imports) of the analyzed excess supply (demand) regions and model-estimated shadow prices at each excess supply and demand region. Yet several efforts were made to assure that soybean flows to ports and by mode of transportation would happen as several studies suggest.

Regarding exports of the analyzed Brazilian excess supply regions, the percent deviation from actual exports and model estimates ranged from 1.38 percent to 17.91 percent. The latter being the Southeast of Mato Grosso region surplus which had a model estimated surplus of 0.78 MMT. This estimate was 0.12 MMT over the actual data of 0.66 MMT. As for the other exporting countries, the percent deviation of actual surplus and model estimates ranged from -1.74 percent (down 0.42 MMT) for the United States to 14.98 percent (up 1.99 MMT) for Argentina. As for the quantity imported by the importing countries, the percent deviation ranged from -1.93 percent (down 0.45 MMT) for Southeast Asia to -0.60 percent (0.35 MMT) for China.

The model-estimated shadow prices were contrasted to actual data. For the Brazilian excess supply regions, the percent deviation ranged from 1.13 percent (up $2.14/MT) for the Northeast of Mato Grosso to 8.78 percent (up $14.47/MT) for the West of Mato Grosso. The actual price was farm price based on AMS/USDA (2007a). The farm prices for the regions within Mato Grosso were assumed to be $164.88/MT except for the Northeast and Southeast, which were assumed to be equal to Goiás and

Mato Grosso do Sul farm prices ($189.63/MT). The exporting countries shadow prices percent deviations from actual prices were ranged from -1.06 percent (down $2.61/MT) for the United States to 7.21 percent (up $16.37/MT) for Argentina. The United States price was based on the FAS/USDA (2007b) unit value for 2006 ($245.90/MT). Canada was assumed to have the same export price as the United States. Argentina export price ($227/MT) was sourced from the FAS/USDA (2007c).

As for the importing countries, the percent deviation had an interval of 3.29 percent (up $9.17/MT) to 7.39 percent (up $19.28/MT) for the EU. The source for the importing countries CIF price was the AMS/USDA for 2006 (2007a). The EU and China CIF price were $261/MT and $279/MT, respectively. Southeast Asia was assumed to have the same CIF price as China.

Results

Separate Effects of Transportation Improvements

The completion of the BR-163 highway is comparatively large and has the largest effect of any single transportation improvement on exports, prices, and revenues (Table 8). By completing the BR-163 highway, the soybean price in Brazil increases by $14.98/MT while soybean prices in the United States and Argentina decreases by $2.24/MT each. Consequently, Brazil soybean exports increase about 0.873 MMT and revenues about $144.7 million. On the other hand, the United States and Argentina exports decline 0.364 MMT and 0.273 MMT, respectively. Likewise, United States and Argentina revenues decrease $184 million and $124 million, respectively. Because of reduction in transportation costs in Brazil, the soybean producer price increases as does the exports. In contrast, other exporting countries prices, exports, and revenues decline, hence a comparative reduction in international competitiveness.

Table 8. Separate Estimated Effects of Transportation Improvements in Brazil on the Soybean Exporting Countries.

Exports (TMT)	Tapajós-Teles Pires	BR-163 Highway	Mortes-Araguaia	Ferronorte (1)	Ferronorte (2)	Ferropar
United States	-144.71	-364.31	-93.92	-5.7	-105.19	-7.75
Brazil	352.64	873.7	228.88	16.25	256.35	18.89
Argentina	-108.49	-273.14	-70.41	-4.27	-78.87	-5.81
Canada	-5.73	-14.43	-3.72	-0.22	-4.17	-0.31
Prices ($/MT)						
United States	-0.89	-2.24	-0.58	-0.03	-0.65	-0.05
Brazil	17.04	14.98	14.19	0.74	6.56	1.74
Argentina	-0.89	-2.24	-0.58	-0.03	-0.65	-0.05
Canada	-0.89	-2.24	-0.58	-0.03	-0.65	-0.05
Revenue (mill. $)						
United States	-76.12	-184.86	-47.86	-2.48	-53.64	-4.13
Brazil	153.36	144.69	4.38	4.45	82.55	9.63
Argentina	-49.58	-124.78	-32.31	-1.67	-36.21	-2.79
Canada	-3.04	-7.65	-1.98	-0.10	-2.22	-0.17

(1) Expansion to Rondonópolis.
(2) Expansion to Uberlândia.
Source: Author’s calculation.

Brazil also experiences significant gain from construction of the Tapajós-Teles Pires and Mortes-Araguaia waterways as well as expansion of the Ferronorte and Ferropar railroads. However, the waterways gains are noteworthy. The Tapajós-Teles Pires waterway yields important price gains to West of Mato Grosso ($22.48/MT). The other waterway, Mortes-Araguaia, increases the price in Northeast Mato Grosso around $17.67/MT. With respect to the railroad improvements, the greatest gain comes from the Ferronorte expansion from Alto Taquari to Uberlândia. The estimated increase in price for the state of Goiás is $10.46/MT.

Combined Effects of Transportation Improvements

Combining all the transportation improvements analyzed in this study, table 9 shows important gains to Brazilian soybean producers. Brazil soybean exporters increase 1.06 MMT, while producer revenues increase about $232.21 million, and the average increase in producer prices in Brazil is $5.62/MT. The average increase in price for the state of Mato Grosso is the largest ($7.91/MT), while the state of Mato Grosso do Sul has the lowest gain ($2.2/MT). The regions within Brazil with the highest impact due to improvement in transportation are the West Mato Grosso, North Mato Grosso, Northeast Mato Grosso, and the state of Goiás, with noteworthy mention the state of Northeast of Mato Grosso ($15.45/MT).

Table 9. Combined Estimated Effects of Transportation Improvements in Brazil

Exports (TMT)	Combined Improvements
United States	-455.06
Brazil	1061.17
Argentina	-341.18
Canada	-18.02
Prices ($/MT)	
United States	-2.80
Brazil	5.62
Argentina	-2.80
Canada	-2.80
Revenues (millions $)	
United States	-231.07
Brazil	232.21
Argentina	-155.98
Canada	-9.56

Source: Author’s calculation.

Regarding soybean flow by transportation mode, important gains are made in Mato Grosso where 48 percent of production is shipped by via the BR-163 highway to the Amazon river port of Santarém with an average gain in price of $8.56/MT, and 27 percent is shipped to the same port by barge via the Tapajós-Teles Pires waterway, which accounts for an average increase in the price of $5.56/MT. Remaining Mato Grosso production is shipped via the Mortes-Araguaia waterway (13 percent) and Madeira-Amazon waterway (12 percent). As a result, Mato Grosso production that heavily relies on highways in trips to the Atlantic Ocean ports of Santos and Paranaguá, now becomes a consumer of ports located in on the North and Northeast of Brazil. As for the state of Goiás, the expansion of the Ferronorte railroad from Alto Taquari to Uberlândia makes available a less costly shipment to the exporting port of Santos. Consequently, all production for this state is shipped by railroad. This new route represented an average gain in price of $8.31/MT.

The analyses show, as expected, that producers in regions with improved transportation system efficiency experience an increase in price, and ultimately in exports and revenues. In consequence of the expanded exports, world price declines. For the Brazilian regions with transportation improvements, the higher price that results from their improved transport efficiency exceeds the decline in price that happens from additional exports into the world market. For those regions or countries not having improvement in transportation (United States, Argentina, and Canada), prices decline as does their exports and revenues. The results show Brazil's improved transportation infrastructure decrease world price by -$2.80/MT (Table 9). Thus, in the United States the decrease in price reduces soybean producer revenues about $231 million and exports about 0.455 MMT. Likewise, Argentina and Canada have a decrease in revenues and exports.

In summary, even though the absolute revenue and export loss is substantial for the United States, the relative loss is modest. The United States soybean price, exports, and revenues decrease 1.15, 1.9, and 1.15 percent, respectively. As for Argentina, the losses are relatively similar to the United States. The Argentina's soybean price, exports, and revenues decline 1.15, 2.22, and 1.15 percent, respectively. In Brazil, the gains tend to be relatively high as compared to the United States losses. The Brazil's soybean price, exports, and revenues increase 2.94, 2.24, and 1.22 percent, respectively.

Conclusions

Results show that the largest gain for the Brazilian soybean producers is associated with those transportation system improvements related to one specific transportation mode: waterway. Brazil has abundant rivers, especially in the North. However, environmental concerns still are the main setback waterways development. For example, the Tapajós-Teles Pires and Mortes - Araguaia waterways yields comparatively large gains since soybeans are shipped through less costly mode and smaller distances for the West and Northeast of Mato Grosso. Both waterways are future projects that have been put aside due to environmental issues. If the environmental problems are solved in the future, the gains in revenues from utilizing these waterways are about $103 million for Mato Grosso producers. Exports are also expected to increase about 0.729 MMT caused by the waterways development.

Other transportation projects were important to selected regions. The completion of the BR-163 highway is extremely significant for soybean producers in the North of Mato Grosso. When the highway linking central Mato Grosso to the Amazon river port of Santarém is completed, an increase in price ($8.56/MT) could be expected about of 47 percent of Mato Grosso soybean production. Interestingly, the Ferronorte railroad expansion from Alto Taquari to Uberlândia was found to yield a significant gain in soybean price for the state of Goiás ($8.31/MT). Furthermore, all soybean exports from Goiás were shipped by the Ferronorte railroad to the Santos port. This expansion resulted in an increase in exports and revenues of 0.308 MMT and $105 million, respectively.

With the improvements in Brazil's transportation infrastructure, the United States soybean price decline $2.80/MT, while producer revenues decrease $231.07. United States soybean exports decline 0.45 MMT with Brazil's improved transportation network. Although the absolute losses are significant, the relative impact is modest with the United States exports decreasing about 1.9 percent, while total soybean revenues decline a little bit over 1.15 percent. The losses for Argentina are similar to the United States. Argentinean soybean producer revenues decrease $155.98 million, while soybean price also decreases about $2.80/MT. The loss in exports for Argentina was 0.34 MMT. Similar to the United States, the absolute losses are significant, but in relative terms losses are modest. The Argentina's soybean price, exports, and revenues decline 1.15, 2.22, and 1.15 percent, respectively.

Brazil's gains to its soybean producers are comparatively great relative to the United States losses. Soybean exports increase approximately 1.06 MMT with improvements in its transportation infrastructure while average soybean price increases $5.62/MT. Brazil's estimated relative increase in soybean price, exports, and revenues are 2.94, 2.24, and 1.22 percent, respectively.

In conclusion, this article shows that improvements in Brazil's transportation infrastructure to affect international competitiveness; however, it is important to note that certain transportation modes should get more attention than others as in the case of the waterways. The most important transportation improvement for Brazilian producers analyzed in this study is the development of the Tapajós-Teles Pires and Mortes-Araguaia waterways. It is also important to state the importance of the BR-163 highway, especially for the Mato Grosso soybean producers. As for the moment, environmental concerns have been blocking the development of both waterways and the completion of the BR-163 highways. Therefore, as such problems are solved, the expectations are Brazil becoming more competitive in the world soybean market and other exporting countries (e.g. United States) losing competitiveness.

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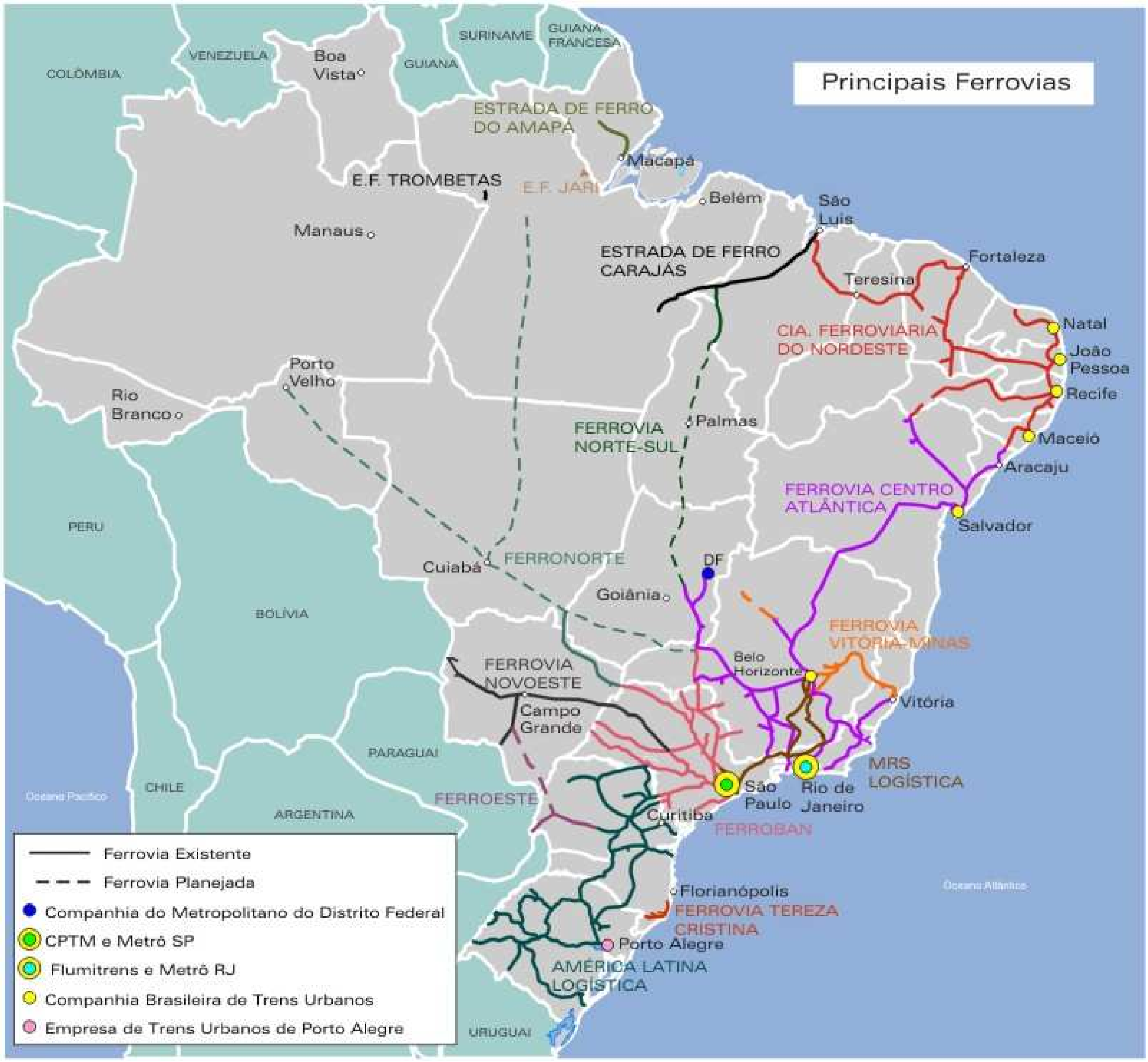
APPENDIX A – Maps of Railroads, Waterways, and Ports in Brazil

Figure A1. Map of Ports in Brazil.

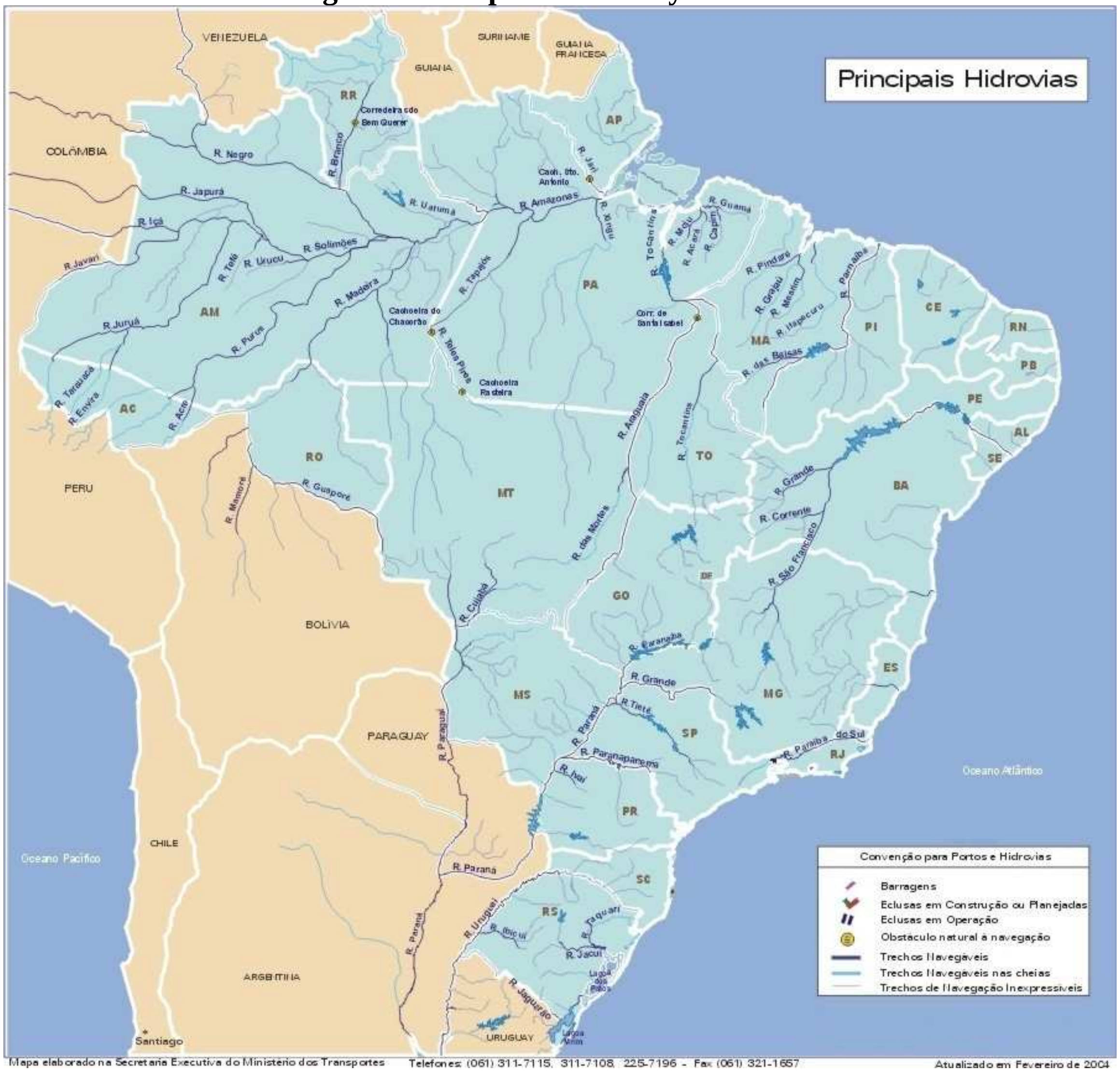
Source: Ministério dos Transportes (2007).

Figure A2. Map of Railroads in Brazil.



Source: Ministério dos Transportes (2007).

Figure A3. Map of Waterways in Brazil.



Source: Ministério dos Transportes (2007).

APPENDIX B – Estimation of Selected Parameters Used in the Model

Table B-1. Estimated Soybean Hectare Supply Response Equation for Selected Brazilian Sub-regions/States/Regions

North - Mato Grosso							
$lnPlHect_t$ =	0.55	+	0.66	$lnPlHect_{t-1}$	+	0.69*	$lnPrice_{t-1}$
	(1.07)		(0.17)			(0.30)	
			Adj. R^2:	0.93			
West - Mato Grosso							
$lnPlHect_t$ =	1.46	+	0.72	$lnPlHect_{t-1}$	+	0.39**	$lnPrice_{t-1}$
	(1.15)		(0.14)			(0.18)	
			Adj. R^2:	0.93			
Northeast - Mato Grosso							
$lnPlHect_t$ =	-2.27	+	0.59	$lnPlHect_{t-1}$	+	1.22*	$lnPrice_{t-1}$
	(0.87)		(0.10)			(0.17)	
			Adj. R^2:	0.95			
Southeast - Mato Grosso							
$lnPlHect_t$ =	3.98	+	0.54	$lnPlHect_{t-1}$	+	0.39*	$lnPrice_{t-1}$
	(2.18)		(0.19)			(0.11)	
			Adj. R^2:	0.90			
Goiás							
$lnPlHect_t$ =	2.37	+	0.64	$lnPlHect_{t-1}$	+	0.45*	$lnPrice_{t-1}$
	(1.66)		(0.16)			(0.16)	
			Adj. R^2:	0.91			
Mato Grosso do Sul							
$lnPlHect_t$ =	1.51	+	0.76	$lnPlHect_{t-1}$	+	0.31*	$lnPrice_{t-1}$
	(2.17)		(0.16)			(0.08)	
			Adj. R^2:	0.83			
Southeast of Brazil							
$lnPlHect_t$ =	3.38	+	0.62	$lnPlHect_{t-1}$	+	0.31*	$lnPrice_{t-1}$
	(1.41)		(0.11)			(0.05)	
			Adj. R^2:	0.95			
Rest of Brazil							
$lnPlHect_t$ =	3.29	+	0.69	$lnPlHect_{t-1}$	+	0.27*	$lnPrice_{t-1}$
	(1.74)		(0.12)			(0.06)	
			Adj. R^2:	0.93			

( ) Standard errors. * Significant at the 0.05 level. ** Significant at the 0.10 level.
Source: author's calculation.

Estimating Elasticity of Total Demand for Soybeans in Brazil

To estimate the elasticity of total demand for soybeans in Brazil, first the average soybean disappearance for Brazil during the period 1990-2005 was calculated to be (s^d = 0.7787). The average Brazilian soybean, soymeal, and soyoil export prices for the same period were 224.43 \$/MT (P_b), 191.53 \$/MT (P_m), and 466.12 \$/MT (P_o), respectively. Based on Piggott and Wohlgenant (2002) calculation for yields in the United States, the soymeal (α) and soyoil (β) yields were 0.792 and 0.178, respectively. The elasticities of meal (η_m) and oil (η_o) demand for Brazil were -0.06 and -0.05, respectively (Meyers et al, 1991).

As for the elasticity of export demand for soybeans for Brazil (η_{xb}), the following equation was developed (Piggott and Wohlgenant, 2002):

$$BRExp_t = f(CIFPrice_t, WGDPCap_t, BRExp_{t-1})$$

where $BRExp_t$ is soybean exports by Brazil, $CIFPrice_t$ is Rotterdam real CIF price, $WGDPCap_t$ is the average world GDP per capita, and $BRExp_{t-1}$ is the lag soybean exports by Brazil. By taking the natural logarithm (ln) of both sides of the above equation, it gives

$$\ln(BRExp_t) = \alpha_0 + \alpha_1 \ln(CIFPrice_t) + \alpha_2 \ln(WGDPCap_t) + \alpha_3 \ln(BRExp_{t-1}) + \varepsilon_t$$

where α_0 is the intercept and ε_t is the residual term. The elasticity of export demand for soybeans (η_{xb}) was obtained from the estimated coefficients on the lag price variable (α_1). The signs on the coefficients for all variables were as expected. The coefficient for the price variable was significant at the 0.10 level. Adjusted R-squares for the equation was 0.9241. The estimated elasticity of export demand for soybeans was -0.9087. All the data ware from FAS/USDA(2007a and 2007c) and except the world GDP per capita which was sourced from ERS/USDA (2007).

Last, the following linear equation was used to estimate the elasticity of price transmission (ε_{fb}):

$$CIFPrice_t = f(FOBPrice_t)$$

where $CIFPrice_t$ is the Rotterdam real CIF price and $FOBPrice_t$ is Brazil real export price. By using price data from FAS/USDA (2007c) over the period 1990-2005 and taking the natural logarithm (ln), the following linear regression was estimated:

$$\ln(CIFPrice_t) = 1.359 + 0.77 \ln(FOBPrice_t)$$

where 0.77 was the elasticity of price transmission for soybeans. The coefficient for the variable $FOBPrice_t$ was significant at the 0.01 level. Adjusted R-squares for the equation was 0.6582.