THREE ESSAYS ON INTERNATIONAL AGRICULTURAL TRADE

A Dissertation

by

RAFAEL DE FARIAS COSTA

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

May 2012

Major Subject: Agricultural Economics

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ABSTRACT

Three Essays on International Agricultural Trade. (May 2012)

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There are many factors that affect international agricultural trade. One of them is international transportation costs. Another important factor is non-tariff barriers such as sanitary and phytosanitary regulations caused by animal disease outbreaks. The main purpose of this dissertation was to analyze how these factors interfere in the international agricultural trade by examining three cases.

In Chapter II, a spatial price equilibrium model of the international cotton sector was utilized to evaluate the effects of the Panama Canal expansion (PCE) on the world cotton industry. Three scenarios were evaluated by reducing ocean freight rates from U.S. Gulf and Atlantic ports to Asian destinations. All scenarios suggested that cotton exports from U.S. Gulf and Atlantic ports would considerably increase. On the other hand, the West Coast ports decreased its participation in total U.S. cotton exports. Overall, total U.S. cotton exports were expected to increase due to the PCE.

By using the same model which was used in Chapter II, the third chapter analyzes port improvements in Brazil. By March of 2012, the port of Salvador is expected to have undergone relevant improvements. As a result, the port of Salvador is expected to attract ocean shipping companies which are willing to export directly to Asian importing markets. Scenarios with different reductions in cotton export cost for this port were examined. In general, results indicated a shift in Brazil cotton export flows from the port of Santos to the port of Salvador as well as an increase in exports and producer revenues for the country.

Finally, in Chapter IV, the impacts of the 2005 FMD outbreak on the Brazilian meat market was examined. The imposition of an import ban by Russia on Brazilian meat exports was also investigated. By using time series methods, it was found that the outbreak along with the import ban caused a temporary negative price shock to the Brazilian meat market. Export pork and export chicken prices were found to not fully recover after the removal of the import ban by Russia. On the other hand, the export beef price was indicated to undergo a complete recovery.

DEDICATION

To my parents, Ecio and Vera, and my brothers, Ecio, Diogo, Thiago

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I would like to thank my committee chair, Dr. C. Parr Rosson, and my committee members, Dr. Bruce A. McCarl, Dr. David A. Bessler, and Dr. Julian Gapsar, for their guidance and support throughout the course of this work. Particularly, I want to thank Dr. Rosson for his financial support over the past six years.

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CHAPTER I

INTRODUCTION

World trade has increased significantly since the end of World War II. From 1950-2010, world trade grew at an average rate of six percent per annum. During the same period, the annual growth rate of agricultural trade was 3.5 percent (WTO 2011). Although the forecast for the next ten years is that agricultural trade is expected to grow by two percent per year, which is slower than over the previous decade, world agricultural trade is projected to increase from 563.8 million tons in 2010 to 677.7 million tons by 2019. This represents an increase of 20 percent (OECD 2010).

There are several key factors which supported and explained this rise in international agricultural trade. One potential explanation is the decline in international transportation costs. Economic historians have documented how technological change led to substantial reductions in shipping costs from 1850–1913 (Harley 1989; Mohammed and Williamson 2004). Econometric evidence has subsequently linked shipping cost declines to rapid growth in trade during that first era of globalization (Estevadeordal, Frantz, and Taylor 2003). The decades since World War II experienced significant technological change in shipping, including more time efficient inland transportation routes and the use of containerization in ocean shipping (Hummel 2007).

However, transportation costs still play a major role in enhancing international

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trade. Studies evaluating customs data consistently indicate that transportation costs pose a barrier to trade at least as large as, and frequently larger than, tariffs (Hummel 2007). Trade negotiations have steadily decreased tariff rates, with average U.S. import tariffs dropping from 6 to 1.5 percent since 1950 and worldwide average import tariffs dropping from 8.6 to 3.2 percent between 1960 and 1995 (Clemens and Williamson 2002). As tariffs become a less important barrier to trade, the importance of transportation to total trade costs – inland transportation, ocean shipping, plus tariffs – is increasing. Hence, transportation cost is still an important factor in determining the volume of world trade.

Another important factor which impedes international trade are non-tariff barriers such as sanitary and phytosanitary regulations. Animal disease outbreaks typically remove animals from the market, close export markets, and can reduce domestic demand for animal products. For example, during the 2001 foot and mouth disease (FMD) outbreak in the United Kingdom, the European Union's Standing Veterinary Committee banned related United Kingdom exports. The Treasury of the United Kingdom estimated that the net economic effect of the outbreak was about 0.2% of gross domestic product (Gao 2009). Similarly, in 2003, the discovery of bovine spongiform encephalopathy (BSE, or "Mad Cow" Disease) in the United States resulted in the immediate closure of almost 90% of the U.S. export market for beef (Rich and Winter-Nelson 2007). Most recently, the 2005 FMD outbreak in Brazil caused immense uncertainty and economic losses to the country's meat industry, especially after the import ban by many countries.

It was estimated Brazilian beef exports declined by approximately 30 percent, two months after the outbreak was reported (Costa, Bessler, and Rosson 2011).

Based on these two important factors that impact international trade (transportation and animal disease outbreaks), the main objective of this dissertation is to assess how they impede and affect international agricultural trade. In Chapter II, I assess how the expansion of the Panama Canal will affect the efficiency, distribution and competitiveness of the U.S. cotton industry through its effects on lowering transportation costs. When the Panama Canal expansion (PCE) is completed in 2014, the number and size of vessels that are able to pass through the canal will increase. As a result, ocean freight rates for U.S. Gulf and South Atlantic ports to East Asia destinations will decrease, which will potentially increase cotton shipments via the canal. Moreover, the U.S. cotton industry is expected to gain from this less costly route and enhance its competitiveness in the global market. To perform this analysis, a spatial, intertemporal equilibrium model of the international cotton industry was developed that includes detailed domestic and international transportation networks. The model evaluates U.S. cotton export flows by final destination, changes in export levels, and producer (warehouse level) revenues. In addition, the effects of the PCE on competing cotton exporting countries and their producer revenues were estimated.

The focus of Chapter III is on the Brazilian cotton industry and its port infrastructure. In the last decade, cotton exports in Brazil have been increasing, which has positioned the country as one of the main suppliers of cotton fiber. However, the lack of adequate port infrastructure is forcing cotton producers to export via less efficient routes. In particular, the producers located in the state of Bahia export their products through the congested port of Santos, which in terms of inland transportation cost is nearly 50 percent more expensive than shipping to the closer port of Salvador. On the other hand, the port of Salvador lacks direct ocean shipments to import markets in Asia. The only way for cotton to be exported is via transhipments, which makes the total cost of ocean freight from this port twice the rates from the port of Santos. In lieu of this situation, improvements in the port infrastructure with the purpose of attracting direct shipping lines has been proposed. Such improvements are expected to enhance the competitiveness of the port of Salvador. Hence, the main objective of this study component was to evaluate the effects of reducing the export cost of the port of Salvador to Asian markets by analyzing the effects of direct shipping lines. To perform this analysis, the model employed in Chapter II was utilized. Results focused on changes in Brazilian cotton export flows, changes in export levels, and producer revenues as well as competitiveness of other exporting countries.

The fourth chapter focuses on analyzing the impacts of the 2005 FMD outbreak on the Brazilian meat market for different levels of the industry (export, wholesale and farm). In this essay, the non-tariff barrier for trade is the imposition of an import ban by Russia on Brazilian meat exports. To achieve the study objectives, a vector error correction model (VECM) was estimated. To analyze and present the results of this time series estimation, directed acyclic graphs (DAGs) and historical decomposition of price innovations was used. Results quantified the impacts of the animal disease outbreak, along with Russian import ban, on prices of different meat types (beef, pork, and chicken) at different levels of the marketing channel (export, wholesale, and farm levels), price margin along the supply chain, and price interdependence in the system.

CHAPTER II

THE IMPACTS OF THE PANAMA CANAL EXPANSION ON WORLD COTTON TRADE

Introduction

U.S. Cotton Industry and Trade Overview

In the last two decades, the U.S. cotton sector has faced a number of challenges as domestic mill demand has declined and U.S. exports have increased. During the 1990s, for example, domestic mill demand accounted for about fifty percent of available cotton supplies. Due to the decrease in domestic textile production caused by cheap backhauls and competition from imported textile and apparel products, U.S. mill use dropped to 30 percent of cotton supply for 2000-2005 and has averaged less than 20 percent annually since then (FAS/USDA 2011). The resulting surplus forced the industry to look for alternative markets. Significant changes in the global market for cotton and cotton-based products, particularly an increase in export demand, have provided overseas markets for U.S. cotton. As a result, U.S. cotton exports rose to 17.7 million bales in 2005/06, more than triple the levels of a decade earlier, before settling at about 13 million bales in recent years. This large and rapid increase in exports made the U.S. the largest supplier of cotton to the world market, with an export forecast that will account for 41 percent of world trade in 2010/2011 (FAS/USDA 2011).

The major final destination for U.S. cotton is China. China has emerged as the world's largest cotton importer, creating a strong, but somewhat volatile market for U.S.

cotton. In 2010, about 31 percent of all world cotton exports went to China (FAS/USDA 2011). The United States is responsible for about 40 percent of China's total cotton imports, representing 26 percent of U.S. cotton production. China has been the leading market for U.S. cotton since 2003 and imported 4.9 million bales in 2010, down significantly from 7.6 million bales in 2006, but up from 2.8 million bales in 2009. Turkey is currently the second leading export market for U.S. cotton, importing 2.1 million bales during 2010, down from a peak of 2.7 million bales in 2007, but up from 1.6 million bales in 2008 and 1.8 million bales in 2009 (WISERTrade 2010).

Panama Canal Expansion (PCE) and the U.S. Cotton Industry

The U.S. cotton industry is highly dependent on foreign markets. It is important for the U.S. industry to remain competitive with foreign suppliers such as Brazil, India and Uzbekistan. One of the major factors that will affect the efficiency, distribution and competitiveness of U.S. cotton will be the expansion of the Panama Canal. With sea freight the fastest growing mode of transportation, the number and size of vessels that are able to pass through the Canal will increase after the expansion is completed in 2014. The new Panama Canal locks system will be equipped to handle post-Panamax vessels, up to 12,600 twenty-foot equivalent units (TEU) for containers, compared to a present maximum vessel size of 4,400 TEU (Panamax).

This expansion is necessary not only to accommodate growing commerce, but also because post-Panamax vessels are forecast to account for nearly 25 percent of cargo vessel capacity by 2012 and already account for 35 percent of all vessels carrying cargo worldwide (ACP 2007). The PCE will likely have a role in relieving U.S. West Coast congestion on routes to Asia and potentially increase cotton shipments from the U.S. Gulf and South Atlantic ports to China and other Asian destinations. Drewry Supply Chain Consultants, a maritime industry research firm, projects that the West Coast ports will see increased competition from the post-expansion Panama Canal and noted that the East Coast and Gulf Coast ports could seize up to 25 percent of the traffic coming into the West Coast (CanagaRetna 2010). In addition, U.S. ports have experienced a 156% increase in post-Panamax vessel calls over the past five years, increasing the demand for service of larger vessels (USDOT 2009).

Panama Canal expansion has the potential to increase U.S. cotton exports as the expansion takes place. In 2010, approximately 1.34 million bales of the total U.S. cotton exports originated in the ports of Norfolk, Charleston, and Savannah with final destination East Asia (WISERTrade 2010). Since historically only 6 percent of the total U.S. exports to East Asian countries transited the Suez Canal (Salin 2010), one can conclude that most of these 1.34 million bales cotton exports from the top three Atlantic ports (Norfolk, Charleston, and Savannah) to East Asian countries were via the Panama Canal. This accounts to nearly 10 percent of the total U.S. cotton exports, which were 14 million bales for the 2010 calendar year (WISERTrade 2010).

In addition, due to the present lack of capacity at the Panama Canal to handle post-Panamax vessels, U.S. cotton exports were shipped via Panamax vessels. Therefore, while yet to be verified empirically, as the canal is expanded and post-Panamax vessels are capable of transiting the canal, significant additional volume of U.S. cotton is expected to be shipped via Gulf Coast and East Coast ports to China and the Far East after 2014.[1]

However, it is important to consider the potential of the Panama Canal route after the expansion. First, the effects of PCE on cost structure of operating containership vessels are evaluated. According to Rodrigue (2010) a standard Panamax (4,000 TEUs) container ship has annual operating costs of about $2,314/TEU. Meanwhile, post-Panamax (10,000 TEUs) vessels have the potential to reduce annual operating costs by up to $1,450/TEU. So, in terms of cost structure, the expansion of the Panama Canal will enable maritime shippers to reduce all-water costs by approximately $860/TEU, or 37 percent. Therefore, the economies of scale, which larger ships offer to maritime companies, will be one economic benefit of the PCE.

Another important factor for maritime shippers is the transit time between origin and final destination. When the all-water route via the Panama Canal is compared to the intermodal option (rail to West Coast ports) to a common final destination[2], the former has an average transit time of between 21.6 and 25 days, which is approximately 5 to 7 days longer than the latter (Salin 2010; Rodrigue 2010). Estimates indicate that the all-water route maritime cost is about $490/TEU less than the intermodal option (Ashar 2009). This indicates that the cost differential in term of dollars per TEU corresponds to

[1] This in large part, however, will depend on the expansion of the East coast ports to handle post-Panamax vessels. While East Coast ports such as Savannah, Charleston and Norfolk are in position to benefit initially from the expansion of post-Panamax vessel trade, the amount of additional cargo that may be handled is uncertain until improvements are made in capacity and water depth (CanagaRetna 2010).
[2] Considering the same origin (East Coast, e.g. Savannah port) and destination (East Asia, e.g. Shanghai port, China)

cost savings of \$70-\$75/TEU/day[3]. As the Panama Canal is expanded, this cost savings is expected to increase to the range of \$100-\$125/TEU/day (Ashar 2009), which is equal to a cost of differential of at least \$700/TEU. This implies that the PCE is expected to reduce maritime cost by at least \$210/TEU for the East Coast ports via the Canal to East Asia (\$700/TEU - \$490/TEU = \$210/TEU).

This possible outcome must be cautiously analyzed since the tolls charged by the Panama Canal Authority could reduce part of the significant gains of the expansion. There are reports that the canal administration has substantially increased tolls from \$40/TEU in 2006 to \$72/TEU in 2009, which represents a rise of 80 percent (Ashar 2009). This indicates that the toll increase has already offset nearly one-third of the potential gains of the expansion (\$72/TEU of \$210/TEU). The after toll potential savings is equal to nearly \$140/TEU which gives a new cost differential of \$90/TEU/day (\$630/TEU/7 days) instead of the pre-toll premium of \$100/TEU/day (\$700/TEU/7 days). In summary, taking into account the cost structure, transit time, and the Panama Canal tolls, when compared to the intermodal option, the PCE is expected to reduce maritime costs for shipments from the East Coast ports (e.g. Savannah port) to East Asia (China) by about \$140/TEU. This reduction in maritime costs represents 28 percent of the current total cost of \$490/TEU. Overall, the PCE is expected to be a cost-effective export route for U.S. cotton originated from the East Coast ports to Asian importing countries.

[3] By dividing the values between the range of \$490-\$500/TEU by the range of 5 – 7 days, one can get the \$70-\$75/TEU/day.

Study Objectives and Procedures

Main Objectives

The main objectives of this study are: (i) to assess the impact of the PCE on the U.S. cotton industry by examining U.S. cotton export flows by final destination, changes in export levels, and warehouse revenues and (ii) to evaluate the effects of PCE on the global cotton distribution and competitiveness by focusing on competing country exports and producer revenues.

Procedures

To accomplish the main objectives, three scenarios are examined. The first scenario evaluates the effects of a small reduction (10 percent) in ocean freight rates for vessels originating from the U.S. Gulf and South Atlantic ports to Asian and Pacific countries due to the PCE. The second scenario assumes a larger reduction (28 percent) in ocean freight rates for the same origins and destinations. Such reduction takes into account the total savings generated by the PCE, when compared to the intermodal option[4]. Last, due to a responsive measure to offset decrease in competitiveness with respect to the Gulf and South Atlantic ports, the third scenario goes one step ahead and introduces a 10 percent reduction in ocean freight rates from West Coast ports (Los Angeles-Long Beach) to Asian and Pacific countries along with the 28 percent reduction of scenario two. In other words, scenario three emulates a situation where the West

[4] The PCE is expected to reduce maritime costs for shipments from the East Coast ports to East Asia by about $140/TEU. This reduction in maritime costs represents 28 percent of the current total cost of $490/TEU.

Coast and Gulf and East ports would compete between themselves to attract more vessels and, hence, enhance their capabilities to export more cotton.

Methodology

The analysis is performed with a spatial, intertemporal equilibrium model of the international cotton industry that includes substantial detail on domestic and international transportation. A base model representing the international cotton industry is estimated for the 2008/09 market year and used for comparison for all (one, two and three). For more details on the methodology, data and validation, refer to Appendix A.

The effects of the PCE were determined by solving a base model then adjusting the appropriate parameters (ocean freight rates), obtaining the solution to the model, and contrasting these results with the base model. The lower ocean freight rates were incorporated into the model by reducing ship rates on routes that link U.S. Gulf and Atlantic ports with foreign import demand regions located in the Pacific Ocean. The model solution representing lower ocean freight rates was contrasted with the base model solution to estimate the impacts on U.S. cotton flows, export levels, and warehouse price and revenues. Similarly, impacts on the competing countries were based on export levels, prices, and producer revenues. Similar approach was adopted for the analysis in scenario three.

Results

The first scenario to be analyzed was a reduction of 10 percent in ocean freight rates for vessels originating from the U.S. Gulf and South Atlantic ports to Asian and Pacific countries. The second scenario analyzed a 28 percent reduction in ocean freight rates for the same origins and destinations. Scenario three introduced a 10 percent reduction in ocean freight rates from West Coast ports to Asian and Pacific countries along with the modifications used in scenario two.

Effects on Flow Patterns and Exports

Decreasing the ocean freight rate from U.S. Gulf and Atlantic ports (Savannah, Norfolk, New Orleans, Houston, Charleston, Gulfport, and Mobile) to Asian and Pacific importing countries (China, Indonesia, Thailand, Bangladesh, Pakistan, Honk Kong, Japan, South Korea, Taiwan) due to PCE is expected to increase cotton exports via the Panama Canal. U.S. Gulf and Atlantic ports are expected to increase their share of total U.S. cotton exports. Pacific Coast ports, however, are expected to experience a reduction in exports.

A 10 percent reduction in ocean freight rates for the routes that travel via the Panama Canal causes the model to increase U.S. cotton exports via the Gulf and Atlantic ports except Gulfport, Mississippi, and Mobile, Alabama (Table 1). The absolute change in exports was the largest for the port of Savannah, Georgia, followed by the port of Houston, Texas. The increase from 2,236.7 to 3,907.5 thousand bales (74.7 percent increase) in exports positioned the port of Savannah as the leading cotton exporting port passing the Long Beach – Los Angeles ports (down to 3,697.2 from 6,163.3 thousand bales). The total relative change for the U.S. Gulf and Atlantic ports was equivalent to a positive 50.5 percent, which in absolute value this is equal to an increase of 2,548.8 thousand bales.

Table 1. Estimated Change in U.S. Cotton Flows Resulting from Reducing Ocean Freight Rates Due to the Panama Canal Expansion (1,000 480 lbs. bales)

Port	Base Model	Scenario 1	Change (%)	Scenario 2	Change (%)	Scenario 3	Change (%)
Savannah	2,236.7	3,907.5	74.7	4,450.9	99.0	3,903.3	74.5
Houston	1,551.8	2,046.2	31.8	2,434.5	56.9	1,795.6	15.7
New Orleans	514.7	724.2	40.7	1,197.8	132.7	1,144.7	122.4
Charleston	338.3	534.3	57.9	875.6	158.8	577.9	70.8
Norfolk	282.2	333.5	18.2	617.9	118.9	579.9	105.5
Gulfport	45.3	20.9	-54.9	20.5	-54.9	0.0	-100.0
Mobile	72.8	24.0	-67.0	0.0	-100.0	0.0	-100.0
Total U.S. Gulf and Atlantic	*5,041.8*	*7,590.6*	*50.5*	*9,597.2*	*90.3*	*8,001.4*	*58.7*
L.A.-Long Beach	6,163.3	3,697.2	-40.0	1,879.5	-69.5	3,827.7	-37.9
Oakland	343.8	343.6	-0.1	343.3	-0.1	45.4	-86.8
Total West Coast	*6,507.1*	*4,040.8*	*-37.9*	*2,222.9*	*-65.8*	*3,873.1*	*-40.4*
Laredo-El Paso	1,141.3	1,296.7	13.6	1,269.5	11.2	1,264.6	10.8
Hidalgo-Brownsville	340.6	176.6	-48.1	179.2	-47.4	179.6	-47.3
Total U.S.-Mexico Border Ports	*1,481.9*	*1,473.3*	*-0.6*	*1,448.7*	*-2.2*	*1,444.2*	*-2.5*
Total U.S. Ports	***13,030.8***	***13,104.7***	***0.6***	***13,268.8***	***1.8***	***13,318.7***	***2.2***

Note: Scenario 1 is 10 percent reduction in ocean freight rates from Gulf and Atlantic Ports. Scenario 2 is 28 percent reduction in ocean freight rates from Gulf and Atlantic Ports. Scenario 3 is Scenario 2 plus 10 percent reduction in ocean freight rates from Los Angeles-Long Beach ports.

Furthermore, the share of U.S. cotton exports through the Panama Canal increased from 38.7 percent (5,041.8 thousand bales) to 57.9 percent (7,590.6 thousand bales) after the expansion. West Coast ports decreased shipments considerably by reducing total exports approximately 2,466.3 thousand bales. The route via the intermodal option (rail to West Coast ports) reduces its share of total U.S. cotton exports by nearly 20 percentage points (from 49.9 percent to 30.8 percent). The largest decrease in exports occurs in the Long Beach – Los Angeles ports, going from 6,163.3 to 3,697.2 thousand bales, in relative terms, this is equivalent to a decline of approximately 40 percent.

As expected, cotton flow patterns resulting from the analysis of scenario two (28 percent ocean freight rate reduction) are similar to scenario one in direction, but larger in magnitude. The ports of Savannah and Houston increased cotton exports to 4,450.9 and 2,434.5 thousand bales, respectively (Table 1). An important point is that the port of Houston becomes the nation's second largest cotton exporter. The ports of New Orleans, Charleston, and Norfolk more than double their exports with increases up to 158.8 percent for Charleston. Total exports from the Gulf and Atlantic ports rose to 9,597.2 thousand bales from 5,041.8 thousand bales for the base model (an increase of 90.3 percent). Such increases in exports via the Gulf and Atlantic ports indicate that the PCE could increase the canal's share in total U.S. cotton exports to 72.3 percent from 38.7 percent in the base model.

West Coast ports undergo a decline in exports, going from 6,507.1 thousand bales to 2,222.9 thousand bales. Another key observation is that the intermodal option reduces its share of total U.S. cotton exports. Only 16.7 percent of total U.S. cotton exports are shipped via the West Coast ports, which is equal to a 33.2 percentage points decrease when compared to the base model (from 49.9 percent to 16.7 percent). The largest factor for such reduction is the decrease in exports via the Long Beach – Los Angeles ports, down to 1,879.5 thousand bales which places LA-LB as the third most important port for the U.S. cotton exports (behind the ports of Savannah and Houston).

In scenario 3, after introducing the 10 reduction in ocean freight rates from the ports of Los Angeles-Long Beach, the ports of Savannah and Houston both lose competitiveness when compared to scenario two but their export levels were very similar to scenario one. The main reason is that the increase in competitiveness by the Los Angeles-Long Beach ports attracts more shipments as their exports go to 3,827.7 thousand bales, which is greater than the results under both scenarios one and two. However, when contrasted to the base model, the total exports from the West Coast ports are still lower than the base model (decrease of 40.4 percent). It is interesting to note that the Oakland port also loses competitiveness to their Californian counterpart as its exports are reduced to 45.4 thousand bales (a negative 86.8 percent relative change). Overall, similarly to the other two scenarios, the participation of the U.S. Gulf and Atlantic ports is expected to increase (positive 58.7 percent), with the port of Savannah as the top cotton exporting port.

Although cotton flows are altered with lower ocean freights for the Atlantic and Gulf ports, total U.S. cotton exports are only modestly impacted. For the 10 percent freight rate reduction scenario, the increase in total U.S. cotton exports were equal to

73.9 thousand bales which is equivalent to a 0.6 percent increase (Table 1). As for the second scenario (28 percent reduction), a greater reduction in ocean freight rates increased total U.S. cotton exports. But this also causes only a modest increase in relative terms (1.8 percent), with total U.S. cotton exports rising to 13,268.8 thousand bales, up by 238.0 thousand bales. The largest increase in total U.S. exports is found in scenario three. This result was expected since with more competition between ports, the cotton exporting agents gain the most as they have less costly shipping options. The total cotton exports for this scenario was equal to 13,318.7 thousand bales, which is equal to a growth of 287.9 thousand bales when compared to the base model (2.2 percent increase).

U.S. Warehouse Prices and Revenues

As the PCE occurs, there would be an anticipated reduction in ocean freight rates which corresponds to a decrease in transportation costs linking the U.S. producers (warehouse level) to importers in the Asian and Pacific importing countries. This increases price and production in U.S. regions that ship via the Panama Canal. For example, in scenario one, U.S. cotton-producing regions that ship via the Panama Canal experience an increase in price that ranges from $2.95/bale (Texas) to $7.41/bale (Georgia) (Table 2). Most of the U.S. cotton production regions experienced an increase in price. However, in scenario one, the states of Arizona, California and Oklahoma undergo prices decrease as the PCE occurs. Prices decreased modestly for those U.S. regions since exports are diverted to Asian and Pacific importing countries via the West Coast ports.

Table 2. Estimated Annual Increase in U.S. Cotton Warehouse Revenues (million dollars) and Warehouse Price ($/bale) Resulting from Reduction in Ocean Freight Rates Due to Panama Canal Expansion

State	Scenario 1		Scenario 2		Scenario 3	
	Revenue	Price	Revenue	Price	Revenue	Price
Texas	$22.37	$2.95	$85.73	$11.42	$109.76	$14.04
Georgia	$15.56	$7.41	$44.46	$21.03	$45.22	$21.39
Tennessee	$13.43	$6.31	$42.31	$19.68	$43.22	$20.15
Arkansas	$9.73	$5.99	$30.04	$18.36	$31.67	$19.35
Mississippi	$7.26	$6.39	$21.78	$18.99	$22.19	$19.35
North Carolina	$7.05	$6.51	$23.84	$21.78	$23.58	$21.56
Missouri	$4.45	$5.70	$13.61	$17.32	$13.61	$19.01
South Carolina	$3.67	$7.40	$11.29	$22.60	$11.09	$22.18
Louisiana	$3.16	$6.78	$8.83	$18.82	$9.02	$19.22
Alabama	$2.84	$5.43	$8.79	$16.66	$9.33	$17.70
Virginia	$1.25	$5.94	$4.64	$21.89	$4.62	$21.81
Florida	$0.55	$7.23	$1.58	$20.69	$1.61	$21.11
New Mexico	$0.22	$4.73	$0.78	$16.26	$0.87	$18.04
Kansas	$0.05	$5.70	$0.14	$17.27	$0.15	$19.01
Oklahoma	$0.01	$(0.03)	$3.12	$11.78	$3.25	$12.28
Arizona	$(0.13)	$(0.29)	$(0.45)	$(1.00)	$2.99	$6.65
California	$(0.31)	$(0.26)	$(1.14)	$(0.94)	$4.78	$3.61
U.S. Total	***$91.15***	***$4.93***	***$299.36***	***$16.04***	***$336.97***	***$17.44***

Note: Scenario 1 is 10 percent reduction in ocean freight rates from Gulf and Atlantic Ports. Scenario 2 is 28 percent reduction in ocean freight rates from Gulf and Atlantic Ports. Scenario 3 is Scenario 2 plus 10 percent reduction in ocean freight rates from Los Angeles-Long Beach ports.

As noted in Table 2, the state with the largest gain in revenue due to the PCE was Texas. For scenario one, the increase in warehouse revenues for that state was equal to $22.37 million. Taking into account the relatively small change in price that occurs in Texas ($2.95/bale) when compared to the other states, the main reason for such increase in warehouse revenue is the an expansion of cotton production[5]. Georgia and Tennessee had significant gains in warehouse revenues as well with $15.56 million and $13.43 million, respectively. The gain for Georgia is relevant to discuss since the port of Savannah is located in that state and local cotton warehouses were the beneficiaries of this expansion. Although the impacts were relatively small, as expected, the states that depend heavily on West Coast ports experienced a decline in warehouse revenues (Arizona, California and Oklahoma).

Figure 1 below shows the change in producer (warehouse level) revenue by crop reporting districts (CRD). Due to its large producing area, the state of Texas accrues the most benefits of the canal expansion whereas the gains in warehouse revenue ranged from $0.12 million (CRD number 81, Kennedy county area) to $5.54 million (CRD number 12, Lubbock county area). The state of Georgia comes in second as the CRDs of number 80 (Brooks county area) and 70 (Lee county area) increased their warehouse revenue by $6.49 and $5.14 million, respectively. With a gain of $11.96 million, the CRD of number 10, located in the state of Tennessee (Memphis area), is indicated as the largest beneficiary with respect to warehouse revenue. As it was expected, although relatively small losses, the CRDs located in the state of California is shown to reduce their warehouse revenues.

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[5] According to NASS (2011), cotton production for the state of Texas was approximately 6.3 million bales for the 2008/09 market year, which represented 40 percent of U.S. production.

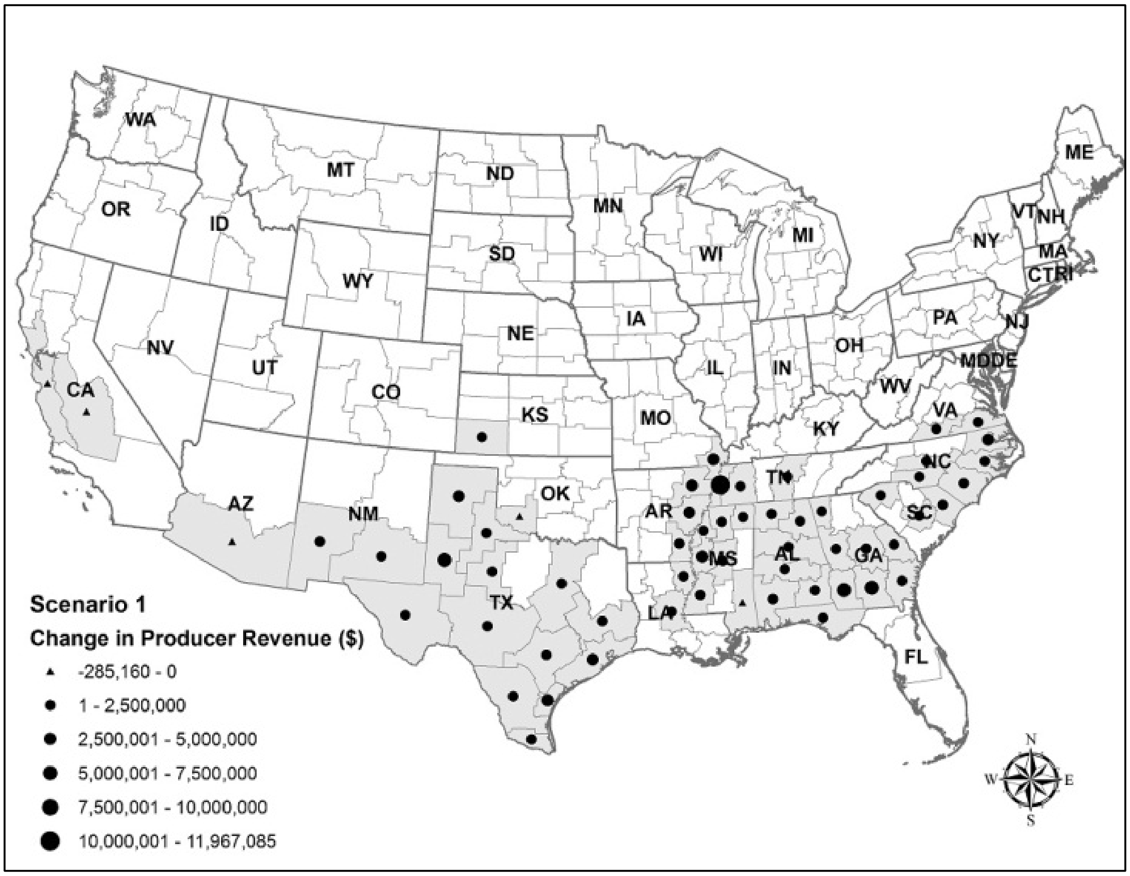

Figure 1. Model-estimated changes in cotton producer (warehouse level) revenues by crop reporting districts for scenario 1
Note: Scenario 1 is 10 percent reduction in ocean freight rates from Gulf and Atlantic Ports.

In scenario two, the 28 percent reduction in ocean freight rates from Gulf and Atlantic ports to Asian and Pacific markets is estimated to increase annual warehouse revenues for all cotton producing states except California and Arizona (Table 2). The state with the largest gain is Texas, with an increase in warehouse revenue equal to $85.73 million. As discussed earlier, Texas is a special case since most of the gain in revenue is due to increased cotton production (up 69.6 thousand bales) and not higher prices. Other states underwent a larger increase in price, but there was less impact on warehouse revenues. For example, with respect to prices, cotton warehouses in South Carolina and Virginia were the greatest beneficiaries of higher prices attributed to the PCE, with increases of $22.60/bale and $21.89/bale, respectively. However, because production in those two states is relatively small compared to the others, warehouse revenues were less when compared to Texas and Georgia. Cotton warehouses in Oklahoma accrue gains in warehouse revenues rather than losses. This occurs because part of the Oklahoma cotton shipments were routed via the port of Houston rather than the intermodal route. Revenue losses to warehouses in California were estimated at $1.14 million which is relatively small when compared to the gains by other states.

As Figure 2 below indicates, the CRDs located in the state of Texas followed by the states of Georgia and Tennessee experience the largest increases in revenues as cotton is mostly shipped through the ports located in the Gulf and East Atlantic. For the state of Texas, the CRD of number 12 (Lubbock area) is shown to gain the most for that state as its revenue increases $21.3 million. As in scenario one, the CRDs of number 80 (Brooks county area) and 70 (Lee county area) in the state of Georgia represent most of the increase for that state as their revenue increase by $18.64 and $14.1 million, respectively. Similarly to scenario one, for the state of Tennessee, the CRD of number 10 (Memphis area) is the largest gainer of the canal expansion, with a warehouse revenue increase of $37.83 million. As for the CRDs located in California and Arizona, the decreases in warehouse revenue were projected to be greater than the estimates from scenario one; however, the estimated losses in warehouse revenues (less than $1.2 million) were comparatively lower than the gains in other states.

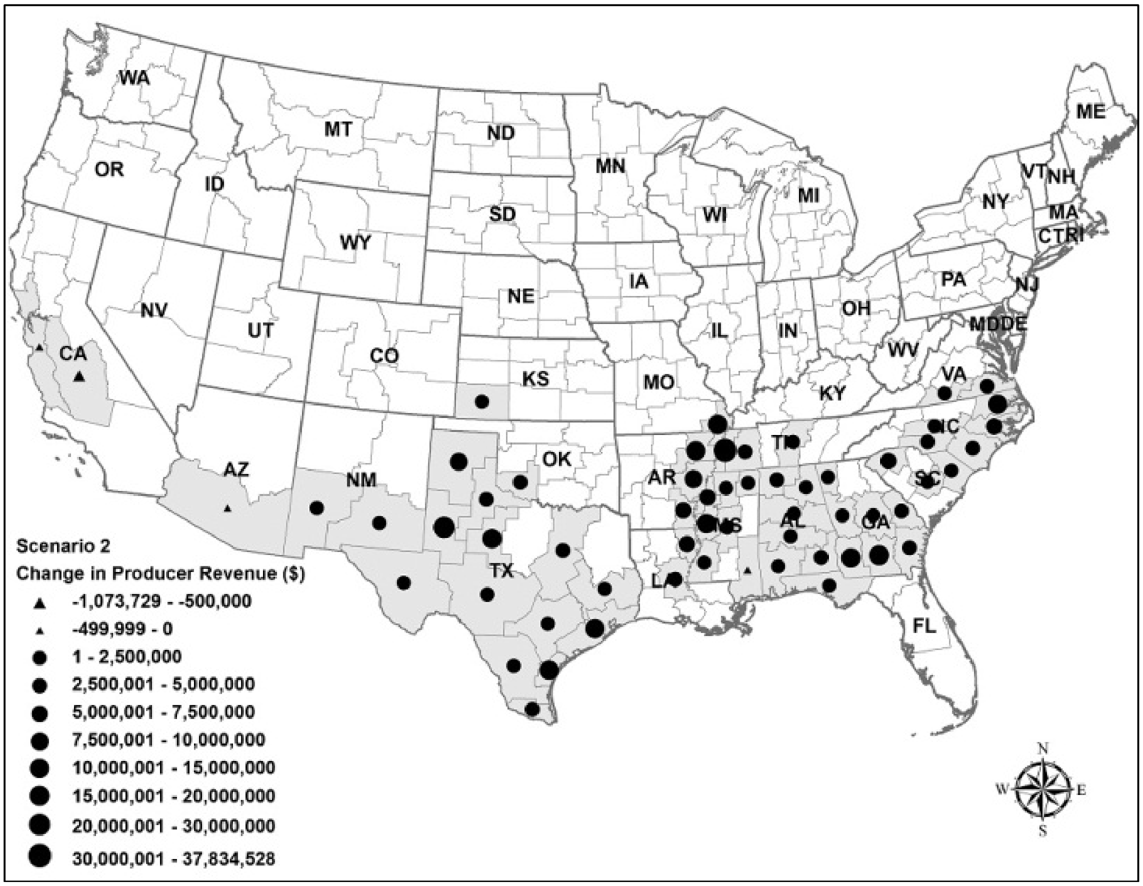

Figure 2. Model-estimated changes in cotton producer (warehouse level) revenues by crop reporting districts for scenario 2
Note: Scenario 2 is 28 percent reduction in ocean freight rates from Gulf and Atlantic Ports.

Scenario three indicates that Texas is the state with the largest increase in warehouse revenue (Table 2). With the 10 percent reduction in ocean freight rates from the Los Angeles-Long Beach ports to Asian countries, the state of Texas is shown to have a significant increase in gains when compared to other states. With an increase in warehouse revenue of $109.76 million, this represents a 28.0 percent greater gain (up $24.03 million) than the gains estimated in scenario two ($85.73 million). On the other hand, when compared to scenario two, the increases in warehouse revenue for the states of Georgia and Tennessee were only $0.76 and $0.91 million, respectively. This indicates that both the PCE and improvements in the Los Angeles-Long Beach ports would substantially enhance the exporting cotton industry of Texas. In contrast to the other two scenarios, all states were shown to have an increase in warehouse revenue. The states of Arizona and California had increases in warehouse revenue of $2.99 and 4.78 million, respectively.

Similarly to the previous two scenarios, the CRDs located in the state of Texas followed by the states of Georgia and Tennessee experience the largest increases in revenues (Figure 3). For the state of Texas, the CRD of number 12 (Lubbock area) is shown to increase its warehouse revenue by $39.03 million, which makes it the largest gain in the nation passing the CRD of number 10 in Tennessee. The increase in warehouse revenue for the CRD 10 (Memphis area) was only $0.12 million greater than the gains from scenario two (from $37.83 to $37.95 million). As in scenario one and two, the CRDs of number 80 (Brooks county area) and 70 (Lee county area) in the state of Georgia represent most of the increase for that state as their revenue increase by $18.96 and $15.04 million, respectively. As previously mentioned, in contrast to the other two scenarios, the states of Arizona and California are presented to have net increases in warehouse revenue.

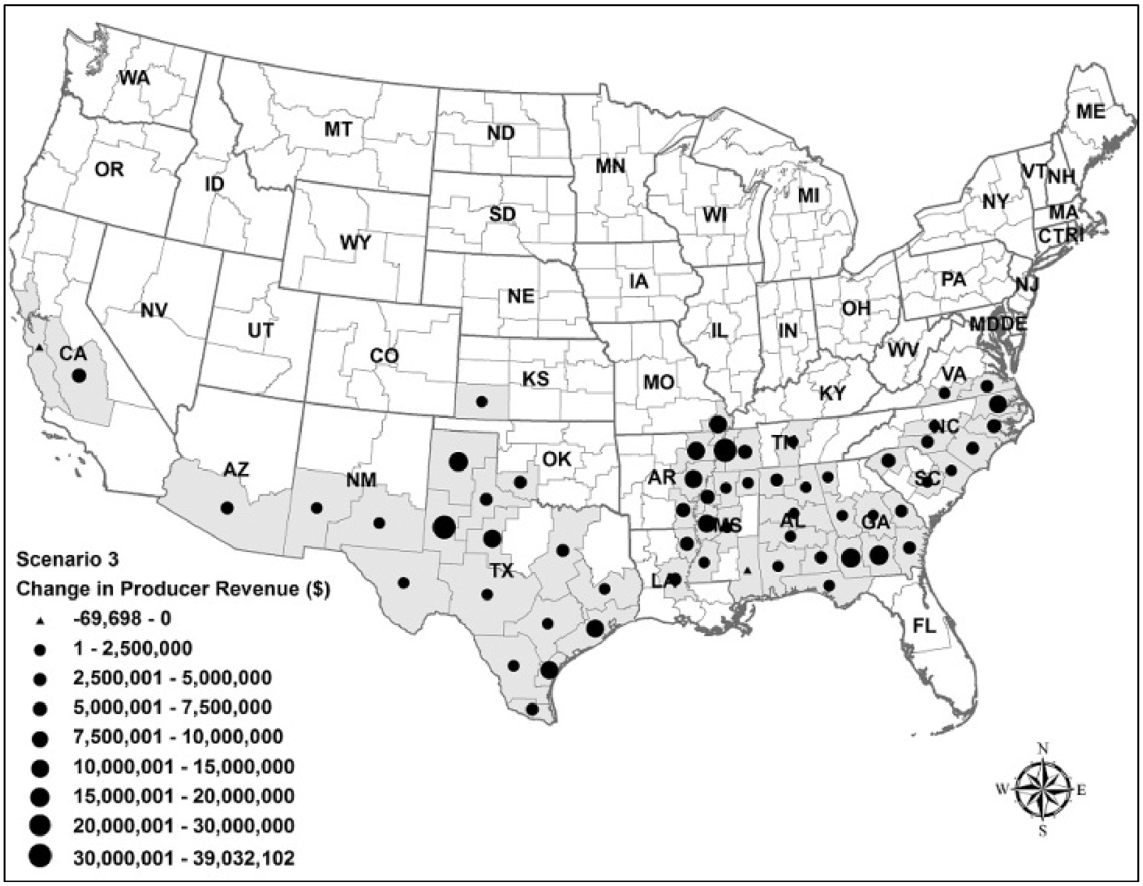

Figure 3. Model-estimated changes in cotton producer (warehouse level) revenues by crop reporting districts for scenario 3
Note: Scenario 3 is Scenario 2 plus 10 percent reduction in ocean freight rates from Los Angeles-Long Beach ports.

As Table 2 shows, the warehouse revenue for U.S. cotton increased for all scenarios. A 10 percent reduction in ocean freight rates from Gulf and Atlantic ports to Asian and Pacific importing countries is projected to increase annual cotton warehouse revenues by approximately $91.15 million. In relative terms, for this scenario, the total increase in warehouse revenue for the U.S. is equal to 2.21 percent. For scenario two, the 28 percent rate reduction causes a greater positive impact on the warehouse revenue for the U.S. The revenue gains to cotton warehouses are larger when the savings in cost due to the PCE is fully considered. Hence, the total increase in U.S. cotton warehouse revenue is equal to $299.36 million, which, in relative terms, is equivalent to an increase of 7.27 percent. Overall, the largest gain in warehouse revenue for the entire country takes place in scenario three. As it was expected, as both the Los Angeles-Long Beach ports and Gulf and Atlantic ports enhance their competitiveness to export cotton, the total increase in warehouse revenue is equal to $336.97 million, which is, in relative terms, a rise of 8.19 percent.

U.S. Cotton Competitiveness in the World Market

The impact of the PCE on the competitiveness of exporting countries is evaluated with the focus on exports, prices, and revenue. Table 3 presents the results of the scenarios that were analyzed. All scenarios indicate that India, Brazil, Sub-Sahara Africa, Uzbekistan and the Rest of the World Exporters experience lower exports, prices, and revenues attributed to PCE. Among these countries/regions, the Rest of the World Exporters were the most affected. Individual and large cotton exporting competitors, such as Brazil and India, lose competitiveness in global cotton trade and losses occur within the national industries. For example, in scenario three, exports, price, and producer revenue in Brazil are estimated to decrease by 37.76 thousand bales, $1.39/bale, and $12.36 million, respectively. However, for all analyzed scenarios, these losses in exports, prices, and revenues are very modest in relative terms. For example, in scenario three, Brazilian exports, price, and revenue are reduced by 1.46, 0.59, and 2.04 percent, respectively.

Table 3. Estimated Effects of Panama Canal Expansion on Exports, Prices, and Revenue for Selected Exporting Countries

Exports (1,000 480 lbs. bales)	Scenario 1	Scenario 2	Scenario 3
United States	73.90	238.00	287.90
India	-9.14	-30.38	-36.91
Brazil	-10.71	-29.02	-37.76
Australia	-0.60	-1.92	-2.33
Sub-Sahara Africa	-2.26	-7.51	-9.13
Uzbekistan	-1.94	-6.44	-7.83
Rest of the World	-9.32	-30.96	-37.62
Prices ($/bale)	**Scenario 1**	**Scenario 2**	**Scenario 3**
United States	$4.93	$16.04	$17.44
India	($0.29)	($0.96)	($1.16)
Brazil	($0.40)	($1.07)	($1.39)
Australia	($0.29)	($0.96)	($1.16)
Sub-Sahara Africa	($0.29)	($0.96)	($1.16)
Uzbekistan	($0.29)	($0.96)	($1.16)
Rest of the World	($0.29)	($0.96)	($1.16)
Revenues (million $)	**Scenario 1**	**Scenario 2**	**Scenario 3**
United States	$91.15	$299.36	$336.97
India	($3.48)	($11.54)	($14.00)
Brazil	($3.53)	($9.51)	($12.36)
Australia	($0.54)	($1.81)	($2.19)
Sub-Sahara Africa	($1.60)	($5.30)	($6.42)
Uzbekistan	($1.34)	($4.45)	($5.38)
Rest of the World	($3.82)	($12.68)	($15.37)

Note: Scenario 1 is 10 percent reduction in ocean freight rates from Gulf and Atlantic Ports. Scenario 2 is 28 percent reduction in ocean freight rates from Gulf and Atlantic Ports. Scenario 3 is Scenario 2 plus 10 percent reduction in ocean freight rates from Los Angeles-Long Beach ports.

Due to the PCE and its potential reduction in ocean freight rates for the Gulf and Atlantic ports to Asian and Pacific markets, the U.S. gains competitiveness through increases in exports, prices, and warehouse revenue (Table 3). For scenarios one and two, the increase in exports is equal to 73.90 and 238.00 thousand bales, respectively.

Cotton price and warehouse revenues also increase in both scenarios. There are greater impacts from scenario two due to the larger reduction in ocean freight rates. With a 28 percent reduction in ocean freight rates, the cotton price and warehouse revenue increase to $16.04/bale and $299.36 million, respectively. Nonetheless, the cotton exporting industry of the U.S. is better off in scenario three. As the Los Angeles-Long Beach ports improve their efficiency to compete with the Gulf and Atlantic ports, exports, price, and warehouse revenue in the U.S. are estimated to increase by 287.90 thousand bales, $17.44/bale, and $336.97 million, respectively.

Conclusions

By 2014, the Panama Canal Authority is expected to complete expansion of the canal. U.S. cotton producers are expected to benefit economically from PCE since the expansion will reduce ocean freight rates along routes for selected U.S. ports (Gulf and Atlantic ports) to final destinations in Asian and Pacific importing countries. A spatial price equilibrium model of the international cotton sector was developed and used to evaluate the effects of the PCE.

Three scenarios were analyzed: (i) 10 percent reduction in ocean freight rates from shipments originated in the U.S. Gulf and Atlantic ports with final destination the Asian and Pacific importing countries; (ii) 28 percent reduction in ocean freight rates for scenario one; and (iii) scenario two plus 10 percent reduction in ocean freight rates from Los Angeles-Long Beach ports to Asian and Pacific importing countries. For the 10 percent reduction scenario, the cotton flows and exports had substantial changes. Cotton exports to Gulf and Atlantic ports increased 50.5 percent with the port of Savannah leading the way with an increase of 74.7 percent. The Long Beach – Los Angeles ports decreased its participation in total U.S. cotton exports considerably, down almost 40 percent. Overall, in scenario one, the percentage of U.S. cotton exports via the Panama Canal relative to the total U.S. cotton exports increased from 38.68 to 57.88 percent. Further, total U.S. cotton exports are expected to increase by 73.9 thousand bales, which is equivalent to a 0.6 percent rise. A 10 percent reduction in ocean freight rates caused by the PCE is projected to annually increase revenues of U.S. cotton warehouses by $91.15 million, with the state of Texas accruing the most gains ($22.37 million) followed by the states of Georgia ($15.56 million) and Tennessee ($13.43 million). With respect to the world cotton trade, the modest increase in exports due to the PCE made the U.S. cotton industry more competitive. On the other hand, all competing export countries had very modest decreases in their exports as well as prices and revenues with individual countries such as Brazil and India experiencing the largest reduction.

The 28 percent ocean freight rate reduction results in a 90.3 percent increase in exports through the U.S. Gulf and Atlantic ports. The largest recipient for this increase is the port of Savannah. Exports increased from 2,236.7 thousand bales to 4,550.9 thousand bales annually. Interesting to note that in this scenario the port of Houston (2,434.5 thousand bales) passes the ports of Long Beach – Los Angeles (1,879.5 thousand bales) in cotton exports and becomes the second largest exporter. Taking into account all these changes, the participation of the Panama Canal as an exporting route increased; the percentage of U.S. cotton exports via the Panama Canal relative to the total U.S. cotton exports increased from 38.68 to 72.31 percent. On the other hand, the rail to West Coast ports route decreased its percentage relative to the total U.S. cotton exports to 14.16 percent.

As it is assumed that the ports of Long Beach – Los Angeles will take action and improve their competitiveness, a scenario is analyzed by introducing a 10 percent reduction in ocean freights from these ports to importing countries in Asia. Estimates of this scenario indicated that the ports of Savannah and Houston both lose competitiveness when compared to scenario two but their export levels were very similar to scenario one. However, when contrasted to the base model, the total exports from the West Coast ports are still lower than the base model (decrease of 40.4 percent). Overall, similarly to the other two scenarios, the participation of the U.S. Gulf and Atlantic ports is expected to increase (positive 58.7 percent), with the port of Savannah as the top cotton exporting port.

As expected, the total expected reduction scenario (28 percent) is projected to annually increase revenues of U.S. cotton warehouses by $299.36 million, an increase of 7.27 percent. Similarly to scenario one, the states of Texas ($85 million), Georgia ($44 million) and Tennessee ($42 million) are the greatest recipients of the expansion with respect to warehouse revenues. Additionally, the U.S. total cotton exports increase 238 thousand bales, which in relative terms is equal to a 1.8 percent rise. As for the scenario where the ports of Los Angeles-Long Beach improve their efficiency, with a rise of $336.97 million (up 8.19 percent) and 287.9 thousand bales (up 2.2 percent), respectively, the U.S. cotton warehouses are shown to benefit the most as the ports compete with each other. On the other hand, in all scenarios, all the competing exporting countries accrue decreases in exports, prices, and revenues.

In summary, the expansion of the Panama Canal is important for U.S. cotton exports. As the expansion is completed, the analysis indicates a shift in U.S. cotton export flows from West Coast ports to Gulf and Atlantic ports as well as an increase in exports and warehouse revenues. In addition, this study suggests that West Coast ports may not face large economic losses due to the canal expansion if improvements are implemented to increase the efficiency of these ports. As for other competing exporting countries, modest declines in exports, prices, and revenues are expected to occur.

CHAPTER III

THE POTENTIAL EFFECTS OF PORT IMPROVEMENTS IN BRAZIL ON THE WORLD COTTON MARKET

Introduction

Cotton Industry in Brazil

In the 18th century, cotton was introduced in Brazil in the Northeastern region of the country. As the Southeastern region of the country started to industrialize in late 1800's, the textile industry followed and eventually cotton cultivation was solidified in the states of São Paulo and Paraná[6]. In the early 1980's, the states of São Paulo and Paraná was shown to represent the majority of the Brazilian production (Figure 4).

[6] For a better understanding of the Brazilian map and its states, see Appendix B.

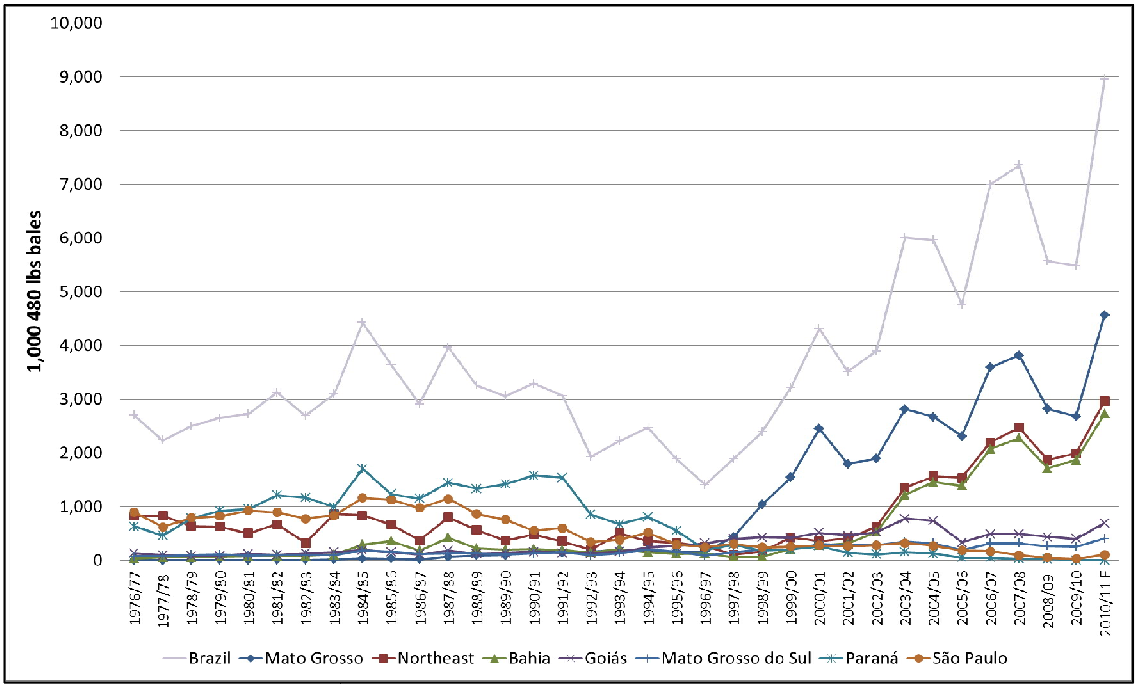

Figure 4. Historical series of cotton production by state and region, 1976/1977 – 2010/11
Source: Companhia Nacional de Abastecimento (CONAB/MAPA 2011a).

However, from 1987/88 to 1996/97, national cotton production decreased substantially from 4,000 to 1,500 thousand bales (Figure 4). According to Buainain and Batalha (2007), the principal factors for the decline were: (i) the boll weevil, especially in the Northeast; (ii) high production costs; (iii) low international prices; and (iv) less expensive cotton imports. Under these circumstances, cotton cultivation migrated to the *Cerrado*[7] region, more specifically to the states of Mato Grosso, Goiás, Mato Grosso do Sul and western region of the state of Bahia. The expansion of cotton production in the *Cerrado* was strongly affected by the following factors: (i) large scale production; (ii)

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

advanced technology with respect to planting and harvesting; (iii) local government support regarding research and development; and (iv), although small, investment in transportation infrastructure in these portions of the *Cerrado* (Buainain and Batalha 2007).

As noted in Figure 4, in the 1997/98 marketing year, cotton production for the state of Mato Grosso began to rise significantly. By 2000/01, the production share by the state of Mato Grosso reached 57 percent (2,450.6 thousand bales) of the Brazilian production (4,309.1 thousand bales). Three years later, the state of Bahia started to play a major role by increasing its cotton production to 1,218.2 thousand bales, which represents an increase of almost one million bales when compared to 2000/01. In 2009/10, these two states represented more than 80 percent (4,545.5 thousand bales) of the Brazilian production (5,480.9 thousand bales), with the state of Mato Grosso accounting for 50 percent (2,678.3 thousand bales). The remaining 20 percent of the current Brazilian cotton production is mostly represented by the states of Goiás (8 percent) and Mato Grosso do Sul (5 percent), which are also part of the *Cerrado* area. For the forecast of 2010/11, although production has decreased for two years in a row, Mato Grosso is expected to continue as the number one producing state (4,563.4 thousand bales) followed by Bahia (2,726.0 thousand bales), Goiás (693.1 thousand bales), and Mato Grosso do Sul (403.9 thousand bales). Overall, these four states will account for approximately 94 percent of the Brazilian cotton production, which is forecasted to be 8,951.4 thousand bales in 2010/11, an all-time high.

Concerning Brazilian cotton export value, according to the CONAB/MAPA (2011b), the cotton industry accounted for $0.82 billion, which represented 1.1 percent of Brazil's total agricultural export sales ($76.4 billion) in 2010. Although this value is small when compared to other commodities (i.e. soybeans)[8], the cotton export sales for 2011 are forecasted to be $1.3 billion, a 57 percent increase over the previous year.

According to the SECEX/MDIC (2011), South Asia and Southeast Asia are large importers of Brazilian cotton. Based on the average of the 2008 and 2009 calendar years of Brazilian cotton exports, Indonesia, South Korea, and Pakistan imported 502.9, 402.9, and 359.4 thousand bales, respectively, representing 53 percent of Brazil's total cotton exports (2,383.4 thousand bales) (Figure 5). The remaining cotton exports are evenly distributed with most of the exports having final destinations in the Southern and Southeastern parts of Asia. The only exception is the European Union, which accounted for 6 percent (nearly 150 thousand bales) of the export market.

[8] In 2010, the soybean complex (oilseed, meal, and oil) export value was nearly $17 billion, which is equal to 22 percent of the Brazilian total export value (CONAB/MAPA 2011b).

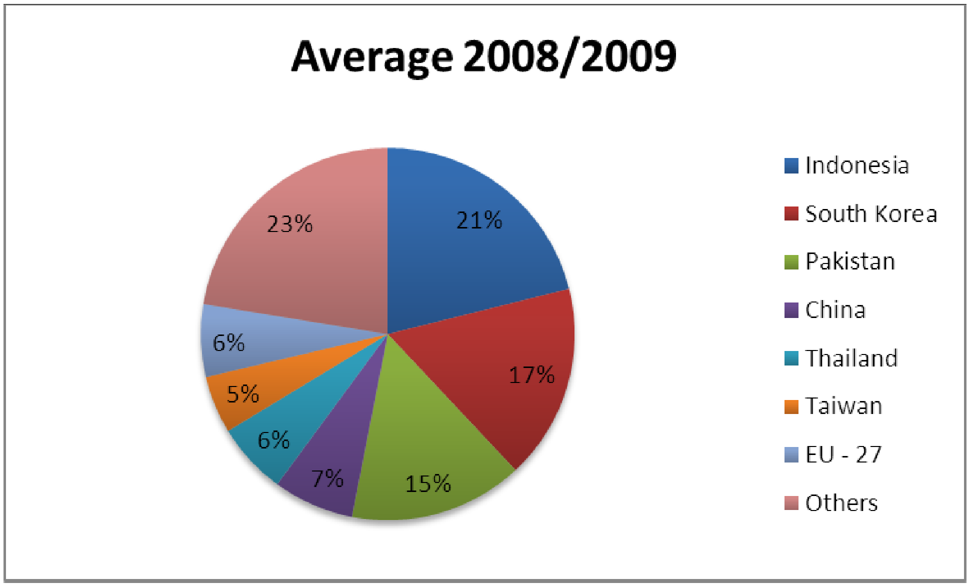

Figure 5. Share of final destination of Brazilian cotton exports, Average 2008/2009
Source: SECEX/MDIC (2011).

Based on the data from SECEX/MDIC (2011), Brazil's total cotton exports are disaggregated to state and region levels as shown in Table 4. Brazil's total cotton exports rose from 1,398.5 thousand bales in 2006 to 2,353.9 thousand bales in 2010. In 2008, the total quantity exported by Brazil reached a record level, which, according to the FAS/USDA (2011), placed Brazil as the third largest cotton exporter in the world behind the U.S. (13,261 thousand bales) and Uzbekistan (3,000 thousand bales). Furthermore, for the 2011/12 market year, the Brazilian total exports is forecasted to be 3,800 thousand bales, which will represent an increase of more than one million bales when compared to the 2010 calendar year.

Table 4. Cotton Exports by State/Region in Brazil (thousand bales), 2006 - 2010

State	2006	2007	2008	2009	2010
Mato Grosso	750.5	1,087.5	1,516.0	1,230.5	1,186.4
Bahia	445.0	586.6	584.8	708.9	819.9
Goiás	94.0	133.8	150.7	200.3	179.0
São Paulo	21.9	26.0	26.3	40.0	57.0
Mato Grosso do Sul	54.2	44.6	77.7	65.8	47.3
Maranhão	11.3	18.7	31.8	53.5	46.8
Minas Gerais	12.6	14.7	50.4	12.8	8.8
Subtotal	*1,389.7*	*1,912.2*	*2,438.0*	*2,312.0*	*2,345.5*
Rest of Brazil	8.7	9.5	9.7	7.0	8.3
Total	**1,398.5**	**1,921.7**	**2,447.7**	**2,319.0**	**2,353.9**

Source: SECEX/MDIC (2011).

Regarding the distribution of exports by state, from 2006 to 2010, the states of Mato Grosso, Bahia, and Goiás accounted for, on average, more than 90 percent of Brazil's total quantity exported (Table 4). The state of Mato Grosso average exports for the analyzed period was 1,154.2 thousand bales, a 55.3 percent share of total exports (2088.2 thousand bales). As for Bahia and Goiás, their participation with respect to the total exports was an average of 30.1 (629.1 thousand bales) and 7.2 (151.6 thousand bales) percent, respectively.

With respect to the cotton consumption (domestic mill), the main input for textile manufacturing is cotton, followed by man-made fibers (synthetic polyester, etc.). Of the total textile production, cotton fiber represents approximately 80 percent of the input (ABIT 2011). In general for the period 2005 to 2009, the cotton consumption was somewhat evenly distributed between three regions: Northeast, Southeast, and South (Table 5). For the same period, the Northeast region was the leading cotton yarn producer representing on average 38.1 percent (1,941.4 thousand bales) of the Brazilian cotton consumption followed by the Southeast (33.2 percent) and the South (27.6 percent). For the same period, the largest cotton producing region of Brazil, Central-West, only accounted for nearly one percent (48.9 thousand bales) of the total domestic consumption.

Table 5. Cotton Yarn Production by Region in Brazil, 2005 – 2009 (thousand bales)

Region	2005	2006	2007	2008	2009	Average
North	0.0	0.0	0.0	0.0	0.0	0.0
Northeast	1,762.9	1,870.5	1,940.8	2,030.8	2,101.9	1,941.4
Southeast	1,712.0	1,687.0	1,731.8	1,675.7	1,658.0	1,692.9
South	1,370.9	1,434.2	1,422.5	1,388.8	1,419.4	1,407.1
Central-West	16.8	43.2	51.4	59.1	74.1	48.9
Total	4,862.5	5,034.9	5,146.5	5,154.4	5,253.3	5,090.3

Source: ABIT (2011).

Cotton Transportation Network in Brazil

Historically, the average share of transportation by mode (truck, rail, barge) of Brazilian total cargo has been largely concentrated on roads (60 percent) followed by rail (20 percent) and waterway (17 percent). With respect to agricultural cargo, this truck reliance increases drastically to 81 percent, as most production is located in remote and underdeveloped areas such as Mato Grosso and Western Bahia (ANUT 2008). As for cotton, the trucking modal share increases to approximately 100 percent of the total cotton transported to ports (Caixeta Filho and Gameiro 2001).

One can argue that trucks prevail in Brazil due to highway improvements, but this is not the case. It is important to note that the highway systems in developed areas of Brazil are very inefficient, and it is even worse in remote agricultural areas. A survey conducted by the Confederação Nacional do Transporte (CNT) shows that 58.8 percent of Brazil's paved highways are considered unsatisfactory, having various deficiencies such as: 58.2 percent of the traffic road signs are inadequate and 39.8 percent of the roads do not have shoulders. In addition, more than 88 percent of the Brazilian roads are one-way which causes very heavy congestion (CNT 2011). Furthermore, due to the poor conditions of the paved roads, estimates are that the Brazilian operational costs of cargo trucks are 28 percent higher than they would be on paved roads under optimal conditions (AMS/USDA 2011).

The main reasons for reliance on truck transportation for cotton are: (i) lack of railroad to link producing areas to exporting ports; (ii) railways have multiple gauges thereby requiring costly transhipment stops when transporting across different-gauged tracks; (iii) most of the Brazilian railroads lack sufficient locomotives and railcars to keep up with transportation demand[9]; and (iv) environmental constraints hinder the development of major waterways (Schnepf, Dohlman, and Bolling 2001; ANUT 2008).

Santos is the leading cotton exporting port with an average share of 65.4 percent of the total cotton exports (Table 6). In the state of Paraná, Paranaguá port comes in second and represents on average 23.4 percent of cotton exports. Historically, Santos and Paranaguá ports together accounted for on average 88.8 percent of Brazilian cotton

[9] The estimates are for a growth in demand and a shortage in supply for railroad transportation over the next five years.

exports. Foz do Iguaçu port is a border port with Argentina and Paraguay where these two countries are mainly the final destination for Brazilian cotton exported via that route. For the 2006-2010 period, these three ports combined represented approximately 95 percent of Brazilian cotton shipments. The port of Salvador (Bahia) had an average of two percent of the total Brazilian exports.

Table 6. Cotton Exports by Ports in Brazil (thousand bales), 2006 - 2010

Port	2006	2007	2008	2009	2010
Santos	821.1	1,283.3	1,522.9	1,644.8	1,615.3
Paranaguá	330.4	390.2	617.4	477.8	644.4
Foz do Iguaçu	149.9	130.8	138.3	96.1	74.2
Salvador	105.7	49.8	4.2	16.0	20.1
Subtotal	*1,398.5*	*1,854.1*	*2,282.7*	*2,234.7*	*2,353.9*
Others	0.0	67.6	165.0	84.3	0.0
Total	***1,398.5***	***1,921.7***	***2,447.7***	***2,319.0***	***2,353.9***

Source: SECEX/MDIC (2011).

Table 7 below presents the participation of each exporting port with respect to each major exporting state. For the state of Mato Grosso, from 2006 to 2010, cotton exports through the port of Santos is equivalent to, on average, 651.0 thousand bales, which represents 56.4 percent of the total exports from Mato Grosso (1,154.2 thousand bales). As for the other two main exporting states, Bahia and Goiás, the share of exports via the port of Santos were equal to 78.3 and 63.0 percent, respectively. As Table 7 shows, the port of Paranaguá is the second most preferred port for exports. Cotton exports from the state of Mato Grosso via the Paranaguá port were equal to 360.7

thousand bales, which gives a share of 31.2 percent. On the other hand, cotton producers located in the state of Bahia only shipped seven percent of its exports through the port of Paranaguá. The Foz do Iguaçu border crossing port had a minor participation as an exporting option for the analyzed states (less than 6 percent for all states). It is important to note that the port of Salvador only accounted for 1.7 percent of the exports from the state of Bahia, and nearly zero percent to the other states.

Table 7. Average and Share of Cotton Exports for Each Port by State, 2006-2010

Port	Mato Grosso		Bahia		Goiás	
	5-year Average[1]	**Share (%)**	**5-year Average**	**Share (%)**	**5-year Average**	**Share (%)**
Santos	651.0	56.4	492.5	78.3	95.5	63.0
Paranaguá	360.7	31.2	43.7	7.0	35.0	23.1
Foz do Iguaçu	66.4	5.8	16.5	2.6	3.8	2.5
Salvador	0.0	0.0	10.7	1.7	0.1	0.1
Subtotal	*1,078.1*	*93.4*	*563.5*	*89.6*	*134.5*	*88.7*
Other	76.1	6.6	65.6	10.4	17.1	11.3
Total	***1,154.2***	***100.0***	***629.1***	***100.0***	***151.6***	***100.0***

[1] Average from 2005 to 2010.
Source: Calculated based on the data from SECEX/MDIC (2011).

In summary, the Brazilian cotton transportation network from supply area to exporting ports is heavily concentrated in three major producing states (Mato Grosso, Bahia, and Goiás). Figure 6 below depicts the supply locations (municipality level) for the three states and the two main exporting ports. It is interesting to note the distance between these locations. For example, the average distances from the farm location in Mato Grosso to the ports of Santos and Paranaguá are equal to 1,100 and 1,240 miles, respectively. As for the producing areas in the state of Goiás, the average truck haul distances to the ports of Santos and Paranaguá are 640 and 880 miles, respectively. Cotton producers in the state of Bahia rely heavily on exports via the port of Santos where the average distance is 1,046 miles. The port of Salvador, which is on average 530 miles away, has a minor role in Western Bahia cotton exports.

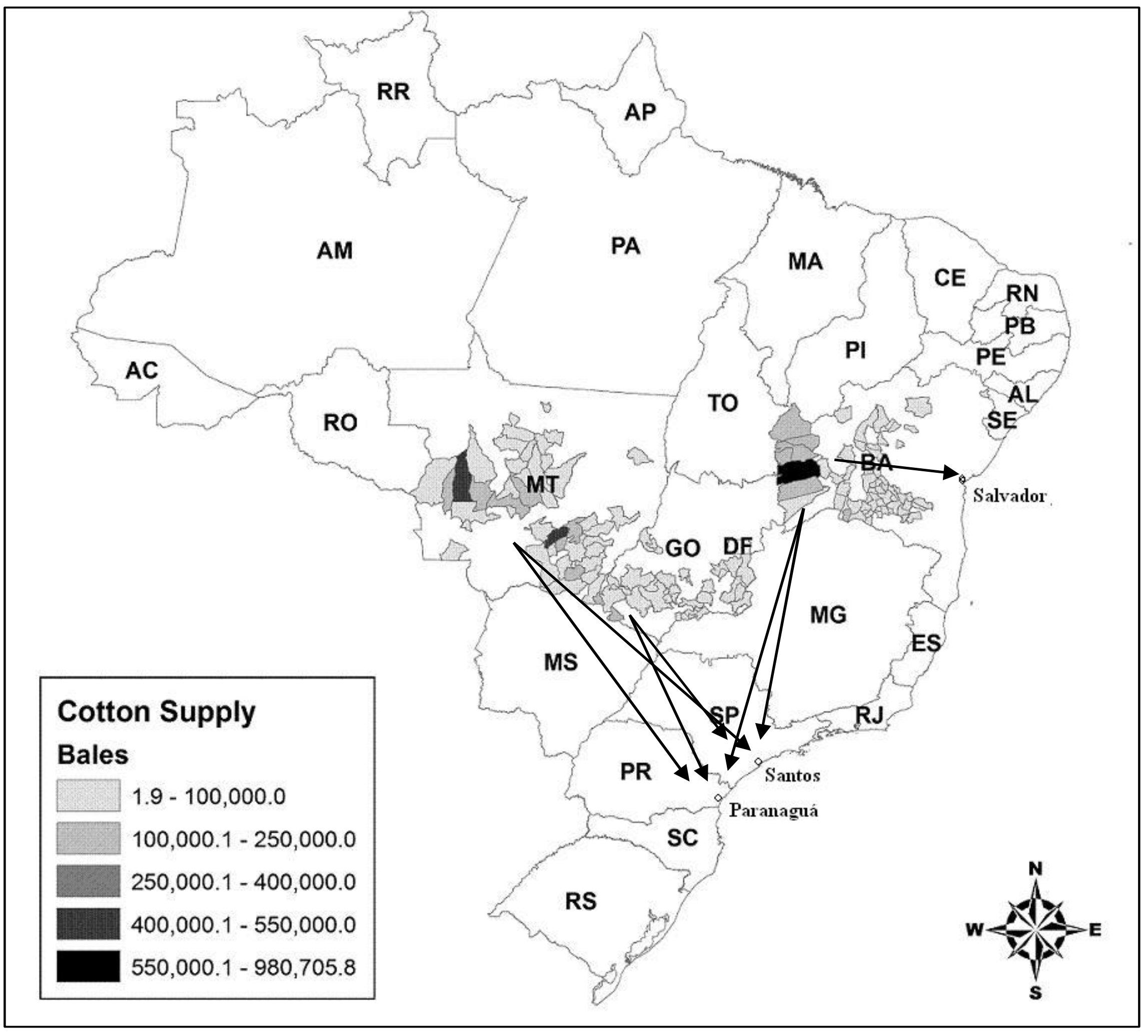

Figure 6. Main export routes for the cotton producing states of Mato Grosso (MT), Bahia (BA), and Goiás (GO)
Source: constructed with data from IBGE/MPOG (2011).

With respect to inland transportation costs, Brazilian truck rates for cotton were based on an estimated truck rate equation. The truck rate equation was estimated from data supplied by CEPEA (2011). Estimated charges for transporting cotton to port at average distances of 400, 600, 800, 1,000, and 1,200 miles for all Brazil regions were $13.35, $16.33, $19.31, $22.29, and $25.27/bale, respectively. During the peak shipping period (harvest quarter), trucking charges are approximately $1.09/bale higher than the off-peak (see appendix A).

Port of Salvador Improvements and Direct Ocean Shipping Lines to Asian Markets

In the previous section, Table 7 indicated that the port of Salvador only accounted for less than two percent of the cotton exports originating in the state of Bahia. As Figure 6 depicted, instead of shipping cotton to the closer port of Salvador, farmers located in Western Bahia deliver most of their cotton via the port of Santos, which is on average 516 miles further than the port of Salvador. According to Lomanto (2011), the main factors which force exporters to haul cotton to the port of Santos are: (i) lack of direct shipments from the port of Salvador to the importing markets in Asia and (ii) very costly ocean freight rates when compared to the port of Santos.

Currently, there are no direct maritime routes from the port of Salvador to Asia and the only way for cotton to be exported is via transhipments. In other words, ocean vessels first have to come from major importing ports in Brazil (such as the port of Santos) then load the cargo in Salvador and eventually head to Asia. Hence, this indirect transhipment route becomes very expensive for the cotton exporters. Estimates suggest that ocean freight rates from the port of Salvador to Asia are double the charges from the port of Santos and the transit time is on average 20 days longer (Lomanto 2011).

Furthermore, when contrasting the trucking costs from same origin in Western Bahia (i.e. Barreiras municipality) to the ports of Santos and Salvador, the latter is found to be a lower cost route. By using data from CEPEA (2011), estimates indicate that the inland truck cost to ship cotton bale from Barreiras municipality in Western Bahia to the port of Santos ($22.98/bale) is nearly 50 percent greater than the truck cost to the port of Salvador ($15.26/bale).

Regarding port capacity, the port of Salvador handled 262,000 TEUs in 2010 (CODEBA 2011a). This amount is greater than what would be required to handle the total cotton exports for the state of Bahia[10]. Therefore, based on inland cost advantages and current port capacity, one can argue that the most appropriate exporting route for the producers in Western Bahia would be utilizing the port of Salvador.

However, as discussed previously, the port of Salvador is practically not utilized for exporting cotton. In lieu of this situation, recently, Wilson Sons maritime company, which runs the container terminal in the port of Salvador (Tecon Salvador), along with the Brazilian government both agreed on cooperating to improve the port infrastructure vis-à-vis attracting direct shipping lines from the port to Asian markets and competing against other major ports for both vessel calls and container availability. The private company will invest nearly $100 million and will be responsible for the improvements of

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[10] If the total cotton exports from the state Bahia was equal to 819.9 thousand bales and one 1 TEU (20 foot container) fits 44 bales, then it would be required 18,634 TEUs (20 foot containers) to export the total state’s cotton exports.

the port facilities and purchase of new equipment. On the other hand, the Brazilian government will spend approximately $250 million on building an expressway to link the Bay of All Saints to a federal highway (BR-324) and dredging of the port access channel from 40 feet to 50 feet (CODEBA 2011b).

According to Lomanto (2011), in order to draw interest from ocean shipping companies to consider direct shipments from the port of Salvador to Asian markets with very affordable ocean freight rates, Tecon Salvador is undergoing the following improvements: (i) structural reinforcement and expansion of the current terminal berth from 210 to 377 meters; (ii) dredging of all the extension of the berth from the current 40 to a 50 feet draft; (iii) purchase of three super Post-Panamax Ship-to-Shore (STS) cranes and six rubber-tire gantry (RTGs) cranes; and (iv) expansion of terminal retro-area from 74 thousand to 118 thousand square meters.

By March 2012, when the aforementioned improvements are expected to be completed, Tecon Salvador will be able to allow efficient access of Post-Panamax ships that can measure in excess 300 meters in length and are capable of transporting 10,000 TEU. According to CODEBA (2011b), several shipping lines have recently shown interest in the port of Salvador. Three ocean shipping companies (CMA CGM, CSAV, and China Shipping) have already offered direct liner services between the port of Salvador and to several different locations in Asia. Additionally, ocean freight charges for the direct shipment from the port of Salvador to East Asia were quoted to be 27 percent lower than the current rate, but still 44 percent higher than the port of Santos (Lomanto 2011).

By assuming that all these improvements will take place in the near future, export cost competitiveness between the ports of Santos and Salvador is analyzed. Table 8 shows that inland trucking costs for cotton originating in Barreiras to the port of Salvador is $7.72/bale cheaper than to the port of Santos. When the port charges are taken into consideration, the total logistics costs for the port of Salvador equals $24.23/bale, which is 28.9 percent lower than the costs for the Santos port. Such low logistics costs for the port of Salvador generates a cotton price at the port (FOB) of $300.38/bale, which is approximately 3.1 percent lower than the FOB cotton price at the port of Santos.

Table 8. Cotton Export Cost Competitiveness between the Ports of Santos and Salvador after Introduction of New Ocean Shipping Lines from the Port of Salvador to Asian Markets, 2008/09 MY

Cost Item	**Santos**	**Salvador**
	$/480 lbs bale	
Farm Price[1] (Barreiras, Bahia)	**276.15**	**276.15**
Distance to Port (kms)	**1046**	**530**
Inland Truck Cost[2]	22.98	15.26
Port Charges[3]	11.11	8.97
Total Logistics Cost	**34.09**	**24.23**
Price at the Port (FOB)	**310.24**	**300.38**
Freight Costs to Asia[4]	7.80	11.32
Price at Asia (CIF)	**318.04**	**311.70**

[1] CEPEA (2011). [2] Based on author's calculation (see appendix A). [3] Mello (2010) and Lomanto (2011). [4] Lomanto (2011).

With respect to shipping charges to Asian importing markets (China, Indonesia, South Korea, etc.) after improvements, Table 8 points out that the new shipping lines will offer a competitive ocean freight rate for the port of Salvador. The ocean freight costs from the port of Salvador to Asian importing markets are expected to be \$11.32/bale, still higher than the rates from the port of Santos by \$3.52/bale. However, in CIF price terms, estimates indicate that the cotton price in Asian countries for the port of Santos and Salvador are \$318.04 and \$311.70/bale, respectively, which gives an advantage to the port of Salvador with respect to export competitiveness. For the importing countries in Asia, importing cotton produced in the state of Bahia from the port of Salvador cost two percent less than the port of Santos.

In summary, as the improvements in the port facilities and infrastructure take place at the port of Salvador, it is expected that direct ocean shipping lines will play a major role in enhancing the port's export competitiveness. For Asian importing countries, buying cotton from the port of Salvador is expected to be two percent cheaper than its largest port competitor[11]. As a result, producers located in the state of Bahia are expected to shift exports to the port of Salvador and eventually gain in competitiveness. On the other hand, the port of Santos is expected to decrease its participation, not only in the state of Bahia's total cotton exports, but also in the total Brazilian exports.

Study Objectives and Procedures

Main Objectives

The main objectives of this study are: (i) to assess the impacts of the introduction of direct ocean shipping lines from the Port of Salvador to Asian importing countries by

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[11] For importing countries in Asia, the CIF prices for cotton exported via the ports of Santos and Salvador are \$318.04 and \$311.70/bale, respectively, which indicates that the port of Salvador is two percent more efficient.

evaluating Brazilian cotton export flows by final destination, changes in export levels, and producer revenues and (ii) to examine the effects of (i) on the global cotton distribution and competitiveness by focusing on competing country exports and producer revenues.

Procedures

To accomplish the main objectives, three scenarios are examined. The first scenario evaluates the effects of introducing the Port of Salvador as a viable option for Western Bahia cotton exporters into the model by reducing the export cost for the port of Salvador by two percent. The second scenario examines the effects of assuming equal ocean freight costs for both the Santos and Salvador ports to Asian importing countries (export cost from Salvador to Asian countries is reduced by 3.1 percent). Last, scenario three assumes an optimistically large reduction in export costs from the port of Salvador to Asian countries by introducing a 10 percent decrease.

Methodology

Similar to essay one, this analysis is performed with a spatial, intertemporal equilibrium model of the international cotton industry that includes substantial detail on domestic and international transportation. A base model representing the international cotton industry is estimated for the 2008/09 market year and used for comparison for all scenarios (one, two and three). For more details on the methodology, data and validation, refer to Appendix A.

The effects of the new direct ocean shipping lines were determined by adjusting the appropriate parameters (ocean freight rates) in the base model, obtaining the solution to the model, and then contrasting these results with the base model. The lower ocean freight rates were incorporated into the model by reducing ocean freight rates on routes that link the Port of Salvador with Asian importing demand regions. The model solution representing lower ocean freight rates was contrasted with the base model solution to estimate the impacts on Brazil cotton flows, export levels, and producer revenues for the domestic cotton sector and competing countries.

Results

Cotton Flow Patterns and Exports by State

As the new direct ocean shipping lines from the port of Salvador are available for cotton exporters located in the state of Bahia, it is expected that a shift of exports from the port of Santos to the more export cost competitive port of Salvador will occur. A two percent decrease in export costs for the Port of Salvador to Asian cotton importing countries increases cotton exports via the port of Salvador (Table 9). The absolute change in exports was a positive 103.4 thousand bales. On the other hand, the port of Santos decreased shipments modestly by reducing total exports approximately 101.5 thousand bales, which in relative terms is equal to a 5.8 percent decrease. The route via the port of Santos reduces its share of total Brazil cotton exports by nearly four percentage points (from 67.4 to 63.4 percent). For the major exporting port of Paranaguá, there was no significant change in cotton exports.

Table 9. Estimated Change in Brazilian Cotton Flows Resulting from Reducing Export Cost from the Port of Salvador to Asian Importing Countries Due to Direct Ocean Shipping Lines (1,000 480 lbs. bales)

Port	Base Model	2% Reduction	Change (%)	3.1% Reduction	Change (%)	10% Reduction	Change (%)
Santos	1,738.9	1,637.3	-5.84	1,310.6	-24.63	567.9	-67.34
Paranaguá	583.4	583.4	0.00	583.4	0.00	583.0	-0.06
Salvador	6.4	109.8	1,616.40	438.1	6,745.61	1,242.6	19,316.11
Subtotal	*2,328.7*	*2,330.6*	*0.08*	*2,332.2*	*0.15*	*2,393.5*	*2.78*
Others	251.0	251.0	0.00	251.0	0.00	251.0	0.00
Total Brazil	***2,579.7***	***2,581.6***	***0.07***	***2,583.2***	***0.13***	***2,644.5***	***2.51***

As expected, cotton flow patterns resulting from the analysis of scenario two (3.1 reduction) are similar to scenario one in direction, but larger in magnitude. The port of Salvador increased cotton exports to 438.1 thousand bales, which in absolute value is equal to an increase of 431.7 thousand bales (Table 9). This increase generates a share of total Brazilian exports for the port of Salvador of almost 17 percent, up 13 percentage points when compared to scenario one. The port of Santos undergoes a decline in exports, going from 1,738.9 thousand bales to 1,310.6 thousand bales, which is in relative terms is a drop of nearly 25 percent. Another key observation is that the port of Santos reduces its share of total Brazilian cotton exports. Half of the Brazilian cotton exports are shipped via the Santos port, which is equal to a 16.7 percentage points decrease when compared to the base model (from 67.4 percent to 50.7 percent). Similar to scenario one, the port of Paranaguá does not undergo any significant change as its exports continues to be equal to the base model values.

In scenario 3, as it was expected, the change in exports by ports is accentuated. The port of Salvador increased cotton exports to 1,242.6 thousand bales (Table 9). With a participation in the country's total exports of 46.9 percent, the port of Salvador becomes Brazil's largest cotton exporting port. In contrast, the port of Santos reduces its exports to 567.9 thousand bales, which represents a decrease of 67.3 percent when compared to the base model. This positions the port of Santos with a share of 21.4 percent of the Brazilian cotton exports, which in percentage points represents a decrease of 46 points with respect to the base model. Even though with a very small reduction in exports (0.37 thousand bales), the port of Paranaguá becomes the number two exporting port of Brazil passing the port of Santos.

Similar to the analysis of the changes in exports by ports, changes in exports by state are presented in Table 10. For scenario one (2 percent reduction), the changes in export levels by state were not significant. The state of Bahia, which was expected to benefit the most due to the location of the port of Salvador, only increased its exports by 0.9 thousand bales (an increase of 0.14 percent). Similarly, the states of Mato Grosso and Goiás were shown to have positive gains in exports, which were not expected. Due to the less costly direct ocean shipping from the port of Salvador, these states were supposed to lose exports to the state of Bahia. Nonetheless, their gains were very insignificant with only slight increases in exports (less than one thousand bales). As for the share of exports by state, since there were no major changes in exports levels, the state of Mato Grosso continued to be the leading cotton exporting state followed by Bahia and Goiás.

Table 10. Estimated Change in Brazilian Cotton Exports by State Resulting from Reducing Export Cost from the Port of Salvador to Asian Importing Countries Due to Direct Ocean Shipping Lines (1,000 480 lbs. bales)

State	Base Model	2% Reduction	Change (%)	3.1% Reduction	Change (%)	10% Reduction	Change (%)
Mato Grosso	1,509.8	1,510.4	0.04	1,511.0	0.08	1,099.2	-27.19
Bahia	667.1	668.0	0.14	670.6	0.53	1,218.0	82.62
Goiás	187.9	188.3	0.15	186.7	-0.69	87.7	-53.32
Subtotal	*2,364.8*	*2,366.7*	*0.07*	*2,368.3*	*0.15*	*2,405.2*	*1.71*
Others	214.9	214.9	0.00	214.9	0.00	239.3	11.37
Total Brazil	***2,579.7***	***2,581.6***	***0.07***	***2,583.2***	***0.13***	***2,644.5***	***2.51***

In scenario two (3.1 percent reduction), like scenario one, the changes in export levels by state were insignificant (Table 10). Cotton exports by the state of Bahia only increased by 3.5 thousand bales, which in percentage terms is equal to a rise of 0.53 percent. Unexpectedly, the state of Mato Grosso was estimated to gain in exports by increasing its total amount by 1.24 thousand bales (0.08 percent increase). On the other hand, as was expected, the state of Goiás is found to decrease its exports by 1.31 thousand bales. As in the case for the other states, in relative terms, this change in exports level for the state of Goiás is very small as its exports only decreased 0.69 percent. As for the share of exports by state, since there were no major changes in exports levels, the state of Mato Grosso continued to be the leading cotton exporting state followed by Bahia and Goiás.

In contrast to scenarios one and two, the 10 percent reduction in export costs for the port of Salvador induced the largest increase in exports for the state of Bahia. Table 10 indicates that the state of Bahia increased its exports by 551.1 thousand bales, which represent a gain of 82.6 percent. It is interesting to note that the total exports of 1,218.2 would be the highest historical level for that state. Since its production was estimated to be 1,700.8 thousand bales by the IBGE/MPOG (2011) for the 2008/09 marketing year, model results suggest that the state would export almost 72 percent of its production. Furthermore, the state of Bahia is shown to become the leading cotton exporting state in Brazil. As for the state of Mato Grosso, cotton exports are reduced to 1,099.2 thousand bales, down 27.2 percent from the base model. This amount leaves the state of Mato Grosso as the second largest exporter of cotton in Brazil. The state of Goiás also loses its share in exports as it reduces its total by 53.3 percent (from 187.9 to 87.7 thousand bales). As for the share of exports, the state of Bahia would account for 46 percent of the nation's total (up 21 percentage points when compared to the base model).

Although cotton flows are altered with the introduction of the direct ocean shipping lines from the port of Salvador to Asian importing markets, total Brazilian cotton exports are only modestly impacted. For scenario one, the increase in total cotton exports from Brazil was equal to 1.9 thousand bales which is equivalent to a 0.07 percent increase (Table 9 or Table 10). As for the second scenario, a greater reduction in export cost for the port of Salvador increased total Brazilian cotton exports by 3.5 thousand bales, which is a modest 0.13 percent increase. The largest increase in total Brazilian cotton exports is found in scenario three. This result was expected since with greater reduction in export costs for the port of Salvador, the cotton exporting producers in Bahia gain the most as they have less costly shipping options than before. The total cotton exports for this scenario was equal to 2,644.5 thousand bales, which is equal to a growth of 64.8 thousand bales when compared to the base model (2.51 percent increase).

Changes in Producer Prices and Revenues in Brazil

As the new direct shipping lines from the port of Salvador to Asia are in place, there would be an anticipated reduction in transportation costs linking the producers in Brazil to importers in the Asian importing countries. This increases price and production in producing areas in Brazil that ship via the port of Salvador. For example, in scenario one, by comparing the gain in prices of the top three exporting states (Mato Grosso, Bahia and Goiás), the state of Bahia experiences the largest increase in price $0.09/bale

(Table 11). The states of Mato Grosso and Goiás also have gains in prices with an increase of $0.04/bale for both states. It is interesting to note that all states were shown to benefit with respect to price gains. However, these values are presented at the state level which averages all the gains and losses of the municipalities.

Table 11. Estimated Annual Increase in Brazilian Cotton Producer Revenues (thousand dollars) and Farm Price ($/bale) for Different Reductions in Export Cost of the Port of Salvador

State	2% Reduction		3.1% Reduction		10% Reduction	
	Revenue	Price	Revenue	Price	Revenue	Price
Alagoas	$4.15	$0.16	$12.89	$0.49	$206.16	$7.75
Bahia	$298.66	$0.09	$1,135.75	$0.37	$24,860.13	$7.51
Ceará	$1.68	$0.16	$5.24	$0.49	$83.91	$7.76
Goiás	$34.74	$0.04	$(7.17)	$(0.01)	$74.59	$0.15
Maranhão	$26.25	$0.16	$81.65	$0.49	$1,306.48	$7.75
Mato Grosso	$195.62	$0.04	$(13.89)	$(0.01)	$(1,237.95)	$(0.23)
MS[1]	$16.58	$0.04	$(3.42)	$(0.01)	$(98.69)	$(0.25)
Minas Gerais	$6.41	$0.04	$(1.32)	$(0.01)	$(38.12)	$(0.25)
Paraíba	$8.83	$0.16	$27.46	$0.49	$439.13	$7.75
Paraná	$2.17	$0.05	$(0.11)	$(0.01)	$(10.50)	$(0.23)
Pernambuco	$2.51	$0.16	$7.82	$0.49	$125.10	$7.75
Piauí	$25.02	$0.15	$81.01	$0.49	$1,296.19	$7.75
RN[2]	$10.08	$0.16	$31.34	$0.49	$501.26	$7.75
São Paulo	$7.38	$0.05	$(1.33)	$(0.01)	$(38.23)	$(0.25)
Tocantins	$5.85	$0.15	$18.93	$0.49	$302.91	$7.75
Total Brazil	***$645.92***	***$0.08***	***$1,374.85***	***$0.19***	***$27,772.38***	***$3.61***

[1] Mato Grosso do Sul. [2] Rio Grande do Norte.

Regarding the gains and losses in producer revenue, in scenario one, the state with the largest gain in revenue was Bahia (Table 11). The increase in producer revenues for that state was equal to $298.6 thousand. Taking into account the relatively small change in price that occurs in Bahia ($0.09/bale), model estimates indicate that the main reason for such increase in producer revenue is the expansion of cotton production[12]. The gain for Bahia is relevant to discuss since the port of Salvador is located in that state and local cotton producers were the beneficiaries of the export cost reductions. Unexpectedly, the states of Mato Grosso and Goiás had significant gains in producer revenues as well, with $195.6 thousand and $34.7 thousand, respectively. In this scenario, it is interesting to mention that all states gain from the reduction in export cost for the port of Salvador.

Figure 7 below shows the changes in producer revenue by municipality for the states of Mato Grosso, Bahia, and Goiás. The state of Bahia accrues the most benefits of the export cost reduction of the port of Salvador whereas the gains in producer revenue were concentrated in the west side of the state. The municipalities of São Desidério and Formosa do Rio Preto obtained gains of $112.2 and $57.6 thousand, respectively. For most of its municipalities, the state of Mato Grosso is shown to have had gains in producer revenue except for two: Sapezal (-$14.5 thousand) and Campos de Júlio (-$5.2 thousand). The largest increase in producer revenue for the state of Mato Grosso occurred in the municipalities of Campo Verde and Pedra Preta with gains of $27.8 and $17.5 thousand, respectively. As for the state of Goiás, all municipalities were found to

[12] According to IBGE/MPOG (2011), cotton production for the state of Bahia was approximately 1,700.8 thousand bales for the 2008/09 market year.

have a positive change in producer revenue, with the largest increase in producer revenue in the municipality of Chapadão do Céu ($9.9 thousand).

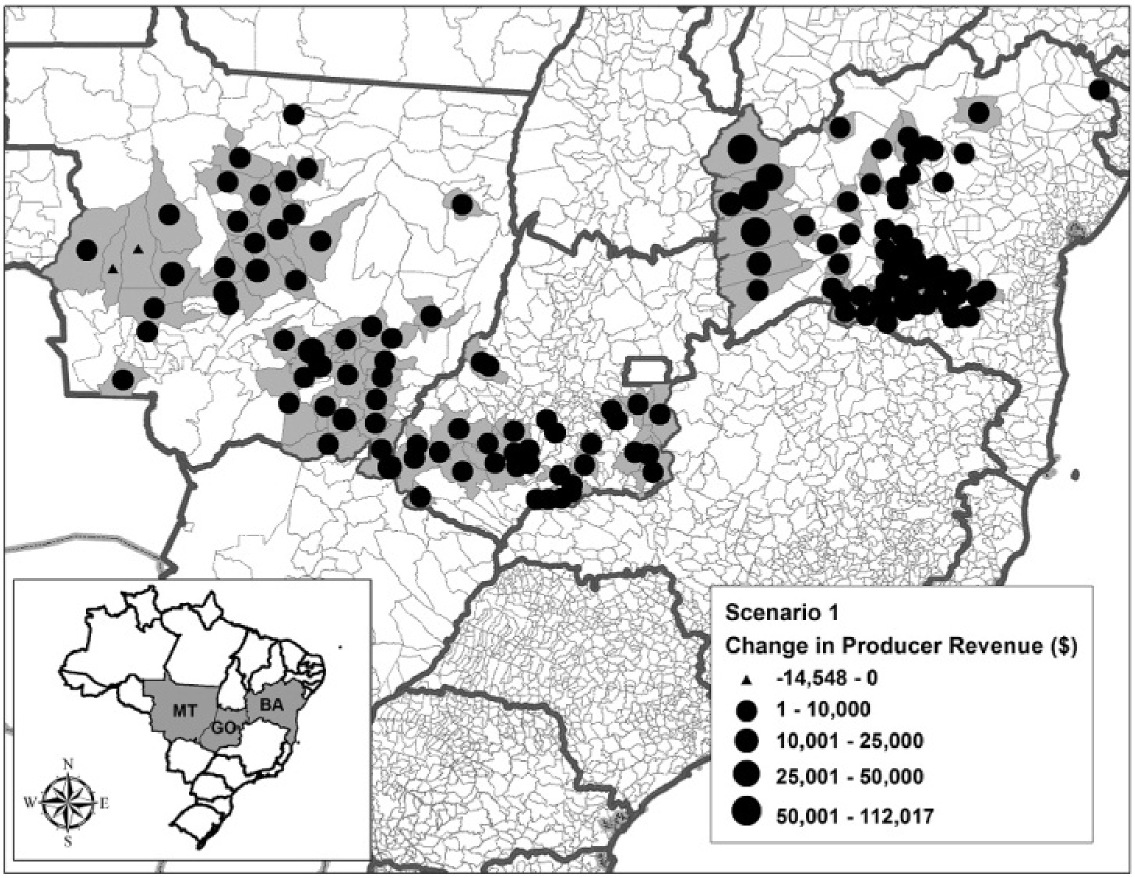

Figure 7. Model-estimated changes in cotton producer revenues by municipalities for the states of Mato Grosso (MT), Bahia (BA), and Goiás (GO) for scenario 1
Note: Scenario 1 is 2 percent reduction in export cost for the Port of Salvador to Asian cotton importing countries.

In scenario two, the 3.1 percent reduction in export cost for the port of Salvador to Asian markets is estimated to increase annual producer revenues for the state of Bahia by $1,135.75 thousand (Table 11). For the state of Bahia, the increase in cotton price of

$0.37/bale was the greatest of all the top three producing states. As discussed earlier, Bahia is a special case since most of the gain in revenue is due to increased cotton production and not higher prices. In contrast to scenario one, decreases in producer revenue are found in this scenario. By losing competitiveness relative to the producers in the state of Bahia, the states of Mato Grosso and Goiás undergo decreases in producer revenues of $13.89 and $7.17 thousand, respectively. Few other states were found to have negative change in producer revenue. However, all decreases in producer revenue were small (less than $15 thousand) when compared to the gains for Bahia ($1,135.75 thousand). In contrast to scenario one, as the export cost reduction gets larger, it leads to losses in producer revenue for some regions.

As Figure 8 indicates, the municipalities located in western Bahia experience the largest increases in revenues as their cotton is mostly shipped through the port of Salvador. Similar to scenario one, the municipalities of São Desidério and Formosa do Rio Preto are shown to gain the most for that state as their revenues increase by $511.1 and $179.1 thousand, respectively. For the state of Mato Grosso, the municipality of Sapezal is the largest loser, with a producer revenue decrease of $12.7 thousand. Only one municipality in the state of Mato Grosso, Bom Jesus do Araguaia, was shown to gain in this scenario (up $5.7 thousand). As for the municipalities located in the state of Goiás, the decreases in producer revenue were projected to take place in the entire state except for two municipalities: Cezarina and Jataí. Still, the gains in producer revenue for these outliers in the state of Goiás were approximately zero.

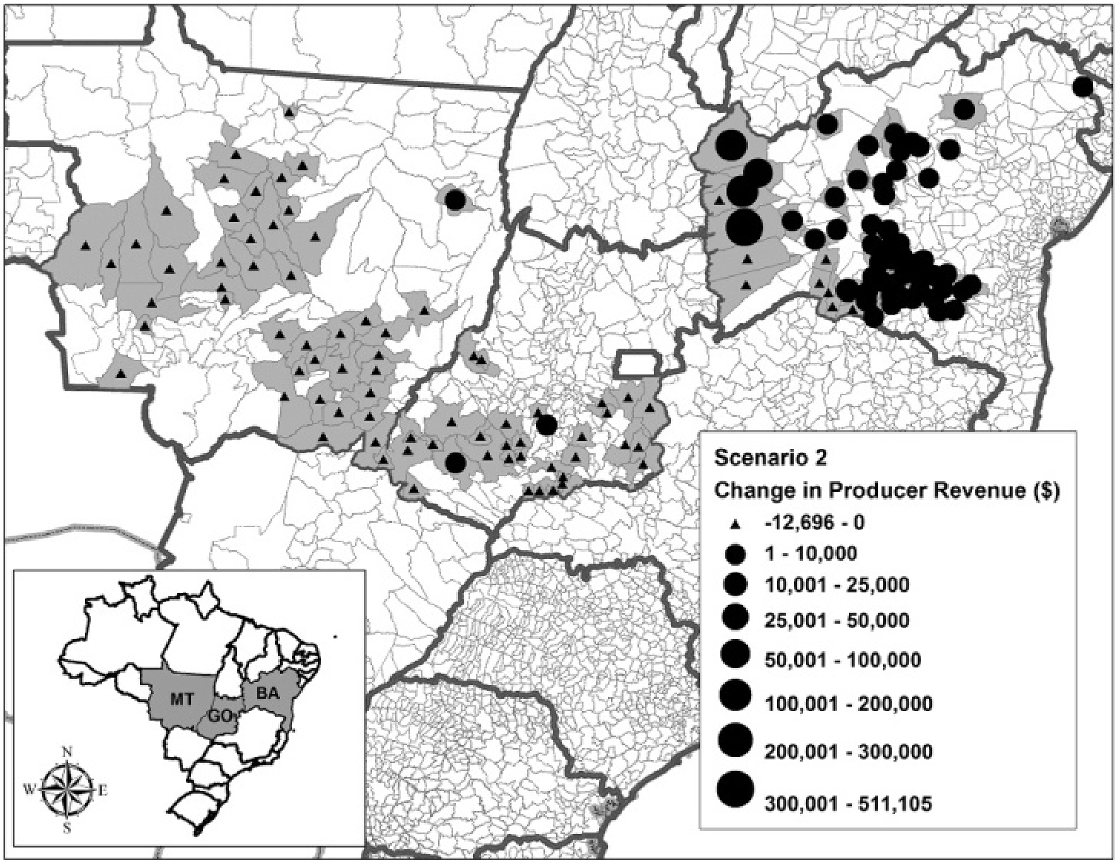

Figure 8. Model-estimated changes in cotton producer revenues by municipalities for the states of Mato Grosso (MT), Bahia (BA), and Goiás (GO) for scenario 2
Note: Scenario 2 is a 3.1 percent reduction in export cost for the Port of Salvador to Asian cotton importing countries.

As Table 11 shows, scenario three also estimates that Bahia is the state with the largest increase in producer revenue. With the 10 percent reduction in export cost for the port of Salvador to Asian countries, the state of Bahia increases its producer revenue by $24.8 million. On the other hand, the state of Mato Grosso decreases its producer revenue by $1.2 million, which is the largest negative change of all analyzed states. In contrast, the state of Goiás is found to gain from the export cost reduction by increasing its revenue (only up by $74.6 thousand). The states of Maranhão and Piauí had increases in producer revenue of $1.30 and $1.29 million, respectively. These values are worth mention since these gains are due to supplying local domestic consumption with higher prices. In other words, these regions gained because the domestic mills were previously supplied by the state of Bahia. Since the production from Bahia started to be more exported, these states gained by offering their cotton to local mills at a higher price.

The municipalities located in the state of Bahia experienced the largest increases in revenues (Figure 9). For the state of Bahia, the municipality of São Desidério is shown to increase its producer revenue by $11.2 million, which represents almost half of the gains for that state ($24.8 million). Furthermore, the Western Bahia region, which is composed of six municipalities[13], accounted for almost 90 percent ($22.3 million) of the gains for the state. As in scenario two, in the state of Mato Grosso, only the municipality of Bom Jesus do Araguaia ($6.8 thousand) was shown to gain producer revenue. The largest decreases in producer revenue for that state occurred in the municipalities of Sapezal and Campo Verde with losses of $179.6 and $159.5 thousand, respectively. As for the state of Goiás, some municipalities obtained increases in producer revenue. The largest increases in producer revenue occurred in the municipality of Rio Verde ($33.5 thousand) followed by Montividiu ($18.9 thousand). On the other hand, the largest decrease in producer revenue took place in the municipality of Chapadão do Céu ($50.1 thousand).

[13] Barreiras, Correntina, Formosa do Rio Preto, Luís Eduardo Magalhães, Riachão das Neves, and São Desidério.

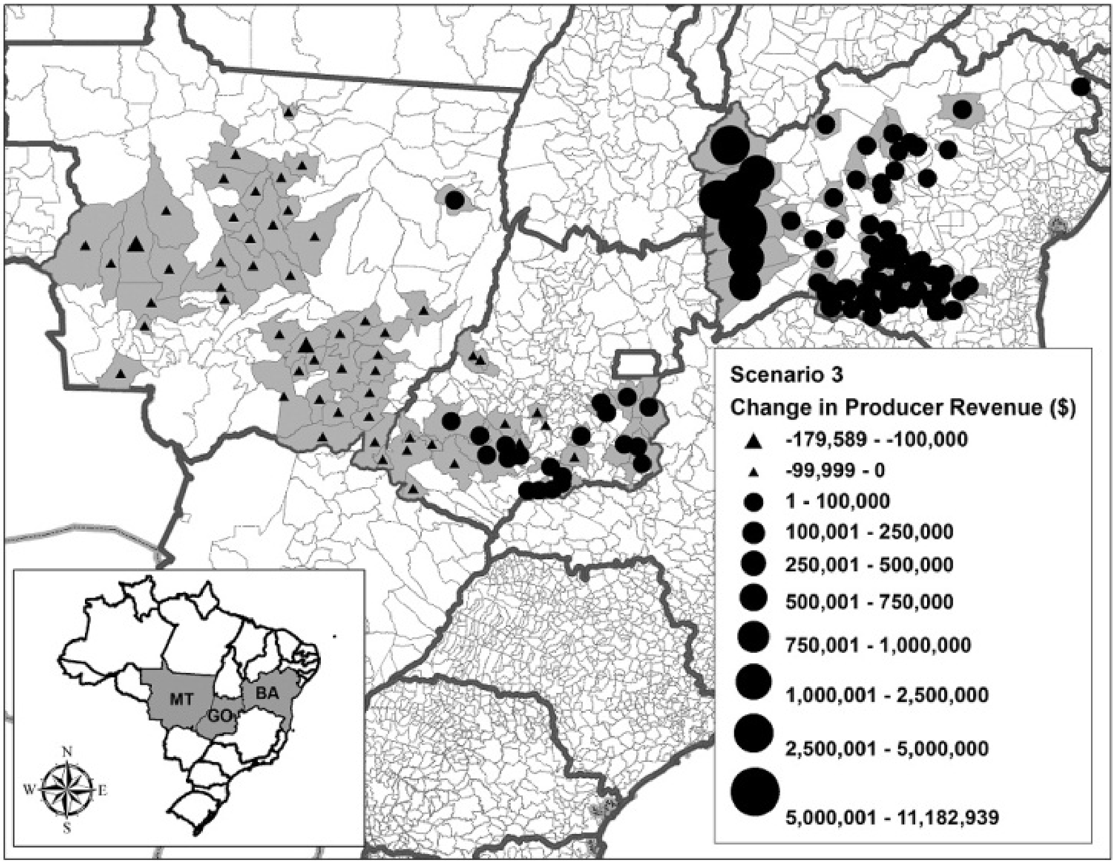

Figure 9. Model-estimated changes in cotton producer revenues by municipalities for the states of Mato Grosso (MT), Bahia (BA), and Goiás (GO) for scenario 3
Note: Scenario 3 is a 10 percent reduction in export cost for the Port of Salvador to Asian cotton importing countries.

In summary, the producer revenue for cotton increased in all scenarios (Table 11). A two percent reduction in export cost for the port of Salvador to Asian cotton importing countries is projected to increase annual cotton producer revenues by approximately $645.92 thousand. In relative terms, for this scenario, the total increase in producer revenue for Brazil is equal to 0.04 percent. For scenario two, the 3.1 percent export cost reduction causes a greater positive impact on the producer revenue for Brazil. The total increase in Brazilian cotton producer revenue is equal to $1.37 million, which, in relative terms, is equivalent to an increase of 0.09 percent. Overall, the largest gain in producer revenue for Brazil takes place in scenario three. As expected, the total increase in producer revenue is equal to $27.77 million, which is, in relative terms, an increase of 1.79 percent.

Brazilian Cotton Competitiveness in the World Market

The impact of the reduction in export cost for the port of Salvador to Asian importing countries on the competitiveness of exporting countries is evaluated with the focus on exports, prices, and revenue. Table 12 presents the results of the scenarios that were analyzed previously. With the exception of scenario one, all scenarios indicate that the U.S., India, Sub-Sahara Africa, Uzbekistan and the Rest of the World Exporters all experience lower exports, prices, and revenues. Among these countries/regions, the Rest of the World Exporters were the most affected followed by India.

Table 12. Estimated Effects of Export Cost Reduction in the Port of Salvador to Asian Importing Countries on Exports, Prices, and Revenue for Selected Exporting Countries

Exports (1,000 480 lbs. bales)	2% Reduction	3.1% Reduction	10% Reduction
Brazil	1.90	3.50	64.83
United States	0.64	-0.13	-4.49
Australia	-0.04	-0.03	-0.52
India	-0.71	-0.51	-8.50
Sub-Sahara Africa	-0.17	-0.12	-2.10
Uzbekistan	-0.15	-0.11	-1.80
Rest of the World	-0.73	-0.50	-8.30
Prices ($/bale)	**2% Reduction**	**3.1% Reduction**	**10% Reduction**
Brazil	$0.08	$0.19	$3.61
United States	$0.02	$(0.01)	$(0.28)
Australia	$(0.03)	$(0.02)	$(0.26)
India	$(0.03)	$(0.02)	$(0.27)
Sub-Sahara Africa	$(0.03)	$(0.02)	$(0.27)
Uzbekistan	$(0.03)	$(0.02)	$(0.27)
Rest of the World	$(0.03)	$(0.02)	$(0.26)
Revenues (thousand $)	**2% Reduction**	**3.1% Reduction**	**10% Reduction**
Brazil	$645.92	$1,374.85	$27,772.38
United States	$457.89	$(198.22)	$(5,720.89)
Australia	$(45.17)	$(35.17)	$(493.23)
India	$(714.15)	$(204.03)	$(3,240.53)
Sub-Sahara Africa	$(176.61)	$(102.95)	$(1,491.16)
Uzbekistan	$(151.49)	$(86.58)	$(1,250.89)
Rest of the World	$(727.86)	$(224.45)	$(3,416.51)

The U.S. is an interesting case since the results indicate that in scenario one there is a gain with respect to competitiveness in global cotton trade. A potential explanation is that the two percent reduction in the export cost for the port of Salvador does not affect a large country such as the U.S. Nonetheless, in scenario three, when the reduction is considered to be 10 percent, the U.S. is the competing exporting country that accrues the most losses ($5.72 million). Overall, for all analyzed scenarios, these losses in exports, prices, and revenues are very modest in relative terms. For example, in scenario three, U.S. exports, price, and revenue declined by 0.03, 0.11 and 0.14 percent, respectively.

As the export cost from the port of Salvador to Asian markets is reduced due to new direct ocean shipping lines, there are gains in competitiveness for Brazilian cotton producers (Table 12). There are increases in exports, price, and revenue for Brazil. The largest impacts were in scenario three due to the larger reduction in export cost for the port of Salvador. The increases in exports, price, and revenue were equal to 64.83 thousand bales, $3.61/bale, and $27.77 million, respectively. However, in relative terms, the Brazilian cotton exporting industry is slightly better off. The percentage increases in export, price, and producer revenue were only 2.50, 1.54, and 1.79 percent, respectively.

Conclusions

By March of 2012, the port of Salvador is expected to have undergone major improvements in port facilities and other important basic infrastructure such as dredging of the main canal. As a result, this port is expected to become more competitive and attract ocean shipping companies which are willing to export products directly to Asian markets. One of the industries that is expected to benefit from these direct shipping lines is the cotton located in the state of Bahia. To analyze the potential impacts of these new direct ocean shipping lines, a spatial price equilibrium model of the international cotton sector was used.

To accomplish the main objectives, three scenarios were examined. The first scenario evaluates the effects of introducing the Port of Salvador as a viable option for Western Bahia cotton exporters into the model by reducing the export cost at Asian importing countries by two percent. The second scenario examines the effects of assuming equal ocean freight costs for both the Santos and Salvador ports at Asian importing countries (export cost from Salvador to Asian countries is reduced by 3.1 percent). Last, scenario three assumes an optimistically large reduction of export cost from the port of Salvador to Asian countries by introducing a 10 percent decrease.

For all scenarios, the port of Salvador was found to become a more attractive option for the cotton exporters located in the state of Bahia. However, the scenario with the largest reduction in export cost for the port of Salvador indicated the largest gains for these producers. For the 10 percent reduction scenario, the cotton flows and exports had substantial changes. Cotton exports via the port of Salvador increased substantially, with total exports reaching to 1.24 million bales. This amount made the port of Salvador the leading exporting port in Brazil. The port of Santos decreased participation in total cotton exports considerably, down almost 68 percent. Overall, in scenario three, the percentage of cotton exported via the port of Salvador relative to the country's total cotton exports increased from 0.24 to 46.9 percent. Further, total Brazilian cotton exports were estimated to increase by 64.83 thousand bales, which is equivalent to a 2.51 percent rise.

With respect to the export share by states, in scenario three, the state of Mato Grosso is shown to decrease its participation in the export total for Brazil by 16.9

percentage points. On the other hand, the port of Salvador makes the producers in the state of Bahia more export competitive which boosts their exports to an all-time high of 1.2 million bales. This increase in cotton exports places Bahia as the leading cotton exporting state in the country. As for the share of exports, the state of Bahia increases its participation in total Brazilian exports to 46.0 percent, up by 20.2 percentage points. As for the state of Goiás, the total exports decreased by 53.3 percent.

A 10 percent reduction in export cost for the port of Salvador is projected to annually increase revenues of Brazilian cotton producers by $27.77 million, with the state of Bahia accruing the most gains ($24.86 million). On the other hand, the largest decrease in producer revenue occurred in the state of Mato Grosso. Since these producers ship most of their exports to the ports of Santos and Paranaguá, they lose competitiveness and undergo losses in producer revenue of $1.23 million.

With respect to the world cotton trade, the modest increase in exports due to a more efficient port of Salvador made Brazil's cotton industry more competitive. On the other hand, all competing export countries had very modest decreases in their exports as well as prices and revenues with individual countries such as the U.S. and India experiencing the largest reduction.

In summary, the new direct ocean shipping lines from the port of Salvador are important for the cotton exporters in Brazil, especially for the producers in the state of Bahia. As the port improvements are completed and the ocean shipping carriers introduce new shipping lines, the analysis indicates a shift in Brazil cotton export flows from the port of Santos to the port of Salvador as well as an increase in exports and producer revenues. In addition, this study suggests that the state of Bahia has the potential of becoming the largest cotton exporter in Brazil. As for other competing export countries, modest declines in exports, prices, and revenues are expected to occur.

CHAPTER IV

THE IMPACTS OF FOOT AND MOUTH DISEASE OUTBREAKS ON THE BRAZILIAN MEAT MARKET

Introduction

In Brazil, foot and mouth disease (FMD) outbreaks have been present in the meat industry for more than a century. In 1895, the first FMD outbreak was reported and, since then, Brazilian authorities have struggled to contain this disease, which was considered endemic until the 1970's. In the mid-1980's, Brazilian livestock producers invested in both more sophisticated production methods and animal vaccination with the purpose of eradicating FMD (Lima, Miranda, and Galli 2005). Since 1998, the Brazilian government has actively implemented efforts to eradicate FMD via the Programa Nacional de Erradicação da Febre Aftosa (PNEFA). The main purpose of this program was to eradicate the disease by the end of 2005 with the implementation of the Brazilian System of Identification and Certification of Origin for Cattle (SISBOV), which tracks and documents all animals (Haley 2005).

As the number of FMD outbreaks decreased partly due to the program mentioned above, the Brazilian government decided to follow the sanitary and phytosanitary guidelines of the World Organization for Animal Health (OIE) and World Trade Organization (WTO) by dividing its territory into five regions with the purpose of managing animal health controls more efficiently. By agreeing with the guidelines and regionalizing its livestock, the competitiveness of Brazilian meat improved significantly in the world meat trade. In 2000, Brazil became the fourth largest beef and pork exporter and the second largest chicken exporter. Five years later, Brazil became the largest beef and chicken exporter in the world and, although it remained the fourth largest exporter of pork, more than quadrupled pork exports. Currently, the Brazilian meat export industry has kept the same positions as before in the rankings of the top meat suppliers in the global market (FAS/USDA 2011).

However, Brazilian meats are still affected by FMD outbreaks. In the last ten years, two major FMD outbreaks occurred in Brazil. The most detrimental and recent outbreak occurred in September, 2005. According to the OIE (2011), the FMD outbreak took place initially in the state of Mato Grosso do Sul. Three months later, an outbreak was reported in the neighboring state of Paraná. The announcement of the FMD outbreak had negative impacts on Brazilian meat exports, especially for beef and pork. Several beef and pork importing countries initiated an import ban, including Russia[14], the number one importer of Brazilian meat. The Russian import ban originally was only on meat originating from the infected states of Mato Grosso do Sul and Paraná. Eventually, the Russian authorities expanded the ban to the states which were contiguous to the infected states. This expansion of the import ban accounted for eight meat producing states in Brazil. After the destruction of 33,741 FMD-susceptible animals (32,549 cattle, 566 pigs, 626 sheep and goats) (OIE 2011) and several rounds of

[14] According to the Secretaria de Comércio Exterior (SECEX/MDIC 2011), for the last ten years, the Russian market is a major destination of Brazilian meat exports, representing 40 percent of Brazilian total beef exports.

meetings between Brazilian and Russian authorities, the import ban was lifted in December 2007, 28 months after the FMD outbreak occurred.

As a consequence, the FMD outbreaks caused immense uncertainty and economic losses to the Brazilian meat industry, particularly for exports. One to two months after the import ban by Russia and other countries, Brazilian beef exports decreased from 93.8 thousand tons in September 2005 to 66.1 thousand tons in December 2005 (a decline of 30 percent) (Figure 10). Furthermore, according to the SECEX/MDIC (2011) database, Brazilian beef exports to Russia decreased from 21.3 thousand tons in September 2005 to 12.5 thousand tons in December 2005 (down 41 percent).

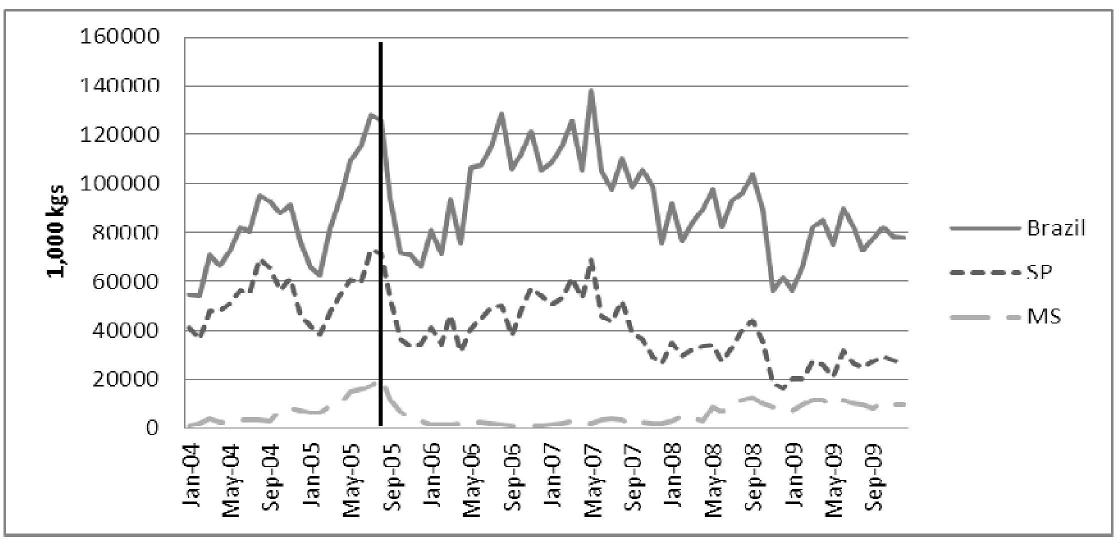

Figure 10. Monthly exports of Brazilian beef at the national level and for the states of São Paulo (SP) and Mato Grosso do Sul (MS) (January 2004-December 2009)
Note: the vertical black line represents the time period of the FMD outbreak (September, 2005).
Source: compiled from SECEX/MDIC (2011)

The purpose of this study is to analyze the impacts of the FMD outbreak on the Brazilian meat market for different levels of the industry (export, wholesale and farm). The imposition of an import ban by Russia on Brazilian meat exports is also investigated. A vector error correction model (VECM) and historical decomposition of price innovations, accompanied by directed acyclic graphs (DAGs) is used for this analysis. This approach quantifies the impacts of the 2005 FMD outbreak in Brazil on prices of different meat types (beef, pork, and chicken) at different levels of the marketing channel (export, wholesale, and farm levels), price margin along the supply chain, and price interdependence in the system.

This work is an important contribution to the literature of animal disease impacts on meat markets for the following reasons: (i) it simultaneously investigates the impacts of animal disease outbreaks on export price levels as well as domestic price levels (wholesale and farm) and (ii) there is no study that analyzes the Brazilian meat market to this detailed extent. This study fills these gaps and provides evidences from a major player in the global meat industry and trade.

The following section presents a brief literature review on animal disease outbreaks on different types of meat markets. This is followed by a discussion of the method of analysis, data utilized in this analysis, empirical results, and conclusions.

Literature Review

Several studies have analyzed the impacts of animal disease outbreaks and their effects on the livestock sector for different countries. Burton and Young (1996) measured the impacts of bovine spongiform encephalopathy (BSE) on the British domestic beef market. Their findings indicated the BSE outbreak led to significant negative impacts for the beef industry in Great Britain. Piggott and Marsh (2004) estimated the impacts of publicized food safety information (media index construction) on meat demand for the United States. Their results indicated that major food scares induced large demand responses, but these responses were rapidly dampened. Park, Jin, and Bessler (2008) quantified the impacts of domestic and overseas animal disease crises on the Korean meat market. Their findings concluded that the Korean market recovered after approximately one year for different animal diseases and the impacts were somewhat different across different levels of the supply chain.

Most recently, Attavanich, McCarl, and Bessler (2011) estimated the impacts of media coverage related to the H1N1 (swine flu) on U.S. meat and related product prices, and quantified the revenue losses across the meat and related markets. Their findings indicate that the media coverage was associated with a significant but momentary negative impact on the nearby lean hog futures price. An important contribution of their work was to analyze the trade bans imposed by several countries to U.S. pork. Their estimates showed that the trade ban negatively affected the pork industry.

Regarding animal disease outbreaks and the impacts on the Brazilian meat industry, there are few studies in the literature. Teixeira and Maia (2008) used the Box-Jenkins time series method to estimate the impacts of the 2004 FMD outbreak on the live cattle farm price. Their findings indicate that the FMD outbreak caused a structural break in the live cattle farm price series. The authors suggest that the import ban by Russia on Brazilian meat exports (originating in the states of Amazonas and Pará) due to the outbreak possibly triggered the structural break. Otuki, Weydmann, and Seabra (2009) analyzed the impacts of the FMD outbreaks in 2004 and 2005 on the price volatility of two series of farm pork prices: national price and the state of Santa Catarina price. The authors employed the Generalized Autoregressive Conditional Heteroskedasticity (GARCH) model to perform their analysis. Their findings were that the FMD outbreaks caused high pork price volatility for both series.

Method of Analysis

To quantify and identify the potential impacts of FMD outbreaks on the Brazilian meat industry, time series methods, mainly VECM, are employed as well as historical decomposition of price innovations. The most important contribution of the VECM method is to allow a comparison between the actual price that is affected by the FMD outbreak and the forecasted price that uses only information before the outbreak occurred. This approach allows us the quantification of the impacts on meat prices for: (i) price levels for different types of meat and (ii) price margins along the supply chain (i.e. export, wholesale, and farm levels). The historical decomposition of price innovations is utilized to identify the dynamic interdependence within meat prices for different levels along the supply chain and to measure the participation of each price series on the net change of a certain meat price following the FMD outbreak.

Vector Error Correction Model

Most commonly, the empirical method used to analyze a set of interrelated variables is a vector autoregression (VAR) model. An unrestricted VAR model with k lags of *M* variables is written:

$X_t = \sum_{i=1}^{k} \Gamma_i X_{t-i} + \gamma + e_t$ (t=1,….,T) (1)

where X is a ($M \times 1$) vector of series at time t, α_i is a ($M \times M$) matrix of coefficients relating series changes at lagged i period to current changes in series, γ is a ($M \times 1$) vector of constants, and e_t is a ($M \times 1$) vector of independent and identically distributed (i.i.d.) innovations (error terms). Equation (1) indicates that each of the M variables is a function of n lags of all M variables, including itself, a constant and a present innovation term. If some series in the set of evaluated variables are nonstationary and cointegrated, the VECM, developed by Johansen (1988), has to be utilized to study both short-run discrepancies and long-run equilibrium. A VECM model is described as follows:

$\Delta X_t = \sum_{i=1}^{k-1} \Gamma_i \Delta X_{t-i} + \Pi X_{t-1} + \gamma + e_t$ (t=1,….,T) (2)

where equation (2) is a VAR model in first differences with the addition of a lagged-level term. The lag of the series in levels (X_{t-1}) is the error correction term and a ($M \times M$) coefficient matrix (Π) contains response information of lagged levels of the analyzed variables to current changes.

The long-run, short-run, and contemporary information in the variables can be identified through the parameters in the Π matrix. To do so, first is necessary to identify the cointegration rank of ECM model. When the rank of Π is a positive number, r, and it is less than the number of series in the system, M, then $\Pi = \alpha\beta'$, where α and β are (M x r) matrices. The α matrix contains the information on the speed of adjustment and β matrix includes the cointegrating parameters.

There are several approaches to specify the rank of the cointegrating vector (r) and the optimal lag length (k). One can perform the conventional approach which is a two-step procedure involving system-based likelihood ratio (LR) tests to determine *r* and *k* sequentially. In other words, optimal lag length is first estimated by the loss metric functions and then the cointegration rank is determined.

The first step is to determine the optimal lag length (*k*) of the VAR representation via loss metric criteria functions. There are two different loss metrics methods: (i) the Schwarz-loss criterion (SIC) and (ii) the Hannan and Quinn (HQ). The first optimal lag length search criteria is argued to be inefficient in the sense that it has a tendency to over-penalize additional regressors in contrast to other metrics (Geweke and Meese 1981). The second criterion is considered to outperform the SIC by giving more consistent results in large samples (Hannan and Quinn 1979). However, both methods will be used in the estimation. The second step is to identify the rank of cointegration vectors based on a trace test (Johansen 1988), with the test statistic given by

$$\text{Trace} = -T\Sigma_{i=r+1}^{k}\ln(1-\lambda_i) \qquad (3)$$

where *T* is the number of observations and λ_i's are ordered Eigenvalues of matrix Π in equation (2).

This two-step approach has its advantages and disadvantages. According to Bruggemann and Lutkepohl (2005), the main advantages of this procedure are theoretically well accepted estimation and computational simplicity. However, unfortunately, one of the main disadvantages of this procedure is that it will likely yield low power and size distortions when the assumption of identically distributed (i.i.d.) does not hold for the error term (Wang and Bessler, 2005). In addition, the two-step procedure requires an arbitrary decision with respect to which should be first determined; the trace test or the optimum lag estimation and vice-versa. Additionally, the choice of the lag order in the first step has an important impact on the cointegration test performance (Boswijk and Franses 1992).

More recently, model selection methods based on information criteria have been proposed and implemented as an alternative to the two-step procedure (Aznar and Salvador 2002; Kapetanios 2004; Baltagi and Wang 2007). This method jointly estimates the cointegration rank and the optimal lag length in a VAR. There are two main advantages of the model selection compared with the two-step procedure. First, it eliminates the arbitrary choice associated with identifying the "appropriate" significance level when using the traditional system-based LR tests. Second, the model selection approach allows the researcher to jointly determine the lag order and cointegration rank by minimizing information criteria over a pool of models with various lag orders and cointegration ranks (Wang and Bessler 2005). Furthermore, simulation evidence by Chao and Phillips (1999) and Wang and Bessler (2005) suggest the information criteria approach can complement traditional parametric tests. As discussed in the two-step method, the HQ loss metric criteria outperforms the SIC loss criteria. Thus, only the HQ loss metric criterion is used to jointly determine the optimal length of the VAR representation and the cointegration rank.

For comparison, both the system-based LR tests (sequential) method and the model selection (joint) procedure are used to determine the optimum lag length (k) and the rank of cointegration (r).

Historical Decomposition

The dynamic response coefficients of a VAR (or VECM) are difficult to interpret (Sims 1980; Swanson and Granger 1997). Instead, the dynamic price relationship can be best summarized through the historical decomposition. Similar to previous studies (Yang and Bessler 2008; Park, Jin, and Bessler 2008; Attavanich, McCarl, and Bessler 2011), the historical decomposition method is applied to investigate abnormal market events from the unanticipated exogenous (demand or supply) shocks. The historical decomposition is derived from the moving average representation of equation (1), where the vector X_t is written as a function of the infinite sum of past innovations

$$X_t = \sum_{i=0}^{\infty} H_i \, \varepsilon_{t-i} \qquad (4)$$

where H_0 is a *MxM* matrix of moving average parameters which map historical innovations at lag i into the current position of the vector X. In other words, H_0 matrix represents the contemporaneous causal patterns between orthogonal innovations ε_t. Since e_t estimated from the VAR may exhibit off-orthogonal contemporaneous correlations, it is necessary to transform e_t to orthogonal price innovations (ε_t), such that

$$\varepsilon_t = \mathbf{A} e_t. \qquad (5)$$

The most used method to account for the orthogonal price innovations is Choleski factorization. However, the Choleski factorization is recursive and may not reflect the "true" causal patterns among a set of contemporaneous innovations (Yang and Bessler 2008). Therefore, this study utilizes the Bernanke structural factorization (Bernanke 1986) based on the directed acyclic graphs (DAGs) which has been used in previous studies (Yu, Bessler, and Fuller 2007; Yang and Bessler 2008; Park, Jin, and

Bessler 2008; Attavanich, McCarl, and Bessler 2011) and will be discussed in the next section.

Based on the orthogonalized price innovations generated by the DAG method, equation (2) can be written in terms of orthogonalized innovations as

$$X_t = \sum_{i=0}^{\infty} G_i \, v_{t-i} \qquad (6)$$

where the matrix G_0 is not diagonal, but summarizes the causal pattern in contemporaneous time between innovations in each price series.

From equation (6), one can estimate the historical partition of the vector X at any date T+i into information available at time t=T and information which is revealed at period t=T+1,T+2,…,T+i. Specifically, the vector X can be written at period T+i as

$$X_{t+i} = \sum_{s=0}^{i-1} G_s \, v_{T+i-s} + \left[\sum_{s=i}^{\infty} G_s \, v_{T+i-s} \right] \qquad (7)$$

where the first part of equation (7) is the difference between the actual price and the base projection which is the second part. The base projection utilizes information available up to time period T. Through the partition, historical decomposition allows the examination of the behavior of each price series in the neighborhood of historical events (FMD outbreaks) and allows an inference of how much each innovation contributes to the unexpected variation of X_{t+i}.

Directed Acyclic Graphs (DAG)

The DAG methodology uses algorithms of inductive causation to best represent the causal flows among variables that have been suggested by prior study or related theory. Causal relationships are represented among a set of variables using an arrow graph or picture. Arrows are a representation of the direction of the causation between variables. No arrows or sequence of arrows is allowed to represent a direct information flow from one variable back to itself.

There are many search algorithms in the machine learning literature which try to represent the causation between variables. Spirtes, Glymour, and Scheines (2000) developed the PC algorithm which has structures and outputs for inference on DAGs based on observational data. A short description of the PC algorithm is as follows: by using the notion of sepset, one starts with forming a complete undirected graph G on the vertex set V[15]. The full undirected graph shows an undirected edge between every variable of the system (every variable in the vertex set V). Edges between variables are removed successively based on zero unconditional correlation or zero partial correlation. Then, Fisher's z statistic is used to test whether conditional correlations are significantly different from zero. The conditioning variable(s) on removed edges between two variables is defined as the sepset of the variables whose edges have been removed (for disappearing zero order conditioning information). The remaining edges are then directed by considering triples X–Y–Z, such that X and Y are adjacent as are Y and Z, but X and Z are not adjacent. Direct the (remaining) edges between triples X–Y–Z as X → Y ← Z if Y is not in the sepset of X and Z. Furthermore, if X → Y, Y and Z are adjacent, X and Z are not adjacent, and there is no arrowhead at Y, then Y–Z should be positioned as Y → Z. Finally, if there is a directed path from X to Y, and an edge between X and Y, then X–Y should be positioned as X → Y. See Spirtes, Glymour, and Scheines (2000) for more information on the PC algorithm. The software TETRAD IV

[15] This part of the DAG explanation was based on Bessler and Akleman (1998).

has programmed the PC algorithm as well as other machine learning algorithms (Spirtes et al. 2005). This work utilized TETRAD IV to conduct DAG analysis.

Data

The data used here are monthly Brazilian meat prices of beef, pork, and chicken at the export, wholesale, and farm level prices from January 1996 to February 2011. All price series at the wholesale and farm levels are provided by the Instituto de Economia Agrícola (IEA 2011) and they represent price quotes from farmers located in different producing regions within the state of São Paulo. In the original dataset, the farm level prices for beef, pork, and chicken are live animals of slaughter weight. Both the beef and pork prices were transformed to Real (R$)/kgs by dividing the value of the animal by the common unit of 15 kg. There was no need to transform the farm chicken prices since they were in R$/kg. The wholesale price for chicken is the equivalent to the fresh chicken and was reported in R$/kg. As for wholesale pork prices, quotes were in half carcass and were in R$/kg. The wholesale beef prices were also in R$/kg and were assumed to be equal to the part of the animal which has the most value: the hindquarter (rear portion).

Export price data are from the Secretaria de Comércio Exterior (SECEX/MDIC 2011) and is in U.S. dollars. Therefore, the nominal exchange rate of the R$ to the U.S. dollar was calculated using data available from ERS/USDA (2011). It is important to mention that the export price was calculated as a proxy from the unit value of the Brazilian exports (total value of exports divided by the quantity). The data were transformed into logarithmic form to reduce the magnitude of the variations without changing the overall appearance and characteristics of the data.

The descriptive statistics for these nine price series are presented in Table 13. The highest meat price is found in the beef market with the export price having the greatest mean (R$5.47/kg). As expected, the mean of the export prices for all the analyzed meats was greater than either the wholesale or farm price. The largest standard deviation was found in the wholesale beef price (R$1.53/kg) and lowest in the farm chicken price (R$0.39/kg).

Table 13. Descriptive Statistics on Brazilian Meat Prices in Different Levels of the Industry, Monthly Data: January 1996–February 2011

Series	Mean	SD*	Minimum	Maximum
Chicken (R$/kg)				
Farm	1.21	0.39	0.58	2.07
Wholesale	1.74	0.55	0.96	3.09
Export	2.40	0.65	1.27	4.12
Pork (R$/kg)				
Farm	2.36	0.88	0.98	4.42
Wholesale	2.96	1.04	1.23	5.44
Export	3.64	1.06	2.02	7.04
Beef (R$/kg)				
Farm	3.41	1.39	1.40	7.28
Wholesale	4.05	1.53	2.07	8.80
Export	5.47	1.16	3.31	9.60

*SD = Standard Deviation.

Nine monthly price series are plotted in Figure 11. The export chicken prices are shown to increase the gap with respect to the wholesale and farm prices after the beginning of 2001 until the end of 2006. On the other hand, the beef export prices seem to reduce the gap with respect to the wholesale and farm prices, especially after the end of 2005. The gap between the different levels of the pork supply chain seems to be very narrow along the entire period of the data series. Overall, with the exception of the farm chicken prices series, all series seem to have a modest upward trend especially after the beginning of 2007.

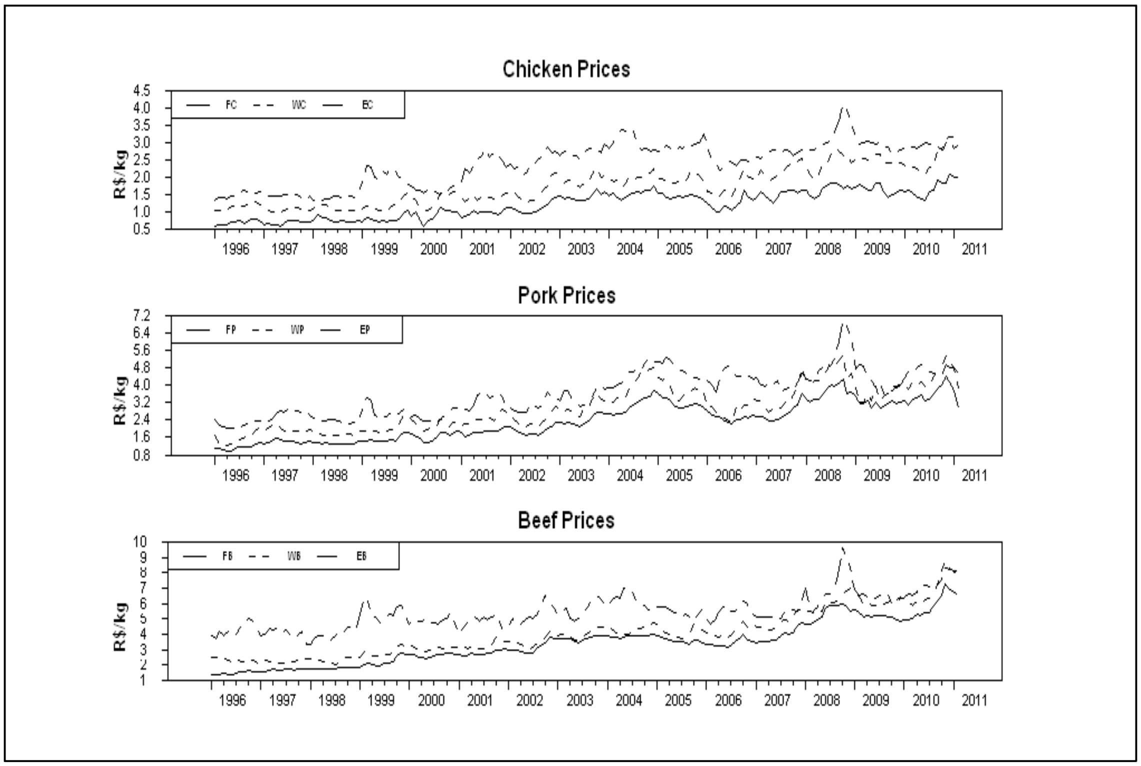

Figure 11. Monthly prices of Brazilian beef, pork, and chicken at the farm, wholesale, and export levels (January 1996–December 2011)

Note: Farm Chicken Price (FC), Wholesale Chicken Price (WC), Export Chicken Price (EC), Farm Pork Price (FP), Wholesale Pork Price (WP), Export Pork Price (EP), Farm Beef Price (FB), Wholesale Beef Price (WB), Export Beef Price (EB).

Empirical Results

In order to determine if the VECM is appropriate for these price data series, nonstationarity of each price series is tested using both Augmented Dickey-Fuller (Dickey and Fuller 1981) and Phillips-Perron (Phillips and Perron 1988) tests. The null hypothesis of both tests is that each evaluated series is nonstationary. The results in Table 14 below indicate that both the Phillips–Perron and the Augmented Dickey-Fuller test fail to reject the null hypotheses of nonstationariaty at the 5 percent significance level. In other words, since the t-statistics are all smaller than the critical value of –2.89, all price series have unit root and thus indicate the appropriateness of conducting a multivariate cointegration analysis.

Table 14. Test for Nonstationarity of Logarithms of Prices and First Differences of Logarithms of Prices for Brazilian Meat Price Series, Monthly Data: January 1996 – February 2011

Meat Price Series	Augmented Dickey-Fuller	Phillips-Perron
	t-test (k)	z-test
Chicken		
Farm	-1.87 (1)	-1.62
Wholesale	-1.71 (1)	-1.41
Export	-1.98 (1)	-1.87
Pork		
Farm	-1.69 (1)	-1.70
Wholesale	-1.83 (1)	-1.85
Export	-2.30 (1)	-1.73
Beef		
Farm	-0.95 (1)	-0.90
Wholesale	-0.78 (1)	-0.23
Export	-1.77 (2)	-2.05

Notes: Schwarz- loss is applied to determine the number of lags.

The next step is to identify the optimal lag length and the rank of cointegration of all price series. First, the estimation from the sequential method is analyzed. Table 15 below lists the outcome of Schwarz and Hannan and Quinn loss metrics on various lag lengths, with and without monthly (seasonal) dummy variables, associated with fit unrestricted VAR on the 9 logged price series. The measures in Table 15 summarize fit on the 9 different models. Half of the models incorporate 11 seasonal variables, with the remaining half having no seasonal variables. Both groups of models use a constant with zero through 12 lags (up to 12 lags were analyzed but results are reported for 6 lags in Table 15). The model with the lowest Schwarz and Hannan and Quinn loss metrics had no seasonal variables, a constant, and prices lagged a single time period.

Table 15. Loss Metrics on the Order of Lags (k) in a Levels Vector Autoregression on Log Prices for the Brazilian Livestock and Meat and 11 Seasonal Dummy Variables, Monthly Data: January 1996 –February 2011

Lags = k	Schwarz-loss	Hannan and Quinn's Φ
	Constant, k lags of Prices and No Seasonals	
1	-53.61*	-54.55*
2	-52.35	-54.14
3	-50.69	-53.33
4	-48.89	-52.39
5	-47.16	-51.53
6	-45.50	-50.75
	Constant, k lags of Prices and 11 Seasonals	
1	-52.41	-54.45
2	-50.93	-53.84
3	-49.29	-53.08
4	-47.56	-52.23
5	-45.90	-51.45
6	-44.33	-50.76

Figure 12 plots Schwarz and Hannan and Quinn loss metrics for specification from one to 12 lag length, both with and without the seasonal dummy indicator variables. The metrics calculated without seasonal dummy variables lie below those calculated with seasonal variables. Both the Schwarz and Hannan and Quinn loss metrics are minimized at one lag. Therefore, based on the results from Table 15 and Figure 12, the optimal lag length for the nine price series levels VAR representation is assumed to be equal to one and has a constant and no seasonal dummy variables.

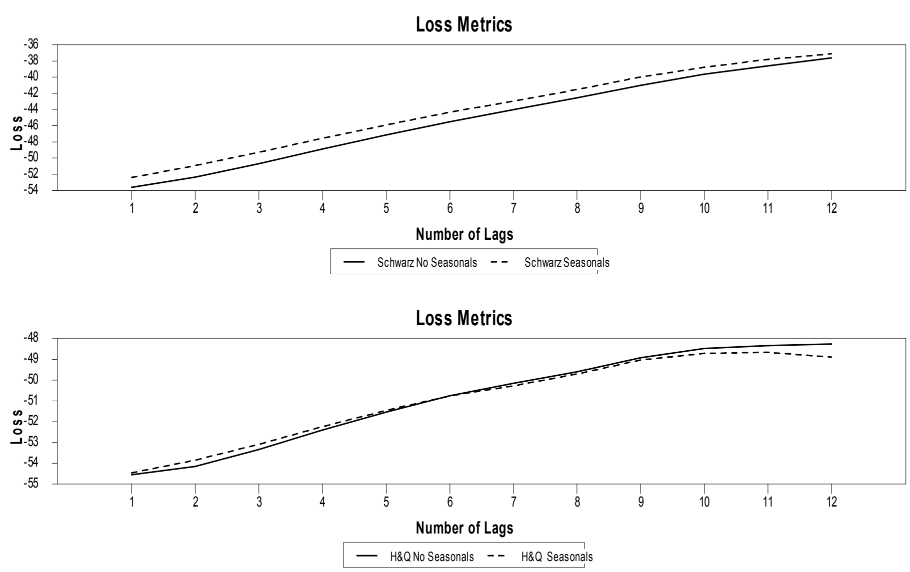

Figure 12. Schwarz Loss and Hannan and Quinn (H&Q) Loss on alternative lags with and without seasonal for Brazilian livestock and meat prices monthly data: January 1996 –February 2011.

After determining the optimal lag length for the levels VAR, trace test is used to specify the rank of cointegration vectors (the second step of the sequential estimation method). Table 16 below presents the trace test statistics on the rank of Π, which is equivalent to the number of cointegrating vectors *r*. The trace tests for both a constant within and outside the cointegrating vector(s) are presented. Table 16 is read from left to right and from top to bottom. Rank of Π being less than or equal to four in both constant within and outside the cointegration vector cases is found to fail to reject the null hypothesis. Thus, there are four cointegrating vectors regardless of the inclusion of a constant in the cointegrating space.

Table 16. Trace Statistics on Order of Cointegration on Logarithms of Prices for Brazilian Meat Price Series, Monthly Data: January 1996 –February 2011

H_0: Rank	Trace	C(5%)	Decision	Trace *	C(5%)*	Decision
r = 0	288.21	203.34	Reject	278.79	192.30	Reject
r ≤ 1	225.32	165.73	Reject	216.12	155.75	Reject
r ≤ 2	167.51	132.00	Reject	158.81	123.04	Reject
r ≤ 3	118.63	101.84	Reject	110.09	93.92	Reject
r ≤ 4	74.19	75.74	**Fail**	65.81	68.68	**Fail**
r ≤ 5	48.05	53.42	Fail	40.18	47.21	Fail
r ≤ 6	29.18	34.80	Fail	21.35	29.37	Fail
r ≤ 7	14.93	19.99	Fail	7.74	15.34	Fail
r ≤ 8	4.86	9.13	Fail	0.89	3.84	Fail

Notes: Trace and C(5%) refer to the trace statistic and critical values at the 5 percent significance level with a constant in the cointegrating vector, respectively. Trace* and C(5%)* refer to trace statistics and critical values at the 5 percent significance level with a constant outside the cointegrating vector, respectively. The trace test considers the hypothesis that the rank of Π is less than or equal to r. Entries in the column labeled "Decision" refer to the decision to "Reject" or "Fail to Reject" the null hypothesis listed in the far column. Critical values are taken from Hansen and Juselius (1995).

As discussed in the methods section, the model selection method is applied. This method determines jointly the optimal lag length and cointegration rank. The Hannan and Quinn (1979) Φ statistics (HQ), a widely used information criterion, was selected in this study. Table 17 below presents the HQ value against possible lag order and cointegration rank. Generally, the lag order of one has a lower HQ value than that associated with other lag orders. Furthermore, with lag order of one, the statistics of cointegration rank equal to four and decline through nine cointegration vectors. Thus, the HQ loss statistic suggests the model with the minimal information criterion has the lag order of one (k = 1) and four cointegration vectors (r = 4).

Table 17. Hannan and Quinn Statistics for Different Values of Cointegration Rank (r) and Lag Length (k)

Cointegration Rank (r)	Number of Lags (k)					
	1	2	3	4	5	6
1	-54.749	-54.405	-53.767	-52.911	-52.080	-51.254
2	-54.810	-54.434	-53.780	-52.906	-52.048	-51.229
3	-54.844	-54.449	-53.799	-52.851	-52.009	-51.214
4	**-54.860**	-54.477	-53.753	-52.811	-51.959	-51.206
5	-54.815	-54.439	-53.700	-52.738	-51.926	-51.183
6	-54.779	-54.397	-53.624	-52.674	-51.859	-51.109
7	-54.749	-54.366	-53.583	-52.631	-51.805	-51.058
8	-54.729	-54.349	-53.562	-52.601	-51.784	-51.022
9	-54.721	-54.339	-53.550	-52.587	-51.772	-51.009

Notes: Hannan and Quinn statistics is calculated according to the following equation: $HQ=\log(|\sum|)+(2.00)(9k+2n+1)x(\log(\log T))/T$ where $\sum$ is the error covariance matrix estimated with 9k+11+1 (the ‘‘11’’ represents the 11 seasonal dummy variables, the ‘‘1’’ represents the constant) regressors in each equation, T is the total number of observations on each series, the symbol ‘‘| |’’ denotes the determinant operator, and log is the natural logarithm. Bold indicates the minimum value of the HQ statistics.

The optimal lag length and the cointegration rank were the same when determined via the two-step procedure (sequentially) or the model selection method (jointly), which is consistent with the results from Wang and Bessler (2005). Therefore, it is concluded that the estimation will be a VECM with one lag and four cointegrating vectors.

The Impacts of the FMD Outbreak on Brazilian Meat Prices

To analyze the impacts of the FMD outbreak in Brazil that occurred in September 2005, a VECM was estimated using the data from January 1996 to August 2005, a month before the FMD outbreak in the state of Mato Grosso do Sul and two months before the beginning of the Russian import ban. Next, out-of-sample forecasting was done for meat prices for 29 months after the event and 6 months after the end of the Russian import ban on Brazilian meat (which was December, 2007). The following formula was used to estimate the percentage change of the actual price relative to the forecasted price for the analyzed period (August 2005 to June 2008):

$$\Delta P_{ij} = \frac{X_{ij} - F_{ij}}{F_{ij}} \times 100 \qquad (8)$$

where x_{ij} and F_{ij} are the actual and forecasted prices, respectively, of the meat type i (c = chicken, p = pork, b = beef) in the j market level (f = farm, w = wholesale, e = export).

Figures 13, 14, and 15 illustrate ΔP_{ij} over time for different meats following the FMD outbreak in September 2005 and, sequentially, the beginning of the Russian import ban in October 2005 through the lift of the import ban by Russia in December 2007. Following is a discussion on the impacts of the FMD outbreak on meat prices for each type of meat.

Beef Prices

In the first four months after the outbreak and three months after the Russian import ban (i.e. by January 2006), the export beef prices underwent ambiguous price movements (Figure 13). One month later (February 2006), export beef prices decreased approximately 12 percent. The export price recovered three months later (around April 2006) and stayed positive until December 2006. After December 2006, the export price dropped below zero and stayed negative for 12 months, with the largest decrease in price (nearly 13 percent) in mid-2007, until the lifting of the import ban by Russia in December 2007. In January 2008, one month after the removal of the import ban by Russia, the export price rose approximately 20 percent relative to the forecasted price.

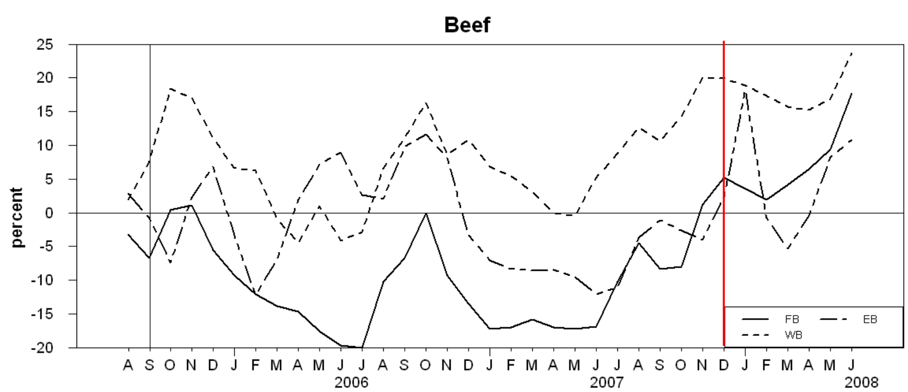

Figure 13. Percentage change in the actual beef prices relative to the forecasted beef price after the FMD outbreak, September 2005, and before the removal of the import ban by Russia, December 2007

Note: Farm Beef Price (FB), Wholesale Beef Price (WB), Export Beef Price (EB).Vertical black line is first FMD outbreak. Vertical red line is the removal of Russian import ban.

As for the wholesale beef price, the impacts of the FMD outbreak were positive in the short run (up almost 18 percent in the first two months) until dropping below zero in March 2006. The wholesale price rebounded five months later and stayed above the forecasted price for most part of the period. Differently to the wholesale price, the effects of the FMD outbreak on the farm beef price were negative for most part of the period. After two months with almost no variation, the farm beef price stayed negative for the next 12 months, decreasing 20 percent by June 2006 and only recovering in October 2006. After a one month recovery, the farm beef price declined again and remained negative for the next 13 months (until November 2007), one month before the import ban removal by Russia.

Pork Prices

The graph in Figure 14 represents the percentage change of the actual price relative to the forecasted price for the pork market. The export pork price reached the lowest percentage decrease six months after the occurrence of the FMD outbreak in September 2005 (down approximately 27 percent), such decrease was the largest in the short run for all the export price series. Three months later, the export pork price recovered, reaching zero percent variation in June 2006. However, one month later, the export pork price decreased and remained negative for the rest of the period analyzed. Overall, the percentage change of the actual price relative to the forecasted for the export pork price was negative for the entire period, with the exception of one month, and never recovered, even with the lift of the import ban by Russia in December 2007.

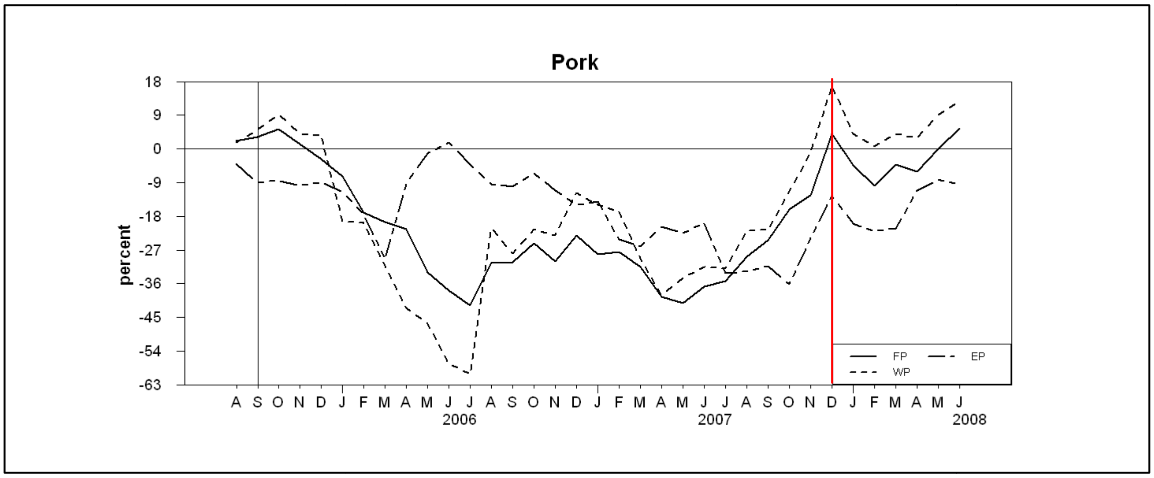

Figure 14. Percentage change in the actual pork prices relative to the forecasted pork prices after the FMD outbreak, September 2005, and before the removal of the import ban by Russia, December 2007
Note: Farm Pork Price (FP), Wholesale Pork Price (WP), Export Pork Price (EP). Vertical black line is first FMD outbreak. Vertical red line is the removal of Russian import ban.

After three months with positive variation, the wholesale pork price underwent severe negative effects due to the FMD outbreak. In July 2006, the decrease in wholesale price reached nearly 60 percent, which is the lowest decrease when compared to other wholesale prices. The actual price went above the forecasted price only in November 2007, one month before the lift of the Russian import ban. This abrupt decrease in the wholesale pork price can be explained by the wholesalers' negative perception toward the market. Regarding the farm pork price, similarly to the wholesale price, the lowest decrease occurred in July 2006 (down almost 40 percent). The recovery of the farm pork price only occurred in November 2007. Of all the farm price series, the actual price for pork spent the longest period under the forecasted price, totaling 24 months before the recovery one month prior to the lift of the import ban by Russia.

Chicken Prices

The graph in Figure 15 presents the percentage change of the actual price to the forecasted price for the chicken market. This market is interesting to analyze since chicken meat is considered to be a substitute for both beef and pork. In addition, since chickens cannot be infected by the FMD, one would expect that the Russian government would not include chicken meat as part of the ban. In the first three months, the export chicken price increased nearly 10 percent. Eventually, the Russian authorities included chicken meat in their import ban of Brazilian meats. As the ban on chicken meats was incorporated, the export chicken price declined 35 percent in April 2006. The export chicken price never recovered, not even after the removal of the import ban by the Russian authorities. This may be explained by the fact that Russia is not a major importer of Brazilian chicken (less than 10 percent of import share) as it is of both beef and pork (more than 40 percent of import share).

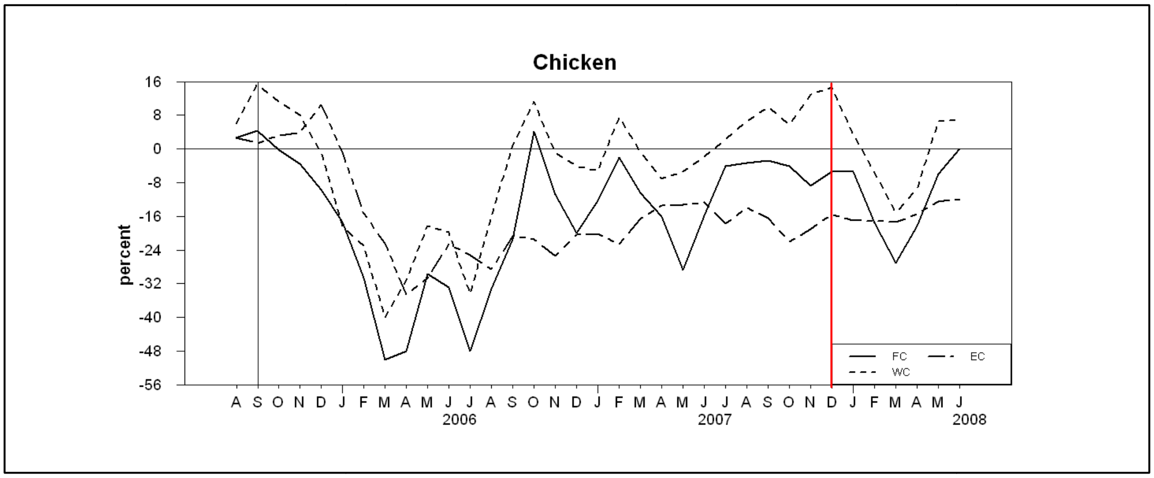

Figure 15. Percentage change in the actual chicken prices relative to the forecasted chicken prices after the FMD outbreak, September 2005, and before the removal of the import ban by Russia, December 2007
Note: Farm Chicken Price (FC), Wholesale Chicken Price (WC), Export Chicken Price (EC). Vertical black line is first FMD outbreak. Vertical red line is the removal of Russian import ban.

The wholesale and farm chicken prices were affected in a similar manner to the export price. After increases in the first three months, both prices had drastic declines three months later (March 2006). However, both prices rebounded six months later (in October 2006). For most part of the analyzed period, the wholesale and farm prices for chicken were both below their respective forecasted prices.

The Impacts of the FMD Outbreak on Price Margins of the Brazilian Meat Supply Chain

To analyze the impacts of the FMD outbreak along the supply chain, the changes in the price margin were estimated for the export, wholesale, and farm levels within each market. The changes in the price margins along the supply chain due to the FMD outbreak are

$PM_{i,ef} = (x_{ie}-x_{if})-(F_{ie}-F_{if})$ export-to-farm (9)

$PM_{i,wf} = (x_{iw}-x_{if})-(F_{iw}-F_{if})$ wholesale-to-farm (10)

$PM_{i,ew} = (x_{ie}-x_{iw})-(F_{ie}-F_{iw})$ export-to-wholesale (11)

where PM is the price margin at level *l* relative to level *m* and can be widen by the FMD outbreak ($PM_{i,lm} > 0$), narrowed ($PM_{i,lm} < 0$), or has no effect on the price margin ($PM_{i,lm} = 0$). Figures 16, 17, and 18 show the changes in the price margins for different meats resulting from FMD outbreak in September 2005 and, sequentially, the beginning of the Russian import ban in October 2005 through the lift of the import ban by Russia in December 2007.

Beef Prices

Figure 16 shows the changes in the price margins resulting from the FMD outbreak along the beef supply chain. The price margin at the export level relative to the farm and wholesale levels decreased in the first month after the FMD outbreak (down R$0.50/kg and R$1.20/kg, respectively) and only recovered two months later (December 2005). This recovery only lasted one more month then decreased again approximately R$0.20/kg and R$0.80/kg for both farm and wholesale levels, respectively, in February 2006. The price margin at the export level relative to the farm level stayed positive for the remainder of the period except for two periods of two months (from June 2007 to August 2007 and October 2007 to December 2007) in 2007. The price margin at the export level relative to the farm and wholesale levels rebounded after the removal of the import ban by Russia (by January 2008). The wholesale-to-farm price margin was positive for the entire period of the analysis.

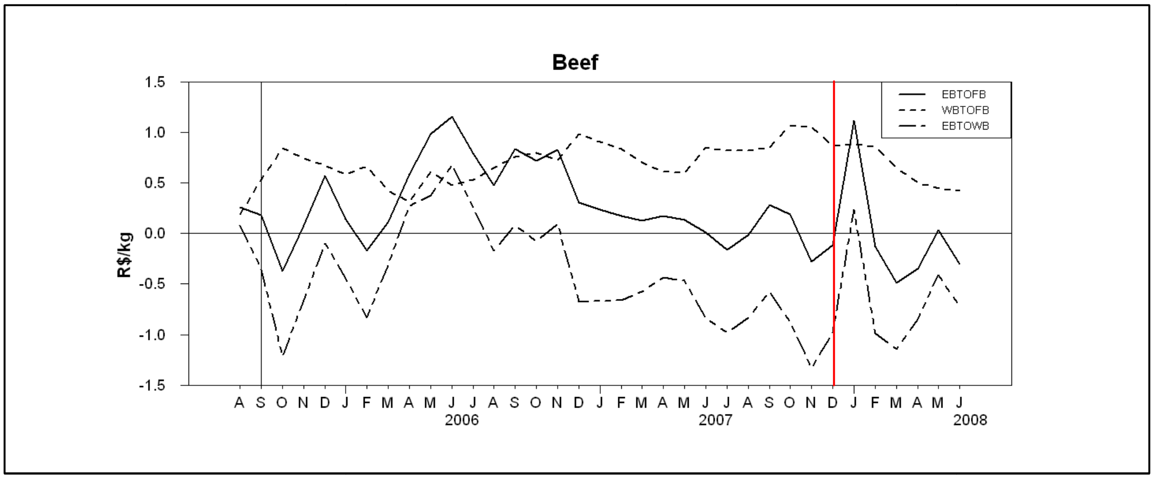

Figure 16. Changes in the price margin along the beef supply chain after the FMD outbreak, September 2005, and before the removal of the import ban by Russia, December 2007

Note: Farm Beef Price (FB), Wholesale Beef Price (WB), Export Beef Price (EB).Vertical black line is first FMD outbreak. Vertical red line is the removal of Russian import ban.

Pork Prices

Figure 17 shows the changes in the price margins resulting from the FMD outbreak along the pork supply chain. The results for the price margin at the export level relative to farm and wholesale levels for the pork are similar to the results from the beef market. The major difference between the results of these two markets is that, at the end of the analyzed period (after the removal of the Russian import ban), both the export-to-farm and export-to-wholesale margins never recovered completely, staying negative for the following three months (from December 2007 to April 2008). For the whole period of the analysis, the wholesale-to-farm price margin was stationary in the range of –R$0.50/kg to R$0.50/kg, which can indicate that there was some type of instability between the farm and wholesale markets.

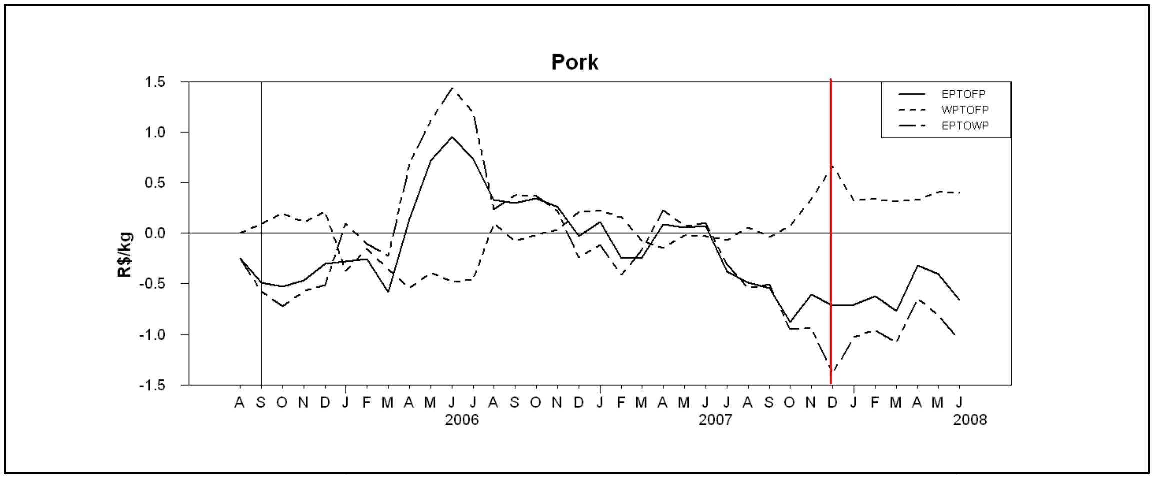

Figure 17. Changes in the price margin along the pork supply chain after the FMD outbreak, September 2005, and before the removal of the import ban by Russia, December 2007
Note: Farm Pork Price (FP), Wholesale Pork Price (WP), Export Pork Price (EP). Vertical black line is first FMD outbreak. Vertical red line is the removal of Russian import ban.

Chicken Prices

The graph in Figure 18 illustrates the changes in the price margins resulting from the FMD outbreak along the chicken supply chain. In this market, the price margins at the export level relative to the farm and wholesale levels had an upward trend in the first three months after the outbreak, then downward trend between month four (December 2006) and nine (May 2006). Both the export-to-farm and export-to-wholesale margins stayed negative for the remainder of the analyzed period, with price margin ranges of –R$0.25/kg to –R$0.75/kg. Even after the removal of the import ban by the Russian authorities, the price margins at the export level relative to the farm and wholesale levels stayed negative. Likewise the beef market, the wholesale-to-farm price margin was positive for the entire period, with the exception of three months (from January 2006 to

April 2006). This indicates that these two markers were stable with no abrupt changes in prices for the period analyzed.

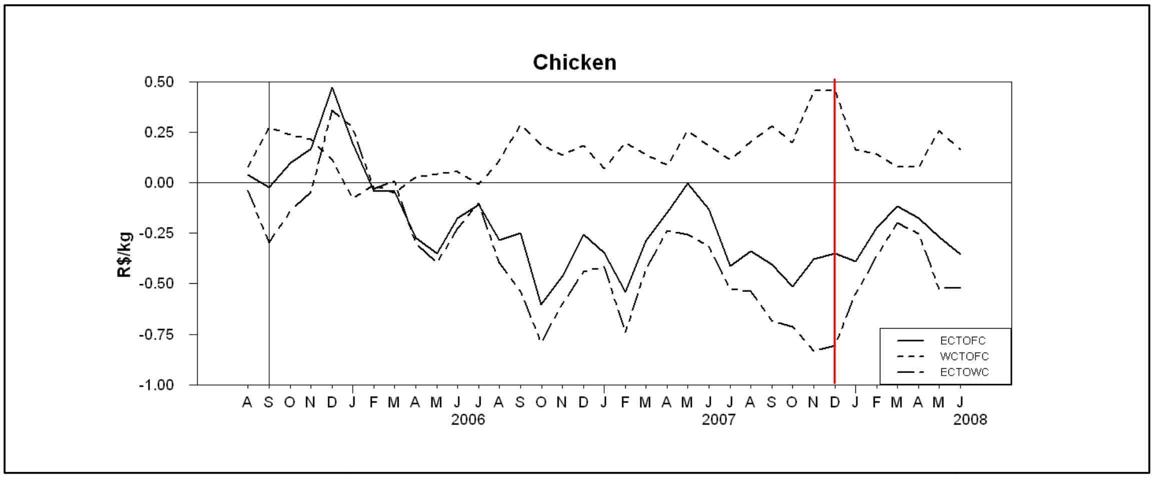

Figure 18. Changes in the price margin along the chicken supply chain after the FMD outbreak, September 2005, and before the removal of the import ban by Russia, December 2007

Note: Farm Chicken Price (FC), Wholesale Chicken Price (WC), Export Chicken Price (EC). Vertical black line is first FMD outbreak. Vertical red line is the removal of Russian import ban.

The impacts of the FMD outbreak on dynamic price interdependence

In this section, historical decomposition was used to analyze potential changes in interdependence among prices due to the FMD outbreak. Analysis is performed to evaluate how much each price innovation accounts for the atypical variation of a certain price due to the FMD outbreak.

By using the correlation matrix of price innovations estimated from the unrestricted VECM estimated, it is employed the TETRAD IV software with the PC algorithm to determine the contemporaneous causal flows between price innovations.

The results in Figure 19 indicate that the innovations in the farm prices directly affected the wholesale prices in all the meat markets. The innovation of the farm pork price also directly affected the farm beef price which is an interesting result since in the literature the opposite holds (Bessler and Akleman 1998). Beef and pork export price changes appear to cause the level prices for both meats, which was expected since the Brazilian meat industry is very export oriented and exports play a major role in the global meat trade. Interesting to note was the result of export chicken price directly causing both the beef and pork export prices. It is difficult to explain the main reason for the export chicken directly cause both export beef and export pork. Perhaps the substitution effects are very important for the Brazilian meat exporters.

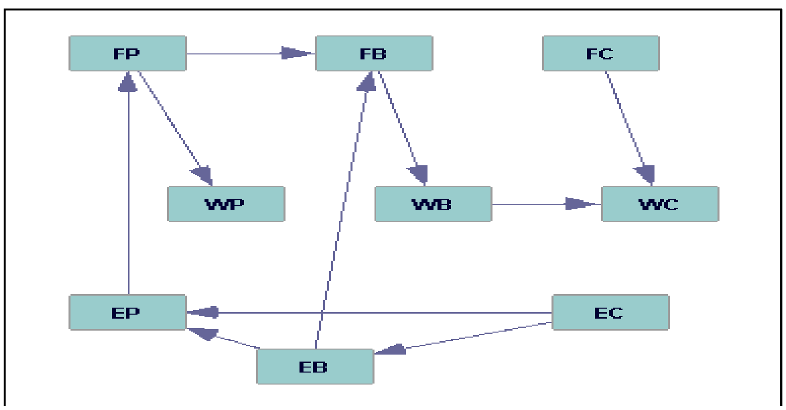

Figure 19. Contemporaneous causalities based on DAG results using the PC algorithm.
Note: Farm Chicken Price (FC), Wholesale Chicken Price (WC), Export Chicken Price (EC), Farm Pork Price (FP), Wholesale Pork Price (WP), Export Pork Price (EP), Farm Beef Price (FB), Wholesale Beef Price (WB), Export Beef Price (EB).

After implementing the contemporaneous relationship identified by the PC algorithm (Figure 19) in the VECM representation, it is evaluated the historical decomposition for the export price for beef as well as the export price for pork[16]. The contribution of each price to historical decomposition is employed over 35 months: one month before the event (August 2005), the month the FMD outbreak occurred (September 2005), and 33 months after the event. Other important months in the analysis are month 1 (October 2005) and month 27 (December 2007) which are the beginning and the end of the Russian import ban on the Brazilian meat exports, respectively.

Dynamic Interdependence in the Export Beef Price

The bar chart in Figure 20 illustrates the contribution of each price series, either negative or positive, to the atypical change in the export beef price responding to the FMD outbreak (September 2005) and the Russian import ban (October 2005).

[16] Historical decomposition figures for the other price series are available upon request.

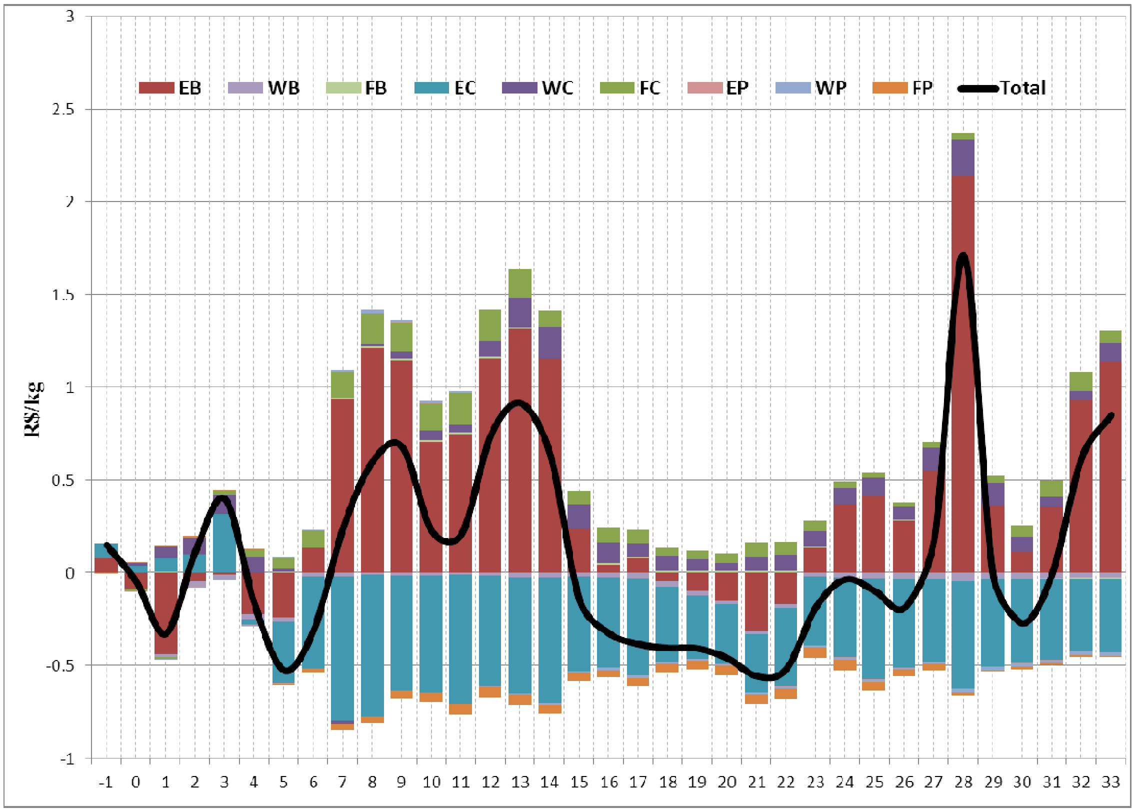

Figure 20. Contribution of each price series on the innovation of the export beef price when responding to the FMD outbreak (and Russian import ban) in September 2005 (in October 2005)

Note: Each stacked bar represents positive or negative contribution of nine price series to innovation of export beef price. The solid line represents the deviation of the actual export beef price from the base projection. The x-axis is the number of months before and after the event while the event occurred in month zero. Farm Chicken Price (FC), Wholesale Chicken Price (WC), Export Chicken Price (EC), Farm Pork Price (FP), Wholesale Pork Price (WP), Export Pork Price (EP), Farm Beef Price (FB), Wholesale Beef Price (WB), Export Beef Price (EB).

The deviation of the actual export beef price relative to the base projection, which is represented by the solid line, indicates that the FMD outbreak in September 2005 (month zero) had an immediate negative impact on the export beef price. The introduction of the Russian import ban (month 1) further decreased the export beef price by nearly R$0.35/kg, where most of the variation was mainly due to its own price innovation. In the following two months, the deviation of the actual price relative to the base price increases by R$0.40/kg, where, unexpectedly, the positive variation was attributed to the price innovations of the chicken export price. Conversely, in the following three months (from months 4 to 6), the price innovations of its own series and chicken series played a major role in the downward movement of the export beef price. For most of the next seven months (from months 7 to 14), the deviation of the actual export beef price relative to the base projection was positive, where the positive deviation was explained by own price and farm chicken price innovations. For the same period, the deviation of the export beef price to the forecasted price was not larger due to the negative contribution of the chicken export price innovations.

From months 15 to 27, the deviation of the actual export beef price relative to the forecasted projection was negative for the entire period. This indicates that the FMD outbreak negatively affected the export beef price for this period. In addition, it was found the lowest negative variation of the deviation for the 34 months, which occurred in month 22 (approximately -R$0.50/kg). It is interesting to mention that, in five months of this 12 month period, the own price innovation played a major role in the negative deviation. As expected, most of the negative export beef price variation was mainly attributed to the export chicken price innovation contributions.

The most important result of the historical decomposition of the export beef price series is revealed in month 28 (January 2008), which is exactly one month after the removal of the import ban by the Russian government. As noted in Figure 20, the deviation of the actual export beef price relative to the forecasted price reached its peak (approximately R$1.70/kg) for the entire study period in month 28. The positive variation of the export beef price for that month was mainly due to the shocks in its own price (R$2.13/kg). If the negative contributions of the beef substitute (chicken) had not been significant (total of approximately R$0.60/kg), the positive variation would have the potential of reaching nearly R$2.40/kg. One can conclude that the removal of the Russian ban on Brazilian meat imports had a substantial positive influence on the beef industry supply chain in general, and the export level in particular.

Dynamic Interdependence in the Export Pork Price

Similarly to Figure 20, the bar chart in Figure 21 below presents the contribution of each price series, either negative or positive, to the atypical change in the export pork price responding to the FMD outbreak (September 2005) and the Russian import ban (October 2005).

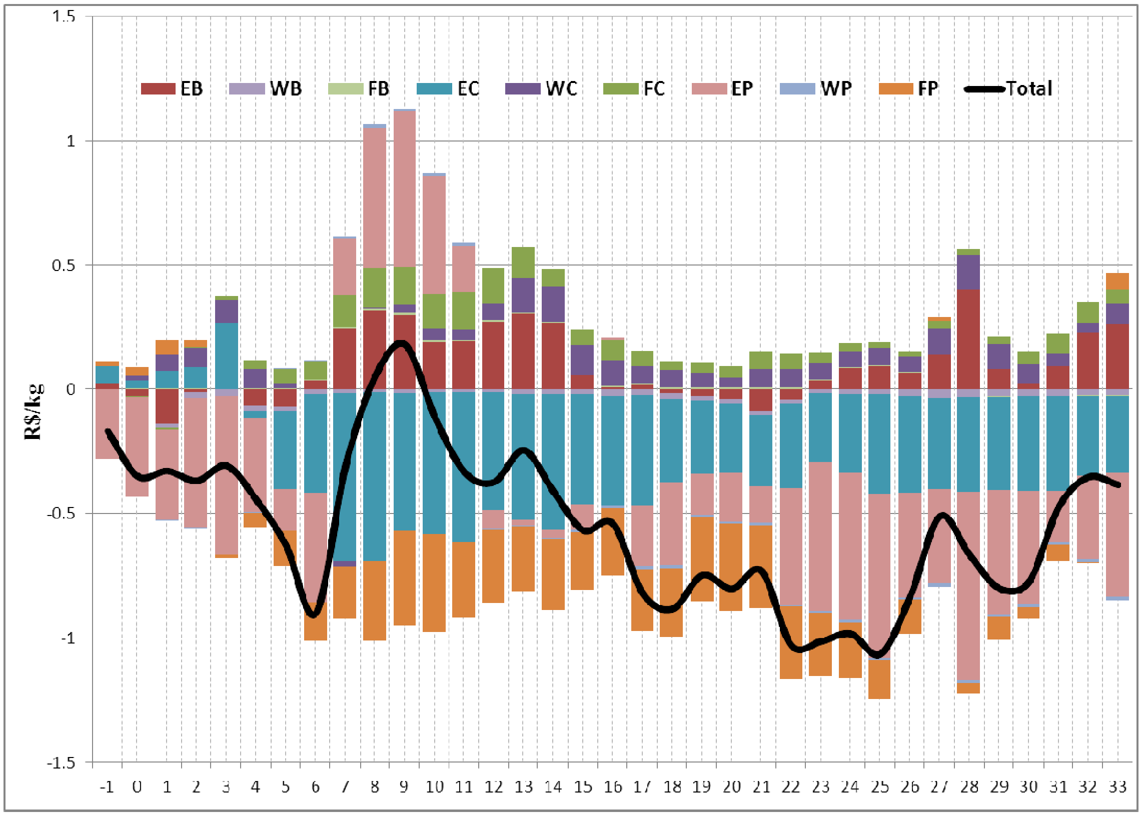

Figure 21. Contribution of each price series on the innovation of the export pork price when responding to the FMD outbreak (and Russian import ban) in September 2005 (in October 2005)

Each stacked bar represents positive or negative contribution of nine price series to innovation of export pork price. The solid line represents the deviation of the actual export pork price from the base projection. The x-axis is the number of months before and after the event while the event occurred in month zero. Farm Chicken Price (FC), Wholesale Chicken Price (WC), Export Chicken Price (EC), Farm Pork Price (FP), Wholesale Pork Price (WP), Export Pork Price (EP), Farm Beef Price (FB), Wholesale Beef Price (WB), Export Beef Price (EB).

In the first six month after the occurrence of the FMD outbreak and five months after import ban by Russia, the deviation of the actual export pork price relative to the base projection exhibited a negative trend, with the most negative deviation (-R$0.90/kg) occurring in month 6 (March 2006). For these first six months, the largest contribution for the price variation was its own price innovation followed by the export chicken price.

In the following three months, the deviation of the actual price relative to the base price began a upward trend, reaching a positive variation of approximately R$0.20/kg in month 9 (June 2006). For these three months, the positive variation was attributed to the price innovations of its own price and export beef price. On the other hand, the negative price innovations of the export chicken price and the farm pork price played a major role in the downward movement of the export pork price.

From months 10 to 27, the deviation of the actual export pork price relative to the forecasted projection was negative for the entire period. For the period between July 2006 (month 10) to January 2007 (month 16), the export chicken price was the major contributor of the negative variation followed by farm pork price. Beginning in February 2007 (month 16), the own price innovation increased its participation in explaining the negative deviation of the actual export pork price relative to the base projection. In month 25 (October 2007), the lowest negative variation of the deviation for the 35 month period was found, which is equivalent to approximately -R$1.10/kg, and most of it is explained by its own innovation followed by the export price for chicken and the farm price for pork. Similarly to the beef export price analysis, most of the negative variation was mainly attributed to the export chicken price innovation contributions.

Unlike the historical decomposition of the export beef price series, the removal of the import ban by the Russian authorities was not sufficient for the recovery of the export price for pork. As indicated in Figure 21, the deviation of the actual export pork price from the base projection remained negative even with the lifting of the import ban in month 27. Interesting to note is that one month after the removal of the ban (month

28), the own price innovation, with -R$0.75/kg, contributed the most to the negative deviation. The positive price innovation for that month was mainly due to the shocks of the export beef price (R$0.40/kg). In contrast to the export beef price, one can conclude that the removal of the Russian ban on Brazilian meat imports presented no positive impacts on the pork industry supply chain in general, especially at the export level. Likewise in the beef case, the export chicken price was found to negatively impact the export pork pricing during the period of analysis.

Conclusions

This study estimates the market impact associated with the 2005 FMD outbreak in Brazil, along with the consequences of the meat import ban by Russia, and its effects on the Brazilian meat supply chain. By using time series methods, mainly VECM and historical decomposition of price innovation, complemented by DAGs, it was discovered that the 2005 FMD outbreak caused a price shock to the Brazilian meat market. Beef, pork, and chicken export prices all decreased after the FMD outbreak. However, for certain commodities, the export prices recovered over time, while others did not. For example, export pork and export chicken prices never fully recovered after the import ban imposed by Russia. On the other hand, after months under negative impacts, the export beef price had a complete and strong recovery after the Russian government opted to lift the import ban.

As for the farm prices for the different type of meats, the beef and pork prices underwent a negative impact due to the FMD outbreak only rebounding after the lifting of the import ban by Russia. The farm chicken price surprisingly never recovered during the analyzed period. As for the wholesale prices, the beef series was positive for most of the analyzed period, while the pork and chicken series were shown to undergo negative impacts.

The impacts of the FMD outbreak on price margins of the Brazilian meat supply chain were different for the three different types of meat. For the beef market, the price margin at the export level relative to the farm level decreased in the first month after the FMD outbreak and only recovered two months later (December 2005). After months of positive outcomes, the price margin at the export level relative to the farm level decreased to negative values until rebounding post-removal of the import ban by Russia.

As for the pork supply chain, after six months of negative outcomes, the price margin at the export level relative to farm and wholesale levels were positive for only eleven months. Contrary to the beef supply chain, at the end of the analyzed period (after the removal of the Russian import ban), both the export-to-farm and export-to-wholesale margins never recovered completely.

In the chicken supply chain, the price margin at the export level relative to the farm and wholesale levels started with an upward movement for first four months then declined for the rest of the period. Even after the removal of the import ban Russia, the price margin at the export level relative to the farm and wholesale levels never recovered.

The causal flows among the nine price series analyzed in this study are identified by machine learning algorithms such as the PC algorithm. The results suggest that the farm level price innovation has played a major role in explaining the innovations of the wholesale prices in all three meat markets. The innovation of the beef and pork export prices directly caused the farm level prices for both meats which was expected since the Brazilian meat industry is very export oriented and plays a major role in the global meat trade. Interesting to note was the result that export chicken price innovations directly causing both the beef and pork export prices. This can be explained by a possible substitution effect which perhaps is present in the data series.

Historical decomposition is used to identify the interdependence among the price series and its change after the FMD outbreak and the import ban by Russia. The historical decomposition of the export beef price and export pork price are evaluated based on the contemporaneous relationship identified by the DAGs method. Regarding the export beef price, most of the positive deviation of the actual price to the base projection was mainly explained by the price innovations of its own price series. As for the negative deviation, the price innovations of the export chicken series played a major role in the downward movement of the export beef price. The most important result of the historical decomposition analysis was the possibility that the removal of the Russian ban on Brazilian meat imports had a major positive influence on the beef industry supply chain in general, especially at the export level.

For most of the period analyzed, the deviation in the actual export pork price to the base projection was negative. Similarly to the export beef price historical decomposition, the largest contributor to the negative deviation was the export chicken price. Results suggested ambiguous effects of the own price innovations to the export pork price. Initially, the positive deviation of the actual export pork price to the base projection was explained mostly by its own price innovations. Eventually, the own price innovation of the export pork price ended up accounting for most of the negative variation. Regarding the import ban by Russia, the removal of the import barrier in December 2007 was not enough for the export pork market to recover to previous levels.

CHAPTER V

CONCLUSIONS, LIMITATIONS AND FUTURE RESEARCH

This dissertation examined the effects of two important factors that impact international agricultural trade: transportation infrastructure and animal health regulations. Specifically, using a spatial, intertemporal equilibrium model of the international cotton industry, and time series econometrics methods, the following were examined

- The impacts of the Panama Canal expansion on the world cotton industry by evaluating with detail the U.S. cotton export flows, changes in export levels, and warehouse revenues.
- The effects of port improvements in Brazil on the world cotton industry with detailed analysis on the Brazilian cotton exports by ports and states, changes in export levels, and producer revenue.
- The impacts of the foot and mouth disease outbreaks on the Brazilian meat market for different levels of the industry (export, wholesale and farm).

In Chapter II, a spatial, intertemporal equilibrium model of the international cotton sector was utilized to evaluate the effects of the PCE on the world cotton industry, with more emphasis given to the U.S. cotton industry. By assuming that the canal expansion will be completed in 2014, three scenarios were analyzed. Due to the PCE, scenario one and two assumed 10 and 28 percent reductions in ocean freight rates from the U.S. Gulf and Atlantic ports to Asian and Pacific importing countries, respectively.

Scenario three simultaneously assumed scenario two plus a 10 percent reduction in ocean freight rates from Los Angeles-Long Beach ports to Asian and Pacific importing countries.

Some consistent results were observed throughout all three scenarios. In general, all scenarios suggested that cotton exports to Gulf and Atlantic ports would increase considerably with the port of Savannah leading the way. On the other hand, the Long Beach – Los Angeles ports would decrease its participation in total U.S. cotton exports significantly. Overall, the percentage of U.S. cotton exports via the Panama Canal relative to the total U.S. cotton exports would increase. Furthermore, total U.S. cotton exports were expected to increase due to the PCE. However, in relative terms, the maximum amount which the U.S. total exports would increase is equivalent to a 2.2 percent increase. It is interesting to note that the scenario three, where the Long Beach – Los Angeles ports are assumed to reduce freight costs, generates the most gain for the U.S. with respect to exports and warehouse revenues. As for the other competing countries, for all analyzed scenarios, these losses in exports, prices, and revenues are very modest in relative terms.

In Chapter III, the same spatial price equilibrium model of the international cotton sector was used; however, the emphasis of the study was on the Brazilian cotton industry. By March of 2012, the port of Salvador is expected to have undergone relevant improvements in its facilities and physical structure. As a result of these improvements, the port of Salvador is expected to become more competitive and attract ocean shipping companies which are willing to export products directly to Asian importing markets.

Based on the assumption that port improvements would be completed and new direct ocean shipping lines will be offered, scenarios with different reduction in export cost for the port of Salvador were examined.

For all scenarios, the new direct ocean shipping lines from the port of Salvador to Asian importing countries were found to be important for the cotton exporters in Brazil, especially for the producers in the state of Bahia. As the ocean shipping carriers introduce their new shipping lines, the analysis indicated a shift in Brazil cotton export flows from the port of Santos to the port of Salvador as well as an increase in exports and producer revenues. In addition, results suggested that the state of Bahia would have the potential of becoming the largest cotton exporting state in Brazil. As for the impacts in other competing exporting countries, modest declines in exports, prices, and revenues were shown to occur.

Finally, in Chapter IV, the impacts of the FMD outbreak on the Brazilian meat market for different levels of the industry (export, wholesale and farm) was examined. The imposition of an import ban by Russia on Brazilian meat exports was also investigated. By using time series methods, mainly VECM and historical decomposition of price innovation, complemented by DAGs, it was found that the 2005 FMD outbreak along with the Russian import ban caused a temporary price shock to the Brazilian meat market. Export pork and export chicken prices were found to not fully recover after the outbreak and the import ban imposed by Russia. On the other hand, the export beef price had a complete recovery after the Russian government opted to lift the import ban. As for the farm prices for the different type of meats, the beef and pork prices only rebounded after the lifting of the import ban by Russia. The farm chicken price surprisingly never recovered during the analyzed period. As for the wholesale prices, the beef series was positive for most of the analyzed period, while the pork and chicken series were shown to undergo negative impacts.

The impacts of the FMD outbreak on price margins of the Brazilian meat supply chain were also analyzed. For the beef market, the price margin at the export level relative to the farm level underwent ups and downs rebounding post-removal of the import ban by Russia. As for the pork supply chain, contrary to the beef supply chain, the price margin at the export level relative to farm and wholesale levels never recovered completely. Similarly, for the chicken supply chain, even after the removal of the import ban Russia, the price margin at the export level relative to the farm and wholesale levels never recovered.

To analyze dynamic price relationships between the price series, historical decompositions method is performed for the export beef price and the export port price. For the export beef price most of the positive deviation of the actual price to the base projection was mainly explained by the price innovations of its own price series. As for the negative deviation, the price innovations of the export chicken series played a major role in the downward movement. Importantly, the removal of the Russian ban on Brazilian meat imports had a major positive influence on explaining the recovery of the export beef price. As for the historical decomposition of the export pork price, the largest contributor to the negative deviation was the export chicken price. Results suggested ambiguous effects of the own price innovations to the export pork price. Even after the removal of the import ban by Russia, the export pork price never fully recovered to previous levels.

Given the results presented above, this research makes a significant contribution to not only the academic literature as a whole, but also by improving the information available to decision makers. Through these results, decisions regarding the PCE impacts can be more tailored to providing agents in the cotton industry regarding potential gains and losses. It can also contribute to the authorities in the Long Beach – Los Angeles ports to how improve their port efficiencies. As for the analysis on the port of Salvador improvements and its impacts on the Brazilian cotton industry, certainly this study will give a feedback to local authorities with respect to investments in port infrastructure and how they can assess them. Finally, the study presented in Chapter IV attempted to clarify for the Brazilian meat industry how the effects of the 2005 FMD outbreak along with the Russian import ban affected the export price levels as well as domestic price levels (wholesale and farm).

This work embodies a myriad of limitations which can be summarized as follows:

- The spatial price equilibrium model of the international cotton industry considered the transportation rates as determined and given exogenously. In other words, the model assumes that the transportation rates for all types of modes (truck, tail, and vessel) to be fixed and invariant. This can be changed by implementing a transportation market into the model which would give supply and demand relationship for transportation rates. By doing so, the transportation rates would be endogenously determined by the supply and demand of transportation for each mode.

- Another important aspect to be considered in the spatial price equilibrium model of the international cotton industry is the backhaul problem. Since cotton is considered to be a backhaul cargo, it would be interesting to introduce into the model some type of backhaul weight based on the importing port in the U.S. In other words, ports located in large importing demand cities/regions area (e.g. Los Angeles and Long Beach ports) would be considered as more attractive importing ports for shipments from China. This would potentially generate different results than what was found in Chapter II.
- Another limitation of the spatial price equilibrium model developed in this study is its static nature. The model solution generates solutions which are static and do not consider the effects over time. In other words, as a time dimension is introduced into the model, the results may vary as supply and demand relationships respond over time. A solution to this limitation is to transform the current model into a dynamic setting. This would allow the supply (demand) price of the commodity at any supply (demand) market in any given time period to depend upon, in general, the supply (demand) of the commodity at every supply market in every time period.
- The spatial price equilibrium model developed is deterministic. This limitation can be improved by transforming it to a stochastic framework. To do so, one way to start is to assume randomization of certain important parameters such as

supply and demand prices as well as transportation rates. This would improve the deterministic framework by allowing the model to predict price volatility and volume of trade.

This work opens many possibilities for future research. To mention just a few potential directions:

- In Chapters II and III, the potential impacts of the Panama Canal expansion could have been extended to analyze the Brazilian market. Although the majority of the Brazilian exports to Asian importing countries are via Africa‘s Cape of Good Hope, it would be interesting to analyze if the Panama Canal can actually impact the Brazilian cotton exports.
- Similarly, by analyzing a combined scenario of canal expansion with the port of Salvador improvements, the results of the model may give very interesting and more accurate results. Since both of these transportation improvements are expected to occur in the near future, the gains for the U.S. and Brazil may be different than the current analyzed scenarios. As for the world cotton trade, a combined scenario would potentially show an increase in world cotton trade not observed in the scenarios previously analyzed.
- Another future research question to be addressed is to assume that the railroad companies in the U.S. would respond to the canal expansion by adopting more competitive rail rates. This would be expected since the model results show a reduction in the participation of the West Coast ports to the total cotton exports.

In summary, this scenario could generate large gains for the cotton industry in the U.S.

- In Chapter III, the actual effect of cattle slaughter on meat supplies was not analyzed. For example, the impacts of the mass slaughter of cattle in the event of the FMD outbreak could have been estimated. By having data on quantity, the effects of shortage of supply on the meat market could have been quantified. A larger system, including quantity data, would provide a more complete understanding of the impacts of animal disease outbreaks.

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APPENDIX A

METHODOLOGY: INTERNATIONAL COTTON TRANSPORTATION MODEL

Quadratic Programming Model

The spatial, intertemporal equilibrium model of the international cotton industry is a quadratic programming model that generates interregional trade flows and prices. The objective function specifies the maximization of producer and consumer surplus minus cotton handling, storage, and transportation costs (Samuelson 1952; Takayama and Judge 1971). The model includes considerable detail on regional excess supplies and demands as well as transportation, storage, and cotton handling costs in both the U.S and Brazil. Other cotton trading countries are considered as either an excess supply or an excess demand region.

The international cotton model employed in this analysis includes 567 excess supply regions and 46 excess demand regions. The excess cotton supply regions include 410 U.S. regions (warehouses), 152 Brazilian regions (farm level) and 5 foreign regions (Australia, India, Sub-Sahara Africa, Uzbekistan, and all other exporting countries). Included among the excess cotton demand regions are 11 U.S. regions (domestic mills), 21 Brazilian regions (domestic mills), and 15 foreign demand regions (Bangladesh, China, EU-27, Hong Kong, Indonesia, Japan, Mexico, Pakistan, Rest of South America, South Korea, Taiwan, Thailand, Turkey, Vietnam, and all other importing countries).

The U.S component of the model is a detailed transportation network that links excess supply regions with excess demand regions and ports via truck (truck chassis and flatbed) and rail. Excess supply regions are connected to excess demand regions within the U.S. via truck. There are 15 U.S. ports which are linked to the excess supply regions either by truck direct shipments or truck to 5 intermodal (rail loading) sites. These 15 U.S. ports are then linked to the excess demand regions via vessels. The exception is Mexico where land border port crossings are used exclusively. A representative port in each of the foreign excess supply regions is also linked by ocean freight costs to each of the foreign excess demand regions.

Similarly, the Brazilian component was established by 152 excess supply sub-regions/states and 21 excess demand regions (mills) in Brazil. The 152 cotton excess supply sub-regions/state in Brazil were at the municipality level for the states of Mato Grosso, Bahia, and Goiás. The remaining excess supply regions in Brazil were considered at the state level. The excess demand regions in Brazil were represented at the state level by determining their physical location within the primary cotton consuming states. Excess supply regions are connected to excess demand regions within Brazil solely by truck. Five ports are linked to the excess supply regions by direct truck shipments. These five Brazilian ports are then linked to the excess demand regions via vessels.

Routinely, a major portion of excess supply is exported or consumed domestically during the harvest period. The rest of the production is stored for alternative shipment to port terminals or other domestic demand locations. The quantities consumed and supplied per quarter are endogenously determined by the model. No cotton stocks were considered in the model. The assumptions for the model were that cotton is a homogenous commodity, nondiscriminatory trade policies exist, and system of balanced equations prevailed. The objective of the model was to maximize the summation of producer surplus and consumer surplus subtracting transportation and handling costs.

Mathematical Representation of the Model

A spatial equilibrium model was developed that uses quadratic programming to maximize producers' and consumers' surplus. Through the optimum solution, welfare measures can be achieved as a result of changes in the transportation and handling costs. The solution gives the level of supply (demand) for each selected excess supply (demand) location in both the U.S. and Brazil and other major cotton exporting (importing) countries. Cotton flows from supply locations to domestic demand regions, port areas, or transhipment locations were determined by the optimum solution. The price levels at shipping, transhipment, and final destination locations were captured by examining the dual variables.

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

(1) $$\text{Max } NW=\{\sum_q\{-\sum_i\left(\alpha_{iq}+0.5\beta_{iq}S_{iq}\right)S_{iq}-\sum_b\left(\alpha_{bq}+0.5\beta_{bq}S_{bq}\right)S_{bq}$$

$$-\sum_f\left(\alpha_{fq}+0.5\beta_{fq}S_{fq}\right)S_{fq}+\sum_j\left(\alpha_{jq}-0.5\beta_{jq}D_{jq}\right)D_{jq}$$

$$+\sum_l\left(\alpha_{lq}-0.5\beta_{lq}D_{lq}\right)D_{lq}+\sum_d\left(\alpha_{dq}-0.5\beta_{dq}D_{dq}\right)D_{dq}\}$$

$$-\{\sum_m(\sum_i(\sum_r C_{irm}T_{irqm}+\sum_p C_{ipm}T_{ipqm}+\sum_j C_{ijm}T_{ijqm})$$

$$+(\sum_b(\sum_z C_{bzm}T_{bzqm}+\sum_l C_{blm}T_{blqm}))\}$$

$$-\sum_r(\sum_p C_{rpq}T_{rpq})-\sum_d(\sum_p C_{pdq}T_{pdq}+\sum_z C_{zdq}T_{zdq}+\sum_f C_{fdq}T_{fdq})\ \}$$

subject to:

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

(3) $\sum_m(\sum_l T_{blqm}+\sum_z T_{bzqm})+H_{qq+1}\leq S_{bq}+H_{q-1q}$ for all b and q;

(4) $\sum_p T_{rpq}\leq\sum_i\sum_m T_{irqm}$ for all r and q;

(5) $\sum_d T_{pdq}\leq\sum_i\sum_m T_{ipmq}+\sum_r T_{rpq}$ for all p and q;

(6) $\sum_d T_{zdq}\leq\sum_b\sum_m T_{bzmq}$ for all z and q;

(7) $\sum_m\sum_i T_{ijqm}\geq D_{jq}$ for all j and q;

(8) $\sum_m\sum_b T_{blqm}\geq D_{lq}$ for all l and q;

(9) $\sum_p T_{pdq}+\sum_z T_{zdq}+\sum_f T_{fdq}\geq D_{dq}$ for all d and q;

(10) $\sum_d T_{fdq}+R_{qq+1}\leq S_{fq}+R_{qq-1}$ for all f and q;

(11) $\sum_p T_{pd}\leq PC_p$ for all p;

(12) $\sum_z T_{zd}\leq PC_z$ for all z;

(13) $T,S,D\geq 0$ for all i, b, j, l, f, q, d, r, p, and z;

where equation (1) is the net welfare interpreted as consumer surplus plus producer surplus minus cotton handling, storage, and transportation costs. Equations (2) to (6) are supply balance constraints. Equation (2) constrains the cotton flow from ith (U.S.) excess supply region to all receiving and transhipment points in each quarter to be less than or equal to the quantity supplied or carried over by the supply region i. Similarly, equation (3) constrains quantity supplied or carried-over from each excess supply region b (Brazil) to all excess demand (l) and port (z) locations to be less than or equal to quantity supplied or carried over. Equation (4) limits transhipments at U.S. rail-loading location so that the quantity shipped from each location is less than or equal to total quantities received from all U.S. supply regions for every quarter. Equation (5) balances the inflow and outflow of cotton at each U.S. port in each quarter. Similarly, equation (6) constrains shipments from Brazilian ports (z) to foreign importing countries (d).

Equations (7) to (9) are demand balance constraints. Equation (7) limits quantity shipped by different inland modes to each U.S. demand location (j) to be at least equal to or greater than the quantity demanded for every quarter of the year. Equation (8) constrains quantity shipped by truck to each Brazilian demand location (l) to be at least equal to or greater than the quantity demanded for every quarter of the year. Equation (9) constrains quantity imported by each importing country (d) to be at least equal to or greater than the quantity demanded for each quarter.

Equation (10) limits quantity shipped from exporters (f) to all importing countries (d) to be less than or equal to the quantity supplied at f for all quarters of the year.

Equations (11) and (12) impose shipping capacity limits. Equation (11) constrains cotton exports by U.S. port to be less than or equal to its capacity. Equation (12) constrains cotton exports by Brazilian port to be less than or equal to its capacity.

Equation (13) represents the non-negativity conditions.

Table A1 shows the subscripts, parameters, and variables included in the formulated model.

Table A1. Subscripts, Parameters and Variables Included in Formulated Model

Subscripts	***Definition (quantity)***
Q	quarter (1,2,3,4)
I	U.S. excess supply locations (1,2,3…410)
B	Brazil excess supply locations (1,2,3…152)
F	foreign exporting regions (1,2,3…5)
J	U.S. excess demand locations (1,2,3…11)
L	Brazil excess demand locations (1,2,3…21)
D	Foreign importing countries (1,2,3…14)
M	Inland modes of transportation (1,2,3,4)
R	Rail-loading terminal (1,2,3…5)
P	U.S. ports (1,2,3…15)
Z	Brazil ports (1,2,3,4,5)
Parameters	***Definition***
C	Transportation costs per 480 lb bales by the various modes
Variables	***Definition***
S_i	U.S. excess supply regions
S_b	Brazil excess supply regions
S_f	Foreign excess supply regions
D_j	U.S. excess demand regions
D_l	Brazil excess demand regions
D_d	Foreign excess demand regions
T	Cotton flow in 480 lb bales between nodes
G	Quarterly quantities stored in U.S.
H	Quarterly quantities stored in Brazil
R	Quarterly quantities stored in other major exporting countries
PC	Port capacity

Cotton Production and Consumption in Excess Supply and Excess Demand Regions

U.S. Excess Supply and Demand Regions

Estimated excess supply and demand locations for the U.S. were based on the optimal solution generated by a cost minimizing mathematical programming model developed by Fraire et al. (2011) to represent the U.S. cotton transportation and logistical system as well as excess supply and demand locations for 2008. The model framework developed by Fraire et al. (2011) minimizes the total cost of shipping, handling, and storing cotton that originates at 811 gins and flows to 415 warehouses across the U.S. over four quarterly periods. The model allows routing cotton shipments from originating gins to warehouses and then to sixteen U.S. ports, eleven domestic mill regions, or four major intermodal facilities and then by rail to major West Coast, Gulf and East Coast ports.

The optimum solution to the least cost model is used to represent the excess supply and demand locations in the intertemporal, spatial price equilibrium model within the U.S. cotton industry. The excess supply locations are representative warehouses which were considered to receive cotton shipments from the gins. Similarly, the excess demand locations are domestic mills which use domestic cotton originating from the warehouses. The solution to the least cost model indicated that there are 410 optimal warehouses and 11 domestic mills within the United States. The location of the warehouses is distributed in several states with Texas having the most warehouses (90) followed by Georgia (62) and North Carolina (44). As for the domestic mills, there are

11 optimal locations which are located in the following states: Alabama (2), Georgia (2), North Carolina (2), South Carolina (2), Tennessee (1), Texas (1), and Virginia (1).

By using the optimal solution of the least cost model to indicate the location of the warehouses and their cotton supply, it is estimated the share of each warehouse with respect to the total supply. Each warehouse share with respect to the total warehouse supply was then utilized to estimate the ending stock and surplus for each excess supply region based on data from FAS/USDA (2011). Domestic mill locations and their cotton demand were used to calculate the consumption share by mill. Then, by multiplying the total consumption, with source from FAS/USDA (2011) to the calculated consumption share, mill demand of each excess demand region was quantified. Surplus/deficits were calculated by subtracting the total consumption and ending stock from the total supply. If the final value is positive, the region has a surplus and thus an excess supply. On the contrary, if the final value is negative, the region has a deficit and thus has an excess demand.

Table A2 shows the total supply, total domestic consumption, and surplus/deficits for warehouse state locations and domestic mills in the U.S. The largest concentration of warehouses is in the state of Texas followed by the states of Georgia and Tennessee. This gives us also the largest surpluses for the same states. The largest deficit is located in the state of North Carolina. By summing up the surplus/deficit, the total cotton exports from the U.S. for 2008/09 were obtained, which is equal to the number given by FAS/USDA (2011).

Table A2. Estimated Cotton Supply, Consumption, and Surplus/Deficit at the State Level for the U.S. (Thousand 480 lb bales)

Warehouse State Location	Supply (%)	Supply	Consumption	Surplus /Deficit
Texas	35.05%	8,013.8	0.00	5,792.9
Georgia	11.21%	2,563.2	0.00	1,852.8
Tennessee	11.05%	2,526.1	0.00	1,826.0
Arkansas	8.43%	1,927.1	0.00	1,393.0
Mississippi	5.90%	1,348.7	0.00	974.9
California	5.76%	1,317.8	0.00	952.6
North Carolina	5.65%	1,292.8	0.00	934.5
Missouri	4.02%	920.0	0.00	665.0
Alabama	2.76%	630.2	0.00	455.5
South Carolina	2.58%	590.8	0.00	427.1
Louisiana	2.45%	560.1	0.00	404.9
Arizona	2.19%	501.5	0.00	362.5
Oklahoma	1.19%	272.2	0.00	196.7
Virginia	1.08%	247.8	0.00	179.1
Florida	0.41%	93.2	0.00	67.4
New Mexico	0.23%	51.5	0.00	37.2
Kansas	0.04%	8.4	0.00	6.0
Mill Location	**Consumption (%)**	**Supply**	**Consumption**	**Surplus /Deficit**
North Carolina 1	50.04%	0.00	1,635.4	-1,635.4
North Carolina 2	13.87%	0.00	453.3	-453.3
Georgia 1	10.50%	0.00	343.0	-343.0
South Carolina 1	5.74%	0.00	187.7	-187.7
Alabama 1	5.02%	0.00	164.1	-164.1
Alabama 2	4.66%	0.00	152.1	-152.1
Texas	3.30%	0.00	107.9	-107.8
Virginia	2.42%	0.00	79.0	-79.0
Tennessee	1.88%	0.00	61.4	-61.4
Georgia 2	1.32%	0.00	42.9	-42.9
South Carolina 2	1.25%	0.00	40.7	-40.7
Total		22,866.0	3,268.0	13,261.0
FAS/USDA (2011)		22,866.0	3,268.0	13,261.0

Brazilian Excess Supply and Excess Demand Regions

In order to estimate production and consumption of cotton in excess supply (demand) regions in Brazil, several efforts were made based on data from IBGE/MPOG (2011), RAIS/MTE (2011), and FAS/USDA (2011).

First, the cotton production share of different regions/states in Brazil was estimated for 2008 and 2009 with data from IBGE/MPOG (2011)[17]. The share was then used to estimate the supply and total domestic consumption. Supply was composed by production, beginning stock, and imports. Since there is no data for beginning stock and imports on city-level, these values were obtained by multiplying the share by the total beginning stocks and total imports for Brazil, which was sourced from the FAS/USDA (2011) for 2008/09. The production by region was also a multiplication of production share (IBGE/MPOG 2011) and the total production (FAS/USDA 2011) for 2008/09. The same procedure was applied to calculate the ending stocks.

The region/state domestic consumption was estimated in the following way. The number of active mills by each region/state was retrieved from RAIS/MTE (2011) and was assumed to represent the consumption of these regions/states. Then, by multiplying the total consumption, by the calculated consumption share, mill demand of each region was quantified.

Table A3 shows the total supply, total domestic consumption, and surplus/deficits for selected regions in Brazil. The largest surpluses occur for the São

[17] The IBGE/MPOG (2011) provides cottonseed production by municipality level and not cotton plume data. Therefore, it was assumed that the cotton plume production share was the same as the cottonseed production share.

Desidério municipality, Bahia, followed by Sapezal municipality, Mato Grosso. The largest deficits occur for São Paulo municipality, São Paulo, followed by the Belo Horizonte municipality, Minas Gerais. By summing up the surplus/deficit, the total cotton exports from Brazil for 2008/09 were obtained, which match with the number given by FAS/USDA (2011).

Table A3. Estimated Cotton Supply, Consumption, and Surplus/Deficit for Selected Excess Supply and Demand Regions in Brazil (Thousand 480 lb bales)

Excess Supply Region[1]	Production (%)	Supply	Consumption	Surplus /Deficit
São Desidério – BA	14.82%	1,746.46	0.00	1,006.4
Sapezal – MT	6.43%	757.74	0.00	436.6
Campo Verde – MT	6.26%	737.22	0.00	424.8
Mato Grosso do Sul (MS)	3.72%	437.83	0.00	252.3
Luís Eduardo Magalhães – BA	3.51%	413.91	0.00	238.5
Pedra Preta – MT	3.42%	403.40	0.00	232.4
Formosa do Rio Preto – BA	3.42%	403.18	0.00	232.3
Barreiras – BA	3.26%	383.84	0.00	221.1
Dom Aquino – MT	3.08%	362.99	0.00	209.1
Nova Mutum – MT	2.69%	316.85	0.00	182.5
Rest of Brazil Supply	49.38%	5,817.59	0.00	3,352.4
Excess Demand Region[2]	**Consumption (%)**	**Supply**	**Consumption**	**Surplus /Deficit**
Sao Paulo – SP	17.92%	0.00	725.87	-725.8
Belo Horizonte - MG	11.61%	0.00	470.16	-470.1
Cuiabá – MT	11.20%	0.00	453.67	-453.6
Florianopolis - SC	10.18%	0.00	412.42	-412.4
Fortaleza – CE	8.35%	0.00	338.19	-338.1
Salvador – BA	7.74%	0.00	313.44	-313.4
Curitiba – PR	7.54%	0.00	305.19	-305.1
Goiânia – GO	5.70%	0.00	230.96	-230.9
João Pessoa – PB	4.28%	0.00	173.22	-173.2
Recife – PE	4.07%	0.00	164.97	-164.9
Rio de Janeiro – RJ	3.05%	0.00	123.73	-123.7
Natal – RN	2.04%	0.00	82.48	-82.4
Campo Grande – MS	1.63%	0.00	65.99	-65.9
Aracaju – SE	1.43%	0.00	57.74	-57.7
Maceió – AL	1.02%	0.00	41.24	-41.2
Rest of Brazil Demand	2.24%	0.00	90.73	-90.7
Total		11,781.00	4,050.00	2,739.0
FAS/USDA (2011)		11,781.00	4,050.00	2,739.0

[1]Only showing the top 10 surplus regions. [2]Only presenting deficit regions with shares over 1 percent.
Note: See Appendix B for description of states.

Exporting and Importing Countries

For the exporting and importing countries, the data for exports and imports were sourced from FAS/USDA (2011). Table A4 below presents the cotton exports and imports by country/region which was utilized in the model. It is important to note that exports from the U.S. and Brazil are presented in Table A2 and Table A3, respectively.

Table A4. Cotton Exports and Imports by Different Countries/Regions for 2008/09 (thousand 480 lb bales)

Exporting Country/Region	Exports
Australia	1,201.0
India	2,360.0
Sub-Saharan Africa	3,509.0
Uzbekistan	3,000.0
Rest of the World Exporters	4,106.0
Total World Exports (minus U.S. and Brazil)	14,176.0
Total World Exports	30,176.0
Importing Country/Region	Imports
Rest of South America	251.0
Bangladesh	3,800.0
China	6,996.0
European Union – 27	1,009.0
Hong Kong	334.0
Indonesia	2,000.0
Japan	430.0
Mexico	1,315.0
Pakistan	1,950.0
South Korea	988.0
Taiwan	787.0
Thailand	1,602.0
Turkey	2,919.0
Vietnam	1,226.0
Rest of the World Importers	4,569.0
Total World Imports	30,176.0

Source: compiled from FAS/USDA (2011).

Estimation of the Excess Supply and Excess Demand Equations

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

(14) $E_{ES}=E_S(Q_P/Q_E)-E_D(Q_D/Q_E)$

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.

In the case of the excess supply regions for the U.S. cotton industry, each region was exporting all of its surplus (warehouses), which indicates that the sum of the quantity demanded (Q_D) for the warehouses was equal to zero. Hence, the excess supply elasticity for the warehouses was equal to its own-price supply elasticity ($E_{ES} = E_S$). Similarly, the Brazilian excess supply regions had zero demand, thus the excess supply elasticity is equivalent to its own-price elasticity. Supply elasticities by U.S. cotton producing regions were taken from Pan et al. (2006). The cotton price supply elasticities were 0.18 and 0.16 for the warehouses located in the Delta (Arkansas, Missouri, Tennessee, Louisiana, and Mississippi) and Southeast (Alabama, Georgia, Florida, North Carolina, South Carolina, and Virginia) regions, respectively. As for the Southwest (Texas, Kansas, Oklahoma, and New Mexico) and West (California and Arizona) producing regions, the supply elasticities were assumed to be 0.34 and 0.42, respectively. As for the Brazilian regions, for simplicity, the supply elasticity was equal to 0.62 and was assumed to be equal across the country (Shepherd 2006).

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

(15) $E_{ED}=E_D(Q_D/Q_I)-E_S(Q_P/Q_I)$

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. As in the case of the excess supply regions, for both the U.S. and Brazilian excess demand regions (mills), each mill had quantity produced (Q_P) equal to zero. Thus, the excess demand elasticity was equal to its own-price demand elasticity ($E_{ED} = E_D$). Domestic own-price elasticity for the U.S. mills was equal to -0.24 and was also taken from Pan et al. (2006). As for the Brazilian mills, the source for the own-price elasticity is Poonyth et al. (2004) and is equal to -0.60.

The cotton price elasticities of supply and demand for the many countries/regions are presented in Table A5. The excess supply and demand elasticities were calculated using the formula (14) and (15), respectively, by using the related elasticities and production, consumption, exports, and imports data from FAS/USDA (2011).

Table A5. Cotton Price Elasticities of Supply (E_S), Demand (E_D), Excess Supply (E_{ES}), and Excess Demand (E_{ED}) for Exporting and Importing Countries/Regions

Exporting Country/Region	E_S	E_D	E_{ES}[4]
Australia	0.46[1]	-0.47[2]	0.57
India	0.30[1]	-0.16[2]	4.07
Sub-Saharan Africa	0.24[1]	-0.60[3]	0.57
Uzbekistan	0.30[2]	-0.25[2]	0.54
Rest of the World Exporters	0.80[3]	-0.60[3]	2.20
Importing Country/Region	E_S	E_D	E_{ED}[4]
Bangladesh	1.20[3]	-0.60[3]	-0.60
China	0.14[2]	-0.26[2]	-2.69
European Union – 27	0.60[2]	-0.60[3]	-1.48
Hong Kong	0.80[3]	-0.60[3]	-0.44
Indonesia	0.80[3]	-0.60[3]	-0.62
Japan	0.74[3]	-0.60[3]	-0.62
Mexico	1.07[1]	-0.14[2]	-0.66
Pakistan	1.20[3]	-0.24[2]	-6.92
Rest of South America	0.63[1]	-0.60[3]	-4.00
South Korea	0.80[3]	-0.60[3]	-0.60
Taiwan	0.80[3]	-0.60[3]	-0.63
Thailand	0.80[3]	-0.60[3]	-0.61
Turkey	0.13[1]	-0.25[2]	-0.49
Vietnam	0.80[3]	-0.60[3]	-0.61
Rest of the World Importers	0.80[3]	-0.60[3]	-0.99

Source: [1]Shepherd (2006), [2]Sumner (2003), [3]Poonyth (2004), [4]Author's calculation.

Given the previously mentioned supply (demand) elasticities, estimation of the intercept and slope parameters for the supply (demand) equations is described. These parameters are introduced into the objective function of the model (Equation 1). According to Fellin (1993), elasticity can be expressed as:

(16) $E_{ei} = \delta Q/\delta P\ (P/Q)$

where E_{ei} is the excess supply (demand) elasticity, $\delta Q/\delta P$ is the first derivative of the excess supply (demand) function, and P and Q are average price and quantity, respectively. A linear supply (demand) function can be described as:

(17) $Q = \alpha + \beta P$

where α and β are the intercept and slope coefficients. Then α and β can be calculated as follows:

(18) $E_{ei} = \beta\ P/Q$,

(19) $\beta = E_{ei}\ Q/P$,

(20) $\alpha = Q - \beta P$.

Transportation, Intermodal Transfer, Port Capacity and Costs

U.S. Cotton Logistics Costs

With respect to the transportation network, cotton handling, and storage charges data of the U.S. portion of model, this study used the estimations from Fraire et al. (2011). In their work, road mileages for trucking between originating gins, warehouses, intermodal facilities, ports, and mill locations were calculated using standard mapping software. Railroad mileages between intermodal or boxcar origins and port destinations were obtained from relevant railroad industry websites. Trucking cost base rates and fuel surcharges were developed based on information collected from various industry sources. These data were used to estimate statistical relationships between trucking mileage and cost. The resulting regression parameters were used to derive point estimates of trucking costs for the specific distance matrix elements for all ginwarehouse, warehouse-intermodal, warehouse-port, and warehouse-mill combinations. Shipping costs from intermodal points to ports were calculated using rail mileage multiplied by the average representative railroad rates obtained from the Surface Transportation Board, railroad industry representatives, and cotton shippers.

Brazilian Cotton Logistics Costs

Truck Transportation Costs

In the Brazilian cotton industry, virtually all cotton shipment from supply (farm) to either demand (mills) or exporting ports occur by truck. Independently of the distance of the cotton haul, truck is the transportation mode used in Brazil. The truck costs in this study were calculated based on the monthly data from CEPEA (2011) for the years 2007 to 2009. The truck cost data is originally in Brazilian currency (R$) per kilometer. Hence, the monthly nominal exchange rate of the R$ to the U.S. dollar was calculated using data available from ERS/USDA (2011). Table A6 below presents a summary statistics of the truck cost and distance of Brazilian cotton interregional shipments. As we can see, the average distance of cotton hauling in Brazil is 866 miles, with minimum and maximum of 44.73 and 2,056 miles, respectively. Average truck cost is $20.32 per bale with standard deviation of 6.89.

Table A6. Descriptive Statistics on Interregional Cotton Shipments Distances and Truck Costs for Brazil, Monthly Data: January 2007–December 2009

Statistic	Miles	$/bale
Mean	866.96	20.32
Standard Deviation	346.25	6.89
Maximum	2,056.11	100.64
Minimum	44.73	4.72
Number of observations	1,009	

Truck costs were estimated with a linear equation based on the distance between shipping points and receiving locations. The following equation was estimated and served as a tool to measure truck transportation costs:

(21) US$/bale = 7.38 + 0.0149*miles + 1.09*DQ3

where the intercept represented the fixed cost (loading and unloading costs) in dollars per bale and the slope accounted for the variable cost per bale/mile (transportation costs). DQ3 is a dummy variable that represent seasonality. The sign for the dummy variable was as expected. The harvest quarter for cotton in Brazil is for the months of July, August, and September (CONAB/MAPA 2011a). The coefficient was positive which means a higher truck cost is charged to transport cotton for that quarter of the year. The R-square for this equation was 0.565. The intercept and the coefficient for the miles were significant at the 0.01 level. The dummy variable DQ3 was significant at the 0.01 level.

Port Costs and Capacity

The port charges for the Brazilian exporting ports were based on estimations from Mello (2010) and Lomanto (2011). According to Mello (2010), the current port charges for the ports of Santos and Paranaguá are approximately $11.11/bale and $9.77/bale, respectively. As for the port of Salvador, the current port charges estimate is $8.97/bale. It is important to note that these estimates are accounting for all of the cotton handling and taxes by port. In other words, the port charges for these studies represent truck unloading, container stuffing, tracking certificate, container handling, and other related port obligations. Regarding the port capacity, no ports were forced to have the amount exported to meet a certain capacity.

Ocean Freight Rates

The estimates of ocean freight rates from U.S. ports as well as Brazilian ports to different foreign excess demand regions were estimated based on the difference between the cotton export price (FOB-free on board) and the import price (CIF-cost insurance and freight). Due to the lack of data by port, in the first instance, all U.S. ports were assumed to have a similar freight rate. Similarly, the Brazilian ports were also assumed to have the same ocean freight rate. Subsequently, for the U.S. and Brazilian ports, the ocean freight rates were adjusted to the equivalent historic flow patterns for each port. Regarding the other exporting countries, similarly to the U.S. and Brazil ports case, the difference between the CIF and FOB cotton prices for trading pairs was used as a proxy for the ocean ship rate. These international cotton ocean freight rates were compiled based on the data from FAO (2011).

Model Validation

This section presents the validation procedure for the spatial price equilibrium model. According to McCarl and Spreen (2003), model validation is a necessary procedure in any empirical analysis. Validation is often done in quadratic programming models vis-à-vis improving model performance and problem insight. Validation for both the U.S. and Brazil components is performed. First, a comparison between the model-generated flows to ports with the actual flow data is done for both countries. Second, model-estimated exports (imports) of the all exporting (importing) regions are compared with actual data. The last section presents the comparison between the model-estimated shadow prices at each excess supply or demand region with the historical data.

Cotton Transhipments at Exporting Ports

Table A7 presents historic flows compared to the solution of the base model. The base model projected flows were within the ranges observed at all major ports during the years of 2007 to 2009.

Table A7. Comparison of Actual U.S. Cotton Flows and Model Flows at Different Ports in the United States (thousand 480 lb bales)

Port	2007	2008	2009	3-Year Average[1]	Base Model	(%)[2]
L.A.-L.B.[3]	6,106.5	7,446.2	5,314.6	6,289.1	6,163.3	-2.0
Savannah	2,994.4	1,733.3	1,966.4	2,231.4	2,236.7	0.3
Houston, TX	1,733.2	1,514.6	1,581.2	1,609.7	1,551.8	-3.6
Laredo-El Paso	1,075.0	907.0	986.0	989.3	1,141.3	15.4
New Orleans	857.1	369.2	362.1	529.5	514.7	-2.8
Oakland	706.1	431.8	303.9	480.6	343.8	-28.5
Charleston	682.2	446.9	310.7	479.9	338.3	-29.5
Hidalgo-Brow.[4]	325.0	443.0	353.0	373.7	340.6	-8.9
Norfolk	298.0	250.6	270.8	273.1	282.2	3.3
Gulfport	89.0	131.0	101.0	107.0	45.3	-57.7
Mobile	50.0	28.0	14.0	30.7	72.8	137.1
Subtotal	*14,916.5*	*13,701.6*	*11,563.6*	*13,393.9*	*13,030.8*	*-3.0*
Others	155.1	155.2	439.2	249.8	-	-
U.S. Total	***15,071.5***	***13,856.8***	***12,002.8***	***13,643.7***	***13,030.8***	***-4.5***

[1] Historic quantities were retrieved from WISER (2010). [2] Relative to the 3 year average. [3] Los Angeles – Long Beach. [4] Hidalgo – Brownsville.

The baseline model indicates that Los Angeles – Long Beach ports are the dominant port of export with 6,163.3 thousand bales. This estimate underestimates the actual data by 125.8 thousand bales, which is equal to a negative deviation of 2.0 percent. Savannah is the second most important port with 2,236.7 thousand bales and a variance of positive 0.3 percent. Houston port and Laredo – El Paso border crossing were third and fourth, respectively, with variance from – 3.6 percent for Houston to 15.3 percent for Laredo – El Paso. The New Orleans port was the fifth most important port, exporting a projected 514.7 thousand bales with a variance of -2.8 percent. The remaining ports each shipped less than 400 thousand bales and had variances ranging from -29.5 percent for Charleston to 137.1 percent for Mobile. This latter port, however, has historically handled only minor shipments, so this large variance is not considered a major enough issue to warrant further analysis. Total U.S. cotton exports were underestimated by 612.9 thousand bales, which is equal to a negative 4.5 percent deviation. Overall, for the most important ports, the model-projected flows were within the ranges observed for the years of 2007 to 2009.

Table A8 below presents a comparison of model estimated flows of Brazilian cotton and historical flows. It is important to note that the Brazilian cotton exports are focused on three main ports: Santos, Paranaguá, and Salvador. As we can see, historically, the subtotal of these three ports accounts for nearly 90 percent of total Brazilian exports. By comparing the model estimates to the actual data, the base model overestimates 8.9 percent of the subtotal of these three ports. Regarding total Brazilian exports, the model overestimates actual observations by 8.2 percent. The largest deviation occurs for the port of Santos, with a positive variation of 155.1 thousand bales. Overall, with the exception of the port of Salvador, all other ports were less than ten percent overestimated and were close to the historical range of the 2008 and 2009 years.

Table A8. Comparison of Cotton Model Flows and Historical Flows at Alternative Brazilian Ports between Exports by Port Model Estimates and Observed Data (thousand 480 lb bales)

Port	2008	2009	2-Year Average	Base Model	Deviation (%)[1]
Santos	1,522.8	1,644.8	1,583.8	1,738.9	9.7
Paranaguá	617.4	477.7	547.6	583.4	6.5
Salvador	7.8	2.9	5.4	6.4	18.5
Subtotal	*2,148.2*	*2,125.5*	*2,136.8*	*2,328.7*	*8.9*
Others	299.5	193.5	246.57	251.00	1.8
Total Brazil	***2,447.7***	***2,319.0***	***2,383.4***	***2,579.7***	***8.2***

[1]Relative to the 2 year average. Source: SECEX/MDIC (2011).

Although the model validation for U.S. state level exports was not possible due to lack of data, Table A9 below shows the comparison between the model estimated exports by state and the historical data for the Brazilian cotton industry. Similarly to the exports by port case, the Brazilian total cotton exports at the state level are accounted by three major states: Mato Grosso, Bahia, and Goiás. The total exports from these three states represent historically nearly 92 percent of Brazilian total exports. As we can see, the subtotal of the model estimates for these three main states is 7.7 percent over the historical data. Overall, when compared to the two year average, the model-estimated Brazilian total exports overestimated the actual data by 8.2 percent. The cotton exports by the state of Mato Grosso was overestimated by the model, however, the deviation was 9.9 percent. With the exception of the others state category, the model-estimated exports at the state level were very close to the actual data with a deviation of less than 10 percent.

Table A9. Comparison of Cotton Model Estimated Exports and Historical Cotton Exports at the State Level in Brazil (thousand 480 lb bales)

State	2008	2009	2-Year Average	Base Model	Deviation (%)[1]
Mato Grosso	1,516.0	1,230.5	1,373.2	1,509.8	9.9
Bahia	584.8	708.9	646.9	667.1	3.1
Goiás	150.7	200.3	175.5	187.9	7.0
Subtotal	*2,251.6*	*2,139.8*	*2,195.7*	*2,364.8*	*7.7*
Others	196.1	179.2	187.6	214.9	14.5
Total Brazil	***2,447.7***	***2,319.0***	***2,383.4***	***2,579.7***	***8.2***

[1]Relative to the 2 year average. Source: SECEX/MDIC (2011).

Domestic and International Markets

According to FAS/USDA (2011), for 2008/09, the total domestic consumption of cotton for the U.S. and Brazil were 3,268.0 and 4,050.0 thousand bales, respectively. For the U.S. market, the model-estimated total domestic consumption overestimated the actual domestic consumption by 3.33 percent (109.8 thousand bales). In the Brazilian model component, the total domestic consumption estimated by the model was 4,044.7 thousand bales, which gives a negative deviation of 0.1 percent. Regarding total domestic cotton supply for the U.S., model-projected results underestimated the FAS/USDA (2011) actual data of 22,866.0 thousand bales by 120.3 thousand bales MMT, which is equivalent to deviation of -0.52 percent. The model-estimated total domestic cotton supply for Brazil was equal to 11,616.5 thousand bales, which is 164.4 below the actual data of 11,781.0 thousand bales (-1.39 percent deviation).

For the exporting countries in this model, the total international cotton trade was estimated by FAS/USDA (2011) to be 30,176 thousand bales the 2008/09 marketing year, whereas the model estimations were 29,995.3 thousand bales in total, an underestimation of 0.60 percent (Table A10). Overall, suggested exports by the model by country/region were approximate to the actual data. The largest variation was in Brazil with a -5.8 percent underestimation. However, when it is compared to the Brazilian exports by ports and by state data (tables A8 and A9, respectively), model-estimated exports are overestimated by 8.2 percent.

Table A10. Comparison of Model-Estimated Exports and Actual Exported Quantity for Different Regions (thousand bales)

Exporting Region	Model Estimates	Actual Data[1]	Absolute Deviation	Deviation (%)
United States	13,030.8	13,261.0	-230.2	-1.7
Brazil	2,579.7	2,739.0	-159.3	-5.8
Sub-Sahara Africa	3,529.3	3,509.0	20.3	0.6
Uzbekistan	3,017.4	3,000.0	17.4	0.6
India	2,442.1	2,360.0	82.1	3.5
Australia	1,206.2	1,201.0	5.2	0.4
Rest of the World	4,189.7	4,106.0	83.7	2.0
Total	***29,995.3***	***30,176.0***	***-180.7***	***-0.6***

[1] FAS/USDA (2011).

Cotton imports by the importing countries were also compared with the historical data sourced from FAS/USDA (2011) for the 2008/09 MY (Table A11). The largest cotton importer in the world is China, followed by Bangladesh. The model was the most inaccurate when predicting imports by Mexico. Pakistan's imports were the most underestimated with a -6.3 percent deviation. In general, the model's estimation was relatively close to the historical data.

Table A11. Comparison of Model-Estimated Imports and Actual Imported Quantity for Different Regions (Thousand MT)

Importing Region	Model Estimates	Actual Data[1]	Absolute Deviation	Deviation (%)
China	6,863.6	6,996.0	-132.4	-1.9
Rest of the World	4,539.1	4,569.0	-29.9	-0.7
Bangladesh	3,786.2	3,800.0	-13.8	-0.4
Turkey	2,908.6	2,919.0	-10.4	-0.4
Indonesia	1,991.2	2,000.0	-8.8	-0.4
Pakistan	1,827.9	1,950.0	-122.1	-6.3
Thailand	1,593.8	1,602.0	-8.2	-0.5
Mexico	1,481.9	1,315.0	166.9	12.7
Vietnam	1,220.6	1,226.0	-5.4	-0.4
European Union - 27	1,002.7	1,009.0	-6.3	-0.6
South Korea	983.8	988.0	-4.2	-0.4
Taiwan	783.5	787.0	-3.5	-0.4
Japan	428.4	430.0	-1.6	-0.4
Hong Kong	332.9	334.0	-1.1	-0.3
Rest of South America	251.0	251.0	0.0	0.0
Total	***29,995.45***	***30,176.0***	***-180.6***	***-0.6***

[1] FAS/USDA (2011).

Shadow Prices

The combination of shadow prices and quantities that are generated by solving the spatial price equilibrium model represent the increase in total benefit that occurs when a marginal unit is demanded by an excess demand region. Therefore, the model gives the shadow prices in the excess supply and demand regions. The actual prices for the excess supply and demand regions are contrasted with model-generated shadow prices vis-à-vis model validation.

Estimated cotton prices in the 410 excess supply regions in the U.S. are compared to actual price received by farmers at the state level reported by NASS/USDA (2011) for 2008/09. For each state, it was taken the average of the model-estimated cotton prices for the supply regions within that state. Table A12 presents the model-generated shadow prices and a comparison with historical prices at the state level. For most states, deviation of the model-generated prices with respect to the actual data were less than 10 percent. The exceptions were the states of Arizona, California, and Florida. The price of the largest cotton producing, Texas, was overestimated by 4.1 percent. Overall, the cotton price for the U.S. was underestimated by $11.1/bale, which is equal to a -4.3 percent deviation.

Table A12. Comparison of Cotton Shadow Prices and Average Market Price at Different Excess Supply Regions in the United States ($/bale)

State	Model Estimates	Actual Data[1]	Absolute Deviation	Deviation (%)
Alabama	245.8	262.3	-16.5	-6.3
Arkansas	247.5	261.4	-13.8	-5.3
Arizona	231.6	298.1	-66.5	-22.3
California	260.3	314.2	-53.8	-17.1
Florida	243.9	280.1	-36.2	-12.9
Georgia	252.4	279.8	-27.5	-9.8
Kansas	241.5	255.4	-13.8	-5.4
Louisiana	247.8	274.1	-26.3	-9.6
Missouri	243.0	250.6	-7.5	-3.0
Mississippi	249.0	264.0	-15.0	-5.7
North Carolina	241.7	244.8	-3.1	-1.3
New Mexico	242.7	268.8	-26.1	-9.7
Oklahoma	249.3	255.6	-6.3	-2.5
South Carolina	254.3	254.4	-0.1	-0.1
Tennessee	253.7	271.7	-18.0	-6.6
Texas	257.4	247.2	10.2	4.1
Virginia	245.6	242.2	3.4	1.4
United States	***250.6***	***261.8***	***-11.1***	***-4.3***

[1] NASS/USDA (2011).

As for the Brazilian excess supply regions, the historical prices used in the model were estimated based on data from CEPEA (2011). Initially, each excess supply location was assumed to have the same price as its state price. Then, these prices were adjusted based on the transportation costs for each municipality. As Table A13 indicates, the model underestimated all the historical prices. However, such differences were less than five percent. The largest deviation was present in the Ceará state region (-8.1 percent). Large producing states such as Mato Grosso and Bahia had negative deviations of 3.9

and 4.2 percent, respectively. In general, the model's shadow prices are close representations of the historical data as all deviations were less than 10 percent.

Table A13. Comparison of Cotton Shadow Prices and Average Market Price at Different Excess Supply Regions in Brazil ($/bale)

State	Model Estimates	Actual Data[1]	Absolute Deviation	Deviation (%)
Alagoas	244.6	254.9	-10.3	-4.0
Bahia	235.9	246.1	-10.2	-4.2
Ceará	233.7	254.4	-20.7	-8.1
Goiás	234.8	245.0	-10.2	-4.2
Maranhão	235.8	246.1	-10.3	-4.2
Minas Gerais	239.2	247.8	-8.5	-3.4
Mato Grosso do Sul	237.2	247.3	-10.1	-4.1
Mato Grosso	227.9	237.2	-9.4	-3.9
Paraíba	245.8	256.0	-10.3	-4.0
Pernambuco	242.1	252.4	-10.3	-4.1
Piauí	238.0	248.3	-10.3	-4.1
Paraná	240.4	250.5	-10.1	-4.0
Rio Grande do Norte	245.1	255.4	-10.3	-4.0
São Paulo	242.0	252.1	-10.1	-4.0
Tocantins	231.5	241.7	-10.3	-4.3
Brazil	***233.7***	***243.7***	***-10.0***	***-4.1***

[1] Based on data from CEPEA (2011).

In the case of the other exporting countries, the historical prices were obtained by using a proxy: the unit value of the cotton export price (FOB-free on board). Likewise, the prices for the importing countries were the cotton import price (CIF-cost insurance and freight) for each country. These proxies were estimated based on the data for 2008/09 from FAO (2011). Table A14 presents the model-generated shadow prices and the historical data. Most of the model's shadow prices were within the range of less than 10 percent deviation. Overall, for most cases, the model estimates matched the historical data from 2008/09 fairly well.

Table A14. Comparison of Cotton Shadow Prices and Average Market Price at Different Exporting and Importing Countries ($/bale)

Exporting Country	Model Estimates	Actual Prices[1]	Absolute Deviation	Deviation (%)
Sub-Sahara Africa	256.2	253.6	2.6	1.0
Uzbekistan	242.1	239.5	2.6	1.1
India	303.8	301.2	2.6	0.9
Australia	341.9	339.4	2.6	0.8
Rest of the World Exporters	280.5	277.9	2.6	0.9
Importing Country	**Model Estimates**	**Actual Prices**	**Absolute Deviation**	**Deviation (%)**
China	362.7	360.1	2.5	0.7
Row of the World Importers	357.6	355.1	2.5	0.7
Bangladesh	376.3	352.5	23.8	6.8
Turkey	347.2	349.9	-2.7	-0.8
Indonesia	362.2	347.3	14.9	4.3
Pakistan	287.1	344.7	-57.6	-16.7
Thailand	360.0	348.6	11.5	3.3
Mexico	306.6	352.4	-45.9	-13.0
Vietnam	341.9	356.3	-14.4	-4.0
EU	392.4	360.1	32.3	9.0
South Korea	359.6	367.8	-8.2	-2.2
Taiwan	362.7	375.5	-12.8	-3.4
Japan	377.8	383.1	-5.4	-1.4
Hong Kong	345.4	390.8	-45.4	-11.6
Rest of South America	340.5	383.0	-42.5	-11.1

[1] FAO (2011).

APPENDIX B

A MAP OF BRAZIL AND ITS STATES

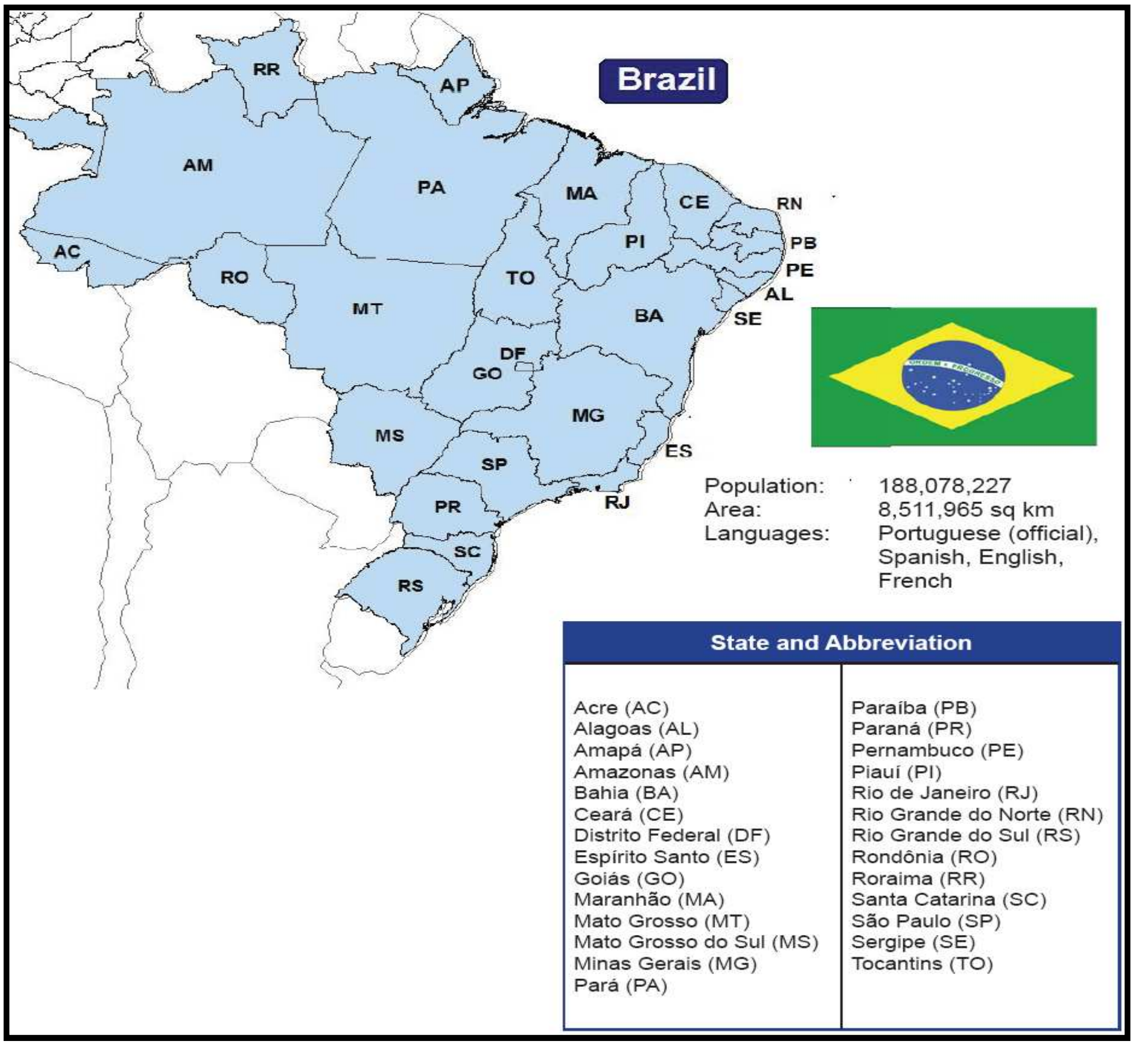

Figure B1. Map of Brazil and its states
Source: Agricultural Marketing Service/USDA (AMS/USDA) (2007).

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