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Effects of the Panama Canal on U.S. Competitiveness on the World Soybean Market

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Introduction

The Panama Canal's purpose is to allow vessels of various types and sizes to move between the Atlantic and Pacific oceans. The canal is the major shipping route from U.S. Gulf ports to the Asian countries, especially China, Japan, and Korea. The canal allows U.S. agricultural commodities to be traded competitively throughout the world. It offers significant advantages for U.S. soybean exporters, especially in delivering to Asia. Fuller and Fellin (2000) estimated that U.S. exports of soybeans could be 2% lower when the canal is not available.

The Panama Canal is projected to be expanded to improve the navigable waterway. While the expansion will increase transportable ship size and efficiency of operation, operation costs of the canal would be increased. Increases in operation costs of the canal may result in increases in toll rates in the Panama Canal. The toll rates may be increased by the Panama Canal Authority (PCA), which has rights for operations and maintenance, to maximize its revenue from the canal. Figure 1 presents U.S. exports, U.S. agricultural exports, and cargo volume transiting the canal. Total volumes, total U.S. export quantities, and U.S. agricultural exports transited through the Panama Canal had continued on an upward trend until 1996. U.S. soybean exports from the Atlantic coast to the Pacific coast through the canal were 8.9 million metric tons in 1998 and were about 65% larger than in 1989.

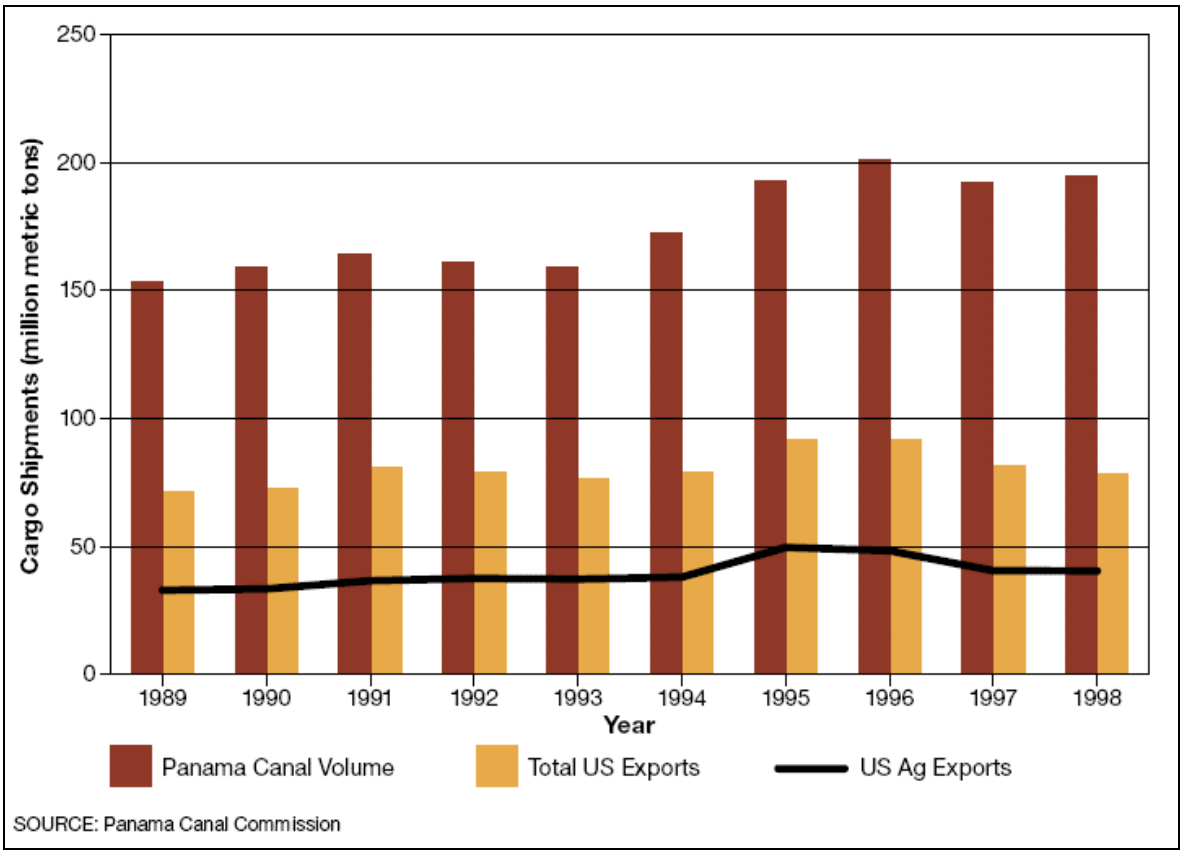

Figure 1. Total U.S. exports, U.S. agricultural exports, and cargo volume transiting the Panama Canal, 1989-98 (million metric tons).
Source: The Panama Canal in Transition: Implications for U.S. Agriculture, USDA – AMS, January, 2000.

U.S. agricultural exports are expected to increase as the Panama Canal improves the waterway system. Projected U.S. Gulf grain and soybean exports using the Panama Canal in 2008 is 39.3 million metric tons and 8.7 million metric tons. Future expansion in U.S. soybean exports from the U.S. Gulf ports through the canal would also depend on the management and operation decisions of the Panama Canal Authority (PCA). However, limitation of vessel transit in the canal may lower the competitiveness of U.S. soybean exports in the world market. Expansion of the canal to increase efficiency of operation to transit vessels will increase the competitiveness of U.S. soybean exports, but also increase

marketing costs for vessels passing through the canal due to increases in toll rates in the canal. If the PCA raises toll rates to maximize their toll revenue, U.S. soybean exports would be most influenced among soybean exporting countries mainly because the route from the Gulf ports to Asia through the canal is the major exporting route for U.S. soybeans. The distribution of U.S. soybean exports could shift to the EU and Africa from the Gulf ports. The PNW ports may increase exports to Asia through the Cape of Good Hope if the canal toll rates are increased, according to a study by Fuller and Fellin (2000).

Despite substantial growth in the consumption of soybeans in foreign countries, the United States' share in the world soybean market has steadily diminished. Brazil and Argentina have gained on the United States' share in the world soybean market due to significant growth in soybean production and exports in these countries. Soybean production in Brazil and Argentina now exceeds that in the United States. Another factor affecting the decline in U.S. market share for soybeans is the recent expansion of U.S. meat exports, which stimulates the domestic use of soybean meal. Increased domestic consumption resulted in decreases in exportable quantities in the United States.

Factors determining the marketing costs of shipping soybeans from producing regions in exporting countries to consuming regions in importing countries are ocean transportation costs, inland transportation costs, handling charges for loading and unloading, and tariffs and subsidies imposed by countries. Domestic transportation in an exporting country and international transportation cannot be separated and examined individually because they affect each other.

There are interactions between domestic and international transportation. Domestic transportation costs affect international trade flows as well as domestic trade flows in an

exporting country. Further, equilibrium conditions in the world soybean market affect domestic trade flows in exporting countries as well as international soybean trade flows. Inland transportation systems in exporting countries are another concern. How efficiently inland transportation systems deliver soybeans from producing regions to both consuming regions and export ports in exporting countries may be a critical measurement of countries' competitiveness in the world soybean market.

Projected expansion of the Panama Canal may positively affect soybean exports in the United States since the Canal is a gateway for shipping U.S. soybeans to Asia. U.S. soybean exports through the canal reached about 10 million metric tons in 2004 and are projected to remain at the same level. By allowing vessels to transit between the Atlantic and Pacific oceans, the Panama Canal saves time and money for the transport of waterborne commodities. For cargo shipped from the U.S. East Coast to Asia, for instance, the canal saves about ten days' sailing time. However, the size of a ship transiting the canal is limited by the size of each lock chamber. Panamax-size ships make a more effective transit through the canal by carrying more cargo, but they diminish the efficiency of the canal because they are limited to daylight transits, require extra pilots and line handlers, take longer to traverse a set of locks, and are restricted to single passage through the narrowest portions of the canal.

There are a few studies about the linkage between international trade and domestic trade in exporting countries. However, those studies do not include recent growth of China's soybean consumption and imports. Examining relationships among the equilibrium condition in the world soybean market, domestic trade flows in exporting counties, and increases in China's soybean imports would be a foothold. It is necessary to

study the impacts on world soybean trade and the competitiveness of the United States when factors determining transportation costs in shipping soybeans from exporting countries to importing countries changed.

Enke (1951) studied the effects of transportation costs on local price and trade movements when there are many different markets by using linear programming. Samuelson (1952) introduced spatial price equilibrium based on a linear programming algorithm. To minimize total power loss, the "net social pay-off" function is defined. The function consists of three components: social pay-off in country *A*, social pay-off in country *B*, and transportation costs between country *A* and *B*.

Takayama and Judge (1971) attempted to convert the Samuelson formulation into a quadratic programming problem. The authors' model indicates that regional prices, quantities, and international flows can be estimated with a quadratic programming model. Shei and Thompson (1977) developed a quadratic programming model to evaluate the effects of unanticipated changes in quantities of wheat traded on the world wheat price. Koo (1984) used a spatial equilibrium model to evaluate optimal flows of wheat from producing regions to domestic consuming regions in the United States and foreign destinations under alternative trade restrictions and transportation costs. Koo and Uhm (1986) developed a spatial equilibrium model on the basis of a quadratic programming algorithm to analyze the incidence of ocean shipping costs. Furtan et al. (1979) used a spatial quadratic programming model to estimate the impacts of changes in transportation costs on the Canadian rapeseed industry.

Koo and Thompson (1982) used a spatial equilibrium model based on a linear programming algorithm to optimize the U.S. grain distribution systems. Koo et al. (1988)

developed a spatial equilibrium model to optimize domestic and international grain flow and showed that ocean transportation costs influenced U.S. grain distribution systems more than domestic transportation costs.

Waters (1970) studied the effects of international transportation costs and tariffs on the competitiveness of U.S. industries. USDA-AMS (2004) analyzed ocean transportation trends and reported that the imbalance of the U.S.-Asia trade does not result in increasing ocean transportation rates and helps keep the rates stable. Binkley (1983) found that inflexibility of the international grain marketing system, such as ocean transportation, caused trade instability and higher marketing costs by using a spatial equilibrium model. Fuller et al. (1984) studied the effects of the Panama Canal toll level on U.S. grain exports by using a multicommodity, multiperiod, cost-minimizing spatial model. The authors found that there is an inelastic relationship between toll rate levels and U.S. export quantities through the canal. The study also indicated that increasing toll rates results in decreases in exports from the Gulf ports to Asia and has the reverse effect on exports from Pacific ports to Asia.

Changes in ocean transportation costs, toll rates in the Panama Canal, and trade policies in exporting and importing countries are also major factors determining the world soybean trade flows. A change in these factors is favorable to some exporting and importing countries, but not favorable to other exporting and importing countries. It is also necessary to evaluate how the changes in these factors affect the world soybean trade and individual exporting and importing countries.

The primary objective of this study is to evaluate the impacts of alternative Panama Canal toll rates in shipping soybeans from major exporting countries to major importing

regions and countries on the United States' competitiveness of soybean exports and the world soybean trade. More specifically, the study is designed to analyze the role of the Panama Canal on U.S. exports of soybeans to the Asian soybean market, focusing on the impacts of toll rates on U.S. exports of soybeans.

A single commodity spatial equilibrium model for the world soybean industry is developed for this study in order to address the problems faced by soybean exporting countries, especially the United States. One base model and several alternative scenarios about the toll rates are developed to accomplish the objectives stated in the previous section. The objectives are accomplished by comparing the result for the base scenario with those for alternative scenarios.

Methodology

Many studies have been published on grain transportation. The studies are, in general, divided into two categories according to the type of analysis: spatial equilibrium and spatial optimization models. The spatial equilibrium model based on a quadratic programming algorithm optimizes trade flows and prices by maximizing the net social payoff defined by Samuelson. The spatial equilibrium model optimizes international trade flows of a commodity from exporting countries to importing countries under the given export supply and import demand for the commodity and the transportation infrastructure. The spatial optimization model is based on a linear programming algorithm of which the objective function is to minimize the production costs of commodities in the producing regions/countries and to minimize the transportation costs for shipping the commodities from the producing regions/countries to the consuming regions. This model determines

optimal flows of commodities from producing regions/countries to consuming regions. Most previous studies in optimizing a grain distribution system have used either a spatial equilibrium or a spatial optimization model. Unlike the previous studies, this study used both spatial equilibrium and spatial optimization models.

The spatial optimization model optimizing domestic flows of a commodity and the spatial equilibrium model which maximizes the social payoff in importing and exporting countries are linked through the quantity handled by export ports as follows:

$$\sum_{i} Q_{ip} \quad = \quad \sum_{q} Q_{pq} \ , \tag{1}$$

where i is an index for producing regions in exporting countries, p is an index for ports in exporting countries, and q is an index for importing countries. Equation 1 indicates that the quantity of soybeans received by each port from producing regions should equal to the quantity of soybeans shipped out for exports. Both the spatial equilibrium model in the world soybean market and the spatial optimization model for domestic soybean production and distribution system interact through Equation 1 in establishing a global equilibrium condition.

The model has several advantages over other models. Since international trade activities and domestic production and distribution systems interact with each other, connecting both the spatial equilibrium and the spatial optimization will provide an unconditional optimality for the entire soybean industry, including international trade, domestic production, and domestic distribution. In addition, this model requires less effort in estimating parameters and collecting data compared to the traditional spatial equilibrium

model. This model can incorporate trade policy and domestic subsidies easily to examine unbiased analysis of the policies and subsidies than the traditional model.

The agricultural commodity considered in this study is soybeans. The model includes major soybean producing countries and consuming countries. Major soybean producing countries are divided into several producing regions based on characteristics of transportation and production and consuming regions based on concentration of crushing plants. Major soybean importing countries are chosen on the basis of their import volume. The 15 largest soybean importing countries and the rest of the world are included in the model. The model also includes several inland transportation modes in the United States to evaluate the effects of intermodal competition on optimal domestic soybean shipments for export in the United States. The model also includes ports for international trade. These ports are used in the transit of soybeans from producing regions in exporting countries to importing countries. Some soybean producing countries have several export ports based on characteristics of transportation. Shipments through the Panama Canal are included in this study to estimate the effects of changes in canal toll rates on U.S. soybean exports and the world soybean trade.

The objective function of the model for this study is to maximize the social payoff value for international trade for soybeans and to minimize production costs of soybeans in producing regions and marketing costs from producing regions to consuming regions and ports in exporting countries. The objective function is presented as follows:

$$
\begin{aligned}
W = & \sum_n \int M_n(Q_n)dQ_n - \sum_p \int E_p(Q_p)dQ_p - \sum_p \sum_n (tc^1{}_{pn} + ha_p + ta_n - es_p)Q^1{}_{pn} \\
& - \sum_p \sum_n (tc^2{}_{pn} + ha_p + \alpha + ta_n - es_p)Q^2{}_{pn} - \sum_i A_i PC_i - \sum_i \sum_j tc_{ij} Q_{ij} \\
& - \sum_i \sum_p tc^t{}_{ip} Q^t{}_{ip} - \sum_i \sum_p tc^r{}_{ip} Q^r{}_{ip} - \sum_i \sum_a tc^t{}_{ia} Q^t{}_{ia} - \sum_i \sum_a tc^r{}_{ia} Q^r{}_{ia} \\
& - \sum_a \sum_p tc^b{}_{ap} Q^b{}_{ap}
\end{aligned}
\quad , \qquad (2)
$$

where i is an index for producing region in exporting countries, j is an index for consuming region in exporting countries, p is an index for port in exporting countries, n is an index for importing country, t is an index for truck transportation mode, r is an index for rail transportation mode, b is an index for barge transportation mode, a is an index for barge access points, A_i is area used to produce soybeans in producing region i, and tc represents transportation costs. M_n is the import demand function for soybeans in port n, E_p is the export supply function for soybeans in port p, PC_i is production cost of soybean in producing region i, Q_p is soybean quantities shipped from export port p, Q_n is soybean quantities shipped to import port n, Q_{ij} is soybean quantities shipped from producing region i to domestic consuming region j, $Q^t{}_{ip}$ is soybean quantities shipped from producing region i to export port p by trucks, $Q^r{}_{ip}$ is soybean quantities shipped from producing region i to export port p by rails, $Q^t{}_{ia}$ is soybean quantities shipped from producing region i to barge access point a by trucks, $Q^r{}_{ia}$ is soybean quantities shipped from producing region i to barge access point a by rails, $Q^b{}_{ap}$ is soybean quantities shipped from barge access point a to export port p by barges, $Q^1{}_{pn}$ is soybean quantities shipped from export port p to import port n without the Panama Canal, and $Q^2{}_{pn}$ is soybean quantities shipped from export port p to import port n through the canal. tc_{ij} represents transportation costs and ta_n is the import

tariff for soybeans in import port n, α is toll rates per vessel in the canal, ha_p is handling charge at export port p, and es_p is the export subsidy for soybeans in export port p given by exporting countries.

The first four terms of Equation 2 represent the objective function for international activities of the world soybean industry which maximizes the social payoff value in shipping soybeans from exporting countries to importing countries. The remaining terms of the objective function is to minimize production costs in producing regions and marketing costs from producing regions to ports and domestic consuming regions. It is assumed that soybeans move to domestic consuming regions by rail and truck, which move to ports by rail and barge.

Major constraints of the model are domestic supply and demand in exporting countries, import demand in importing countries, export supply in exporting countries, and the inventory-clearing condition at export and import ports. The constraints are presented as follows:

$$Q_n = \sum_p Q_{pn}, \qquad n = 1,2,\ldots,\ p = 1,2,\ldots. \tag{3}$$

$$Q_p = \sum_i Q^t{}_{ip} + \sum_i Q^r{}_{ip} + \sum_a Q^b{}_{ap}, \qquad p = 1,2,\ldots,\ i = 1,2,\ldots,\ a = 1,2,\ldots. \tag{4}$$

$$\sum_i Q^t{}_{ia} + \sum_i Q^r{}_{ia} = Q^b{}_{aGulf}, \qquad a = 1,2,\ldots,7. \tag{5}$$

$$Y_i A_i \geq \sum_j Q_{ij} + \sum_p Q^t{}_{ip} + \sum_p Q^r{}_{ip} + \sum_a Q^t{}_{ia} + \sum_a Q^r{}_{ia}, \qquad i = 1,2,\ldots,34. \tag{6}$$

$$\sum_i Q_{ij} \geq \overline{D_j}, \qquad i = 1,2,\ldots,\ j = 1,2,\ldots. \tag{7}$$

$$\sum_i Q_{ip} = \sum_n Q_{pn}, \quad p = 1,2,\ldots, n = 1,2,\ldots. \tag{8}$$

$$A_i \leq TA_i, \quad i = 1,2,\ldots,34. \tag{9}$$

$$A_i \geq MA_i, \quad i = 1,2,\ldots,34. \tag{10}$$

where Y_i is yield in producing region i, TA_i is total arable land in producing region i in exporting countries, and MA_i is minimum land used in producing regions i in exporting countries.

Equations 3 and 4 represent import demand and export supply constraints, respectively. Equation 3 indicates that the quantity of soybeans imported in import port n is equal to the sum of soybeans shipped from export ports to the port. Equation 4 describes that the quantity of soybean exported in port p is equal to quantity of soybeans received from producing regions by rail, truck, and barge. Equation 5 is an inventory-clearing condition at barge access points indicating that the quantity of soybeans received in each barge access points by rail and truck should be equal to the quantity shipped out by barge to the Gulf ports. Equation 6 describes that the total amount of soybeans produced in each producing region in exporting countries should be equal to or lager than the soybean quantities shipped to domestic consuming regions and export ports. It is assumed that a country exporting soybeans should satisfy its domestic consumption first and exports remaining soybeans. Under this assumption, exportable surplus is the total domestic soybean production minus domestic soybean consumption. Equation 7 indicates that domestic demand in each consuming region in the exporting country should be smaller than or equal to the quantity shipped from producing regions to the consuming regions by

domestic production. Equation 8 describes an inventory-clearing condition at ports, indicating that the soybean quantities received by each export port from domestic producing regions must be equal to the soybean quantities shipped to import ports. Equation 9 and 10 represent the physical constraint of arable land in each producing region. Equation 9 indicates that the total land used to produce soybeans should not exceed the total available area for soybean production, while Equation 10 represents the minimum production of soybeans.

Data

Data used for the model are soybean demand in domestic consuming regions and foreign consuming regions, soybean supply in producing regions, export price and quantities at export ports, import price and quantities at import ports, tariffs and subsidies imposed by importing and exporting countries, and transportation costs in shipping soybeans from producing regions to both domestic consuming and foreign consuming regions.

The domestic supply of soybeans is determined by multiplying yields by hectares harvested area which is an endogeneous variable. Export supply equations in each country/region are estimated using time series data. Import demand equations in each country are also estimated using time series data. Estimation of export supply and import demand coefficients and elasticities are presented in Moon (2006). Average harvested areas in producing regions from 2002 to 2004 are obtained from National Agricultural Statistics Services (NASS) – USDA and used to calculate the maximum harvested areas in each producing regions, which is 20 percent larger than the average soybean harvested area

for the three years. Domestic soybean demand data for each consuming region in the United States are obtained from the Proexporter Network (PRX).

Transportation in this study is divided into inland transportation and ocean transportation. Ocean vessels are the transportation mode in shipping soybeans from ports in exporting countries to ports in importing countries. Inland transportation delivers soybeans from producing regions to both consuming regions and export ports. Inland transportation modes used in this study are rails and trucks. Barges are also used as an inland transportation mode from barge access points to the U.S. Gulf ports for exports. Rails and trucks are transportation modes in shipping soybeans from producing regions to the barge access points.

Ocean freight rate is specified as a function of the size of vessel, ocean distance between ports, oil price, and characteristics of destination and origin, following Park and Koo (2004). The ocean freight rate function is estimated with panel data which include both cross section and time series data. The ocean freight rates function in double log form is as follows:

$$OR_{pqt} = f(S_{pqt}, M_{pqt}, P_t, D^R{}_{pqt}, Tr), \tag{11}$$

where OR_{pqt} is ocean freight rate per metric ton in shipping soybeans from export port p to import port q in time period t, S_{pqt} is size of vessel in shipping soybeans from export port p to import port q in time period t, M_{pqt} is ocean distance from export port p to import port q in time period t, P_t is oil price in time period t, $D^R{}_{pqt}$ is a dummy variable for origin and destination in time period t, and Tr is a trend variable.

Barge freight rates are estimated with distance from barge access points to the Gulf ports with seasonality. The barge freight rates function is specified as follows:

$$BC_{it} = \eta_{it0} + \eta_{i1} M_{Bit} + \eta_{t2} D_{Ill} + \eta_{t3} D_{LM} + \eta_{t4} D_{OH} + \eta_{t5} D_{Q1} + \eta_{t6} D_{Q2} + \eta_{t7} D_{Q3} + e_{it}, \tag{17}$$

where BC_{it} is barge freight rate from i^{th} barge access point to the Gulf port at time t, M_{Bit} is distance between i^{th} barge access point to the Gulf ports at time t, D_{Ill} is a dummy variable for barge access points in Illinois River, D_{LM} is a dummy variable for barge access points in the lower Mississippi River 1st quarter, D_{OH} is a dummy variable for barge access points in the Ohio River, D_{Q1} is a dummy variable for the 1st quarter, D_{Q2} is a dummy variable for the 2nd quarter, and D_{Q3} is a dummy variable for the 3rd quarter. There are 8 barge access points considered in this study. Those are St. Paul, Minn; McGregor, Iowa; Lockport, Ill; Cairo, Ky; Winfield, Mo; Louisville, Ky; Cincinnati, Ohio; and Memphis, Tenn. Barge access points in lower Mississippi are Cairo and Memphis. The carge access point on the Illinois River is Lockport. Barge access points on the Ohio River are Cincinnati and Louisville. The coefficient of the distance variable is expected to be positive. Weekly barge freight quotes from 1997 to 2004 are obtained from Transportation and Marketing Programs (TMP) in AMS – USDA.

The rail freight rate equation is estimated with 2002 Public Waybill data for soybean shipments obtained from the Upper Grain Plains Transportation Institute (UGPTI). The Public Waybill data contains information such as date, number of carloads, car

ownership, weight, and so on. Total freight rates are the sum of freight rates, transit charges, and miscellaneous charges. A double logged form is used to estimate the rail freight rate equation. The rail freight rates of 1,500 observations are divided into three car-type; shuttle, large multicar, and individual. It is assumed that shuttle trains are used for shipping soybeans from producing regions to the Gulf ports to compete with barges and large multicars are used to other export ports. Also it is assumed that individual trains are used for domestic shipments. The rail freight rates function is specified as follows:

$$\ln RR = \lambda_0 + \lambda_1 \ln M_R + \lambda_2 \ln CW + e, \tag{18}$$

where RR is rail freight rates per ton, M_R is distance from origin to destination, and CW is weight per carload in tons. Instead of the total weight per rail, weight per carload is used in the rail freight rates function. The total weight per rails represents weight of shipments for all of the railcars regardless of how many railcars are connected. However, weight per carload represents weight of shipment on individual railcars.

Truck freight rates are obtained from the Grain Transportation Report published by TMP in AMS – USDA. Since there are differences in truck availability and fuel prices among regions, AMS divides the United States into five regions. Among the five regions, the truck freight rates in the North Central region are used to estimate the truck freight costs equation mainly because the region consists of most of the soybean producing states such as Iowa, Illinois, Minnesota, and Indiana, and most of the soybean consuming states such as Illinois, Iowa, Indiana, and Ohio.

Handling costs are included in the model to estimate efficiency of ports' operation. Efficiency of operation consists of loading and unloading charges, time to transit, and time for loading and unloading. Only handling costs at export ports are included because handling costs at import ports do not affect competition among soybean exporting countries. Import tariffs and export subsidies are included to evaluate the effects of tariffs and subsidies on the world soybean trade. Data for tariffs and subsidies are obtained from the Center for Agricultural Policy and Trade Studies (CAPTS). It is assumed that the EU has a uniform import tariff for soybeans. It is also assumed that Southeast Asian countries have a uniform soybean import tariff. Mexico has the highest import tariff for soybeans among importing countries in this study. The import tariff for Mexico is $66.

Empirical Results

It is expected that the Panama Canal Authority (PCA) may increase the toll rates to maximize revenue of the canal. An increase (a decrease) in the canal toll rates reduces (increases) quantities of soybeans passing through the canal and also affects inland shipping in the United States and Brazil. Toll rates under the base scenario is $5 and alternative toll rates considered are $0 and $10. This section analyzes decreases in toll rates as well as increases in toll rates because of estimating the economic value of the canal. Results show that the changes in toll rates in the canal mostly affect soybean exports in the United States. The changes in toll rates influence imports in the East Asian countries more than those in the EU.

The changes in toll rates in the Panama Canal influence international trade flows from export ports to importing countries through the Canal (Table 1). Since the canal plays an important role in soybean imports in the East Asian countries, the changes in toll rates

influence trade flows primarily to these countries. The total quantity traded through the canal in the base model is 9.2 million metric tons. The total quantity traded through the canal under the zero toll rate scenario is 11.1 million metric tons of soybeans, which is a 120% increase. The total quantity of soybeans traded through the canal accounts for 21% of the total quantity traded in the world soybean market under the zero toll rate scenario. China increases soybean imports from the Gulf ports through the canal under this scenario. However, there are no shipments through the canal under the $10 toll rate scenario. Under this scenario, shipping costs of soybeans from the Gulf ports to the Asian market through the canal are higher than those through the PNW ports. All soybean shipments to the Asian market are passed through the PNW ports under this scenario.

Table 1. Quantities of soybeans shipped from the Gulf Ports to importing countries through the Panama Canal under alternative toll rates in the canal.

(1000 MT)	China	Japan	Korea	Total
Zero toll rate scenario	7,799	3,557 1,095 (BRZN)	1,341	12,492
$5 toll rate scenario	4,640	3,190	1,374	9,204
$10 toll rate scenario	-	-	-	-

Chinese imports through the Panama Canal are 5.04 million metric tons and account for 78% of the total shipments via the canal under the zero toll rate scenario. Chinese imports through the canal also account for 25% of the total quantity imported in China. Japan imports 4.7 million metric tons of soybeans under the scenario. This result indicates that a reduction in toll rates substantially increases soybean trade volume from the U.S. Gulf ports to the East Asian countries through the canal. However, when toll rates are

increased to $10, there are no shipments through the canal. This is primarily because the total transportation costs from the U.S. Gulf ports to the Asian countries through the canal are higher than those through alternative routes such as shipments to Asian countries through the PNW ports or those through the southern ports in Brazil. This implies that the toll rates are very sensitive to the volume of soybeans shipped through the canal.

Table 2 presents changes in export price and quantities at export ports when there are changes in toll rates in the Panama Canal. The impacts of the toll rates on trade flows and prices of soybeans are not significant. U.S. exports slightly increase as the toll rate decreases. The total export quantities for the United States are 24.8 million metric tons under the zero toll rate scenario, 24.73 million metric tons in the base model with a toll rate of $5 per ton, and 24.70 million metric tons under the $10 toll rate scenario. The decrease in U.S. exports is similar to the decrease in the total quantity traded in the world soybean market under the $10 toll rate scenario, indicating that changes in the toll rates affect U.S. soybean exports more than those in other exporting countries. The United States has a cost advantage in shipping soybeans via the canal and is most influenced by changes in toll rates among exporting countries. The main reasons for this are that the export supply elasticity for soybeans in the United States is more elastic than those of Brazil and Argentina and that the Gulf ports are major export ports for shipping soybeans through the canal.

Table 2. Export price and total quantities of soybeans handled by export ports under the alternative toll rates in the Panama Canal.

Country	U.S.				Brazil		Argentina
Port	Gulf	PNW	Atlantic	Lake	North	South	
Price ($)							
Zero	228.57	228.56	235.74	226.78	194.81	205.12	180.64
$5	226.63	232.26	232.12	224.04	192.94	208.24	183.75
$10	226.33	231.99	232.89	224.82	192.85	208.20	183.71
Quantity (1000 MT)							
Zero	19,750	3,581	377	1,147	9,807	9,914	7,247
$5	19,587	3,637	371	1,134	9,787	9,946	7,272
$10	19,563	3,633	373	1,138	9,786	9,946	7,272

Argentina and the southern ports in Brazil increase their soybean exports as toll rates in the Panama Canal increase. This is mainly because Argentina and the southern ports in Brazil have a relative cost advantage in shipping soybeans to the East Asian countries without using the canal under the $10 toll rate scenario. However, export price and quantities at the Southern ports in Brazil increase as the toll rates decrease. The Southern ports in Brazil decrease soybean exports to China because China increases imports from the Gulf ports under the zero toll rate scenario. On the other hand, export price and quantities at the southern ports in Brazil also increase when the toll rates increase to $10. This is primarily because the southern ports still have a cost advantage in shipping soybeans to East Asian countries over the Gulf ports. Export quantities at the northern ports decrease as the toll rates are increased. Also, imports in the East Asian countries shift this import demand from the Gulf ports to the northern and the southern ports when ocean

transportation costs associated with importing soybeans from the Gulf ports to these countries increase due to the increase in toll rates.

The Gulf ports are the most sensitive export ports to changes in the toll rates in terms of export quantities. Since the Gulf ports are the closest export ports to the Panama Canal and handle significant quantities exported from the United States, the changes in quantities of soybeans exported through the Gulf ports are much larger than the changes in total U.S. exports. Export price and quantities at the Gulf ports decrease as toll rates increase. Exports of soybeans at the Gulf ports increase to 163,000 metric tons under the zero toll rate scenario, while the increased quantity of soybeans exported in the United States is 125,000 metric tons. Similarly, the decrease in export quantities at the Gulf ports is larger than the decrease in the total export quantities from the United States under the $10 toll rate scenario.

Export price and quantity at the PNW ports under the zero toll rate scenario are less than those in the base model. Exports at the PNW ports become less competitive in the world soybean market when toll rates in the Panama Canal decrease because ocean transportation costs associated with the canal become cheaper. The Gulf ports export more soybeans to China and the PNW ports reduce soybean exports to China because the reduction in ocean transportation costs to China through the canal results in a cost advantage in shipping soybeans from the Gulf ports to China through the canal. Another reason for this is that the Gulf ports take more soybeans produced in the United States that would otherwise go to the PNW ports and exports them to the EU because Argentina and Brazil increase market share for soybeans in China.

The impacts of the increase in toll rates on the total quantity traded in the world soybean market are minimal (Table 3). This is primarily because only a few ports, mainly the Gulf ports in the United States and the northern ports in Brazil, ship soybeans to the Asian countries through the Panama Canal. In addition, increases in transportation costs from the United States and Brazil to the Asian countries without using the canal are small. The United States and Brazil use alternative routes to ship soybeans to the Asian countries when the toll rate change. For example, Japan imports soybeans from the Gulf ports through the canal under the base model. However, it can import soybeans from the Gulf ports without using the canal or from other export ports when the toll rate increases under the $10 toll rate scenario. Small quantities of U.S. exports were occasionally routed to Asian countries via the Cape of Good Hope when the canal is congested or light-loading is required.

Table 3. Total quantities of soybeans traded, WAEP, and WAIP in world soybean market under alternative toll rates in the Panama Canal.

Toll Rate	Total Trade (1000 MT)	WAEP ($/ton)	WAIP ($/ton)
No Toll	51,826	211.00	297.82
$5 (Base)	51,738	211.07	298.93
$10	51,712	210.92	299.27

Changes in toll rates in the Panama Canal affect Chinese soybean imports from the Gulf ports. When there are no toll rates in the canal, China's imports of soybeans from the Gulf ports account for about 45% of total Chinese imports because ocean transportation costs from the Gulf ports to China through the canal become more competitive than those

from other export ports to China. China increases its imports from the Gulf ports under the zero toll rate scenario. On the other hand, Chinese import demand for soybeans from the Gulf ports decreases under the $10 toll rate scenario. However, the increases in toll rates do not significantly affect total import volume in China because there are alternative export ports and ocean routes to China.

Results from this study are similar to those from Fuller et al. (1984) and Fuller et al. (2000). These studies found that there is an inelastic relationship between changes in toll rates in the Panama Canal and U.S. export quantities for soybeans. The study by Fuller et al. (1984) found that the increases in toll rates redirect grain to the PNW ports for exporting to Asian countries. However, those results are not found in this study. The main reasons for this are because the study by Fuller et al. (1984) use a cost-minimizing model for their analysis, which redirects commodities flows based on transportation costs. In reality, changes in transportation costs related to a port vary the quantity of soybeans handled by the ports and the price of soybeans at the port. This study shows that U.S. soybean market shares decrease in the Asian market and increase in the EU market when the toll rates of the canal increase. These results are consistent with those found in the study by Fuller et al. (2000).

The Panama Canal enhances soybean trade between major exporting countries and major importing countries. Without the canal, total ocean transportation costs would increase because the canal is one of the major soybean shipping routes. Increases in total ocean transportation costs would be a measure of economic value of the canal. Table 4 shows changes in ocean transportation costs with changes in the canal toll rates. The

economic value of the Panama Canal is estimated at $56 million. This means that ocean transportation costs could be $56 million lower with existence of the canal.

Table 4. Changes in domestic and ocean transportation costs with changes under alternative toll rates in the Panama Canal ($1000).

$0 → $5	Domestic Transportation Costs	Ocean Transportation Costs	Total
U.S.	2,969	33,260	36,229
Brazil	-252	15,325	15,073
Argentina	149	317	466
Total			51,768
$5 → $10			
U.S.	-1,570	-51,305	-52,875
Brazil	-66	57,853	57,787
Argentina	-	20	20
Total			4,932

When the toll rate decreases from $5 per ton to zero per ton, ocean transportation costs in all exporting countries decrease. While there are some export ports with increases in ocean transportation costs, total ocean transportation costs decrease. When the toll rate increases from $5 per ton to $10 per ton, changes in ocean transportation costs are different from exporting countries and less than those with decreases in toll rate from $5 per ton to zero per ton. The main reason for this is that there are no shipments through the Panama Canal when the toll rates are more than $6.50. While other ports experience increasing ocean transportation costs when the toll rate increases from $5 per ton to $10 per ton, the Gulf ports decrease ocean transportation costs because the Gulf ports export more soybeans

to the EU. This is primarily because the Gulf ports increase soybean exports to the EU. The distance from the Gulf ports to the EU is much smaller than the distance from the Gulf ports to Asia. However, total ocean transportation costs increase because the other export ports, except the Gulf ports, ship soybeans to Asia to satisfy Asia's import demands.

This study introduces alternative toll rates in the Panama Canal to examine the impact of changes in toll rates on trade flows of soybeans from exporting countries to importing countries and U.S. competitiveness of soybean exports. The changes in toll rates in the canal influence international trade flows from export ports to importing countries through the canal. Since the canal plays an important role in soybean shipping from the Gulf ports and Brazil to the East Asian countries, the changes in toll rates mostly influence trade flows to these countries. The Gulf ports are most sensitive to changes in the toll rates. Since the Gulf ports are the closest export ports to the canal and handle significant quantities exported from the United States, the changes in quantities of soybeans exported through the Gulf ports are much larger than those in total quantities exported from the United States.

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