Analysis of Factors Influencing Grain Traffic on the St. Lawrence Seaway

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The St. Lawrence Seaway links central regions of North America to the Atlantic Ocean via the Great Lakes navigation system. Harmful non-indigenous aquatic invasive species have increasingly been introduced into the Great Lakes largely through the ballast water of inbound ships involved in international commerce. A variety of solutions have been proposed, with some advocating closure of the St. Lawrence Seaway to international shipping.Historically, it was an important artery linking grain surplus regions in Canada and the United States with international markets. However, during the past two decades the Seaway's role has diminished as a grain transport artery. The objective of this paper is to develop an increased understanding of this decline and to offer thoughts regarding the likely reversal of the forces that may have caused it. Analysis indicates declining imports by selected world regions and domestic transportation legislation is central to the decline.

INTRODUCTION

Completion of the St. Lawrence Seaway in 1959 allowed ocean-going vessels through the St. Lawrence River, around the Niagara Falls and into the Great Lakes for travel to central regions of North America. Since opening the St. Lawrence Seaway to international shipping, non-indigenous aquatic species have increasingly been introduced into the Great Lakes largely through the ballast water of international carriers. The introduction of these harmful, non-indigenous species has been hastened by the increasingly larger vessels that require greater ballast capacity and faster vessels that enhance the probability of livelihood for the invading species. Introduction of these non-indigenous species has created property loss in the Great Lakes, generated management and control costs and altered the ecosystems supporting commercial and recreational activities. A variety of solutions have been proposed, with some advocating closure of the St. Lawrence Seaway to ships that are involved in transoceanic shipping (Transportation Research Board 2008).

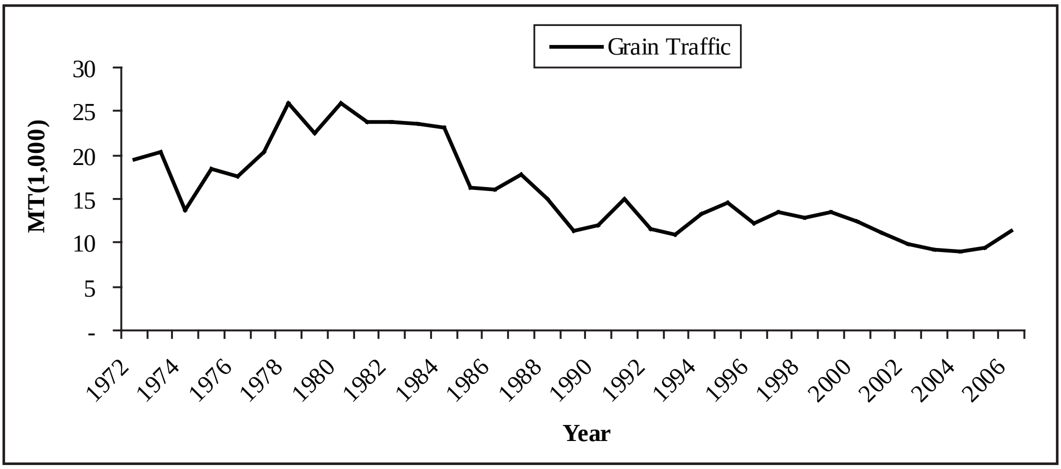
Historically, the St. Lawrence Seaway was an important artery linking grain surplus regions in Canada and the United States with the world market. However, during the past two decades the Seaway has played a more modest role as an export outlet. Regardless, there is concern among agricultural interests regarding the implications of closing the Seaway to international carriers. The objective of this paper is to develop an increased understanding of forces that have influenced grain exports via the Seaway and to offer thoughts regarding the reversal of these forces. This paper (1) offers background on St. Lawrence Seaway grain traffic and related geographic grain flows, (2) offers a review of relevant literature, (3) employs regression analyses to identify and measure forces potentially responsible for the observed trend in Seaway grain traffic, and (4) offers conjecture regarding reversal of discovered forces found to be central to explaining the decline in grain traffic.

BACKGROUND

Trends in Seaway Grain Traffic

St. Lawrence Seaway grain traffic as measured by passage through the Montreal-Lake Ontario section reached a peak in 1980, when nearly 26 million metric tons (MMT) transited this section (Figure 1). From 1981 to 1984, grain traffic edged downward to 23.1 MMT and in 1985 declined to about 16.2 MMT. Subsequent to this period, tonnage continued to decline to slightly over 9 MMT during the 2002-2005 period, but in 2006 and 2007 it rose to 11.3 and 10.1 MMT, respectively. United States Seaway grain traffic peaked at 13.9 MMT in 1978 before declining to recent levels of about 3.3 MMT, while Canadian traffic peaked in 1983 (16.9 MMT) before entering a decline to recent levels (7.4 MMT). Historically, nearly 60% of the Seaway grain traffic originated from Canada (Figure 1). The data presented in this paragraph came from the Seaway's annual Traffic Reports (St. Lawrence Seaway Management Corporation various years).

Figure 1: St. Lawrence Seaway Grain Traffic (1972-2006)



Source: St. Lawrence Seaway Management Corporation. *Traffic Report* (various years).

Originating Grain Ports, Logistics and Export Facilities

United States Seaway grain exports enter the Great Lakes largely at the Duluth-Superior port area in the western-most portion of Lake Superior, but also through ports in Milwaukee, Chicago, Burns Harbor and Toledo. Duluth and Toledo are now the principal grain ports, handling 66% to 80% of U.S. exports via the Lakes (St. Lawrence Seaway Management Corporation various years). The Duluth-Superior grain port hinterland is estimated to extend into the grain surplus regions of Minnesota and eastern North and South Dakota, while Lake Michigan grain ports attract from nearby areas in Illinois, Indiana and Wisconsin. Toledo's market area is estimated to extend into northwest Ohio, southeast Michigan and northeast Indiana. The U.S. Seaway grain traffic has been primarily wheat (40%), corn (26%) and soybeans (24%) (St. Lawrence Seaway Management Corporation various years). USDA data suggest virtually all of the Great Lakes wheat exports originate from Duluth-Superior, while corn and soybean exports transship ports at Toledo, Duluth and other Lake ports (USDAa various years).

Canadian grain exports passing through the Seaway enter the Great Lakes primarily through port facilities at Thunder Bay, which is located on the northwest shore of Lake Superior. This port area is linked to the grain-surplus prairie provinces of Canada by railroad. In recent years, about 80% of Canada's Seaway grain traffic was shipped from Thunder Bay, with the remaining largely shipped through Hamilton, Sarnia, Windsor and Goderich. Although wheat comprises over 70% of Canadian grain exported via the Seaway, important quantities of barley, soybeans, corn, canola and flaxseed also transit this artery (St. Lawrence Seaway Management Corporation various years).

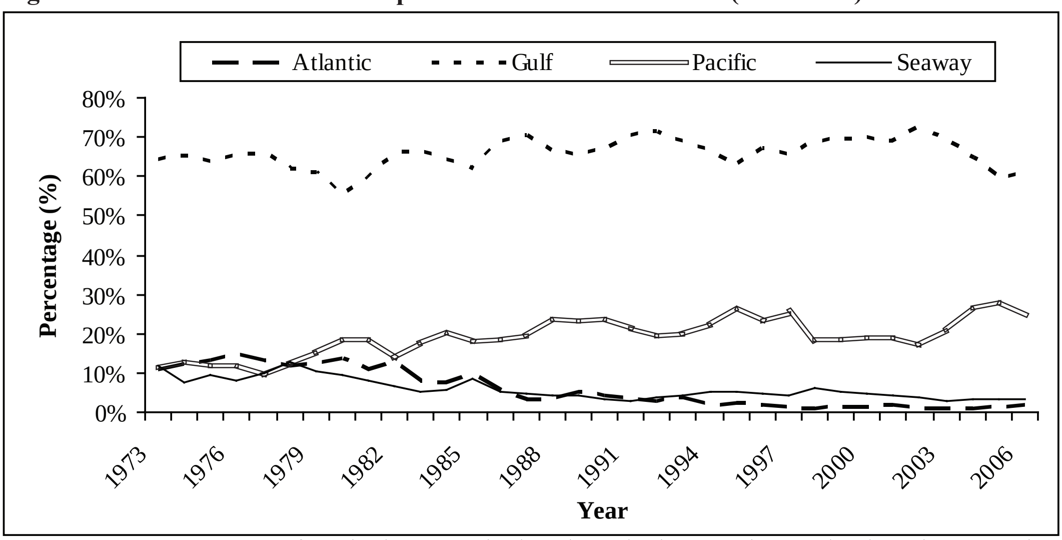
Grain exports through the Great Lakes and Seaway are accommodated via several logistics schemes. Ocean-going vessels (salties) enter the Great Lakes via the Seaway, load at the above identified Lake grain ports and then exit through the Seaway to the open waters of the Atlantic. In recent years, about 40% of Seaway grain traffic was accommodated by this scheme (St. Lawrence Seaway Management Corporation various years). Remaining grain exports are shuttled from Lake grain ports by lake vessels to elevators at Montreal and beyond (facilities downriver from Montreal and on the St. Lawrence River), as well as in the Gulf of St. Lawrence, where salties load the grain cargoes for transport to international markets. Some of the salties that enter the Great Lakes are not fully loaded at the Great Lake ports because of Seaway limitations and therefore top-off at grain elevators located in the Gulf of St. Lawrence at Montreal and beyond. Selected port elevators at Montreal and beyond receive grain by railroad, which can transport grain directly from most surplus grain production regions in Canada.

Competing Grain Port Hinterlands and Associated Transportation Corridors

To determine the port area over which grain will be routed, an international grain trader gives consideration to origin and destination market prices and the grain transportation and handling costs required to link these markets. That routing with the associated port area, which yields the highest net price in the origin area, will be selected. The Gulf of Mexico (Gulf), Atlantic, Pacific and Great Lakes grain ports have hinterlands that partially overlap, thus these ports and associated transportation corridors compete with the St. Lawrence Seaway and its associated grain transportation corridor.

Figure 2 reveals the dominance of U.S. Gulf ports in recent decades as a grain export outlet by annually handling over 60% of the U.S. grain outflow (USDAa various years). Further, the relative role of Pacific ports has been increasing over recent decades while the role of Gulf ports has been unchanging and the role of St. Lawrence Seaway and Atlantic coast ports has declined. United States Atlantic coast grain exports have declined dramatically from about 9 MMT in the early 1980s to less than 0.45 MMT in recent years, a shipment profile that partially parallels the St. Lawrence Seaway (USDAa various issues). The United States total grain exports grew rapidly during the 1970s, increasing from about 80 MMT in 1972 to reach a peak of 132 MMT in 1980 before edging downward to about 115 MMT in recent years (USDAc various years).

Figure 2: Percent of U.S. Grain Exports Via Various Port Areas (1973-2006)



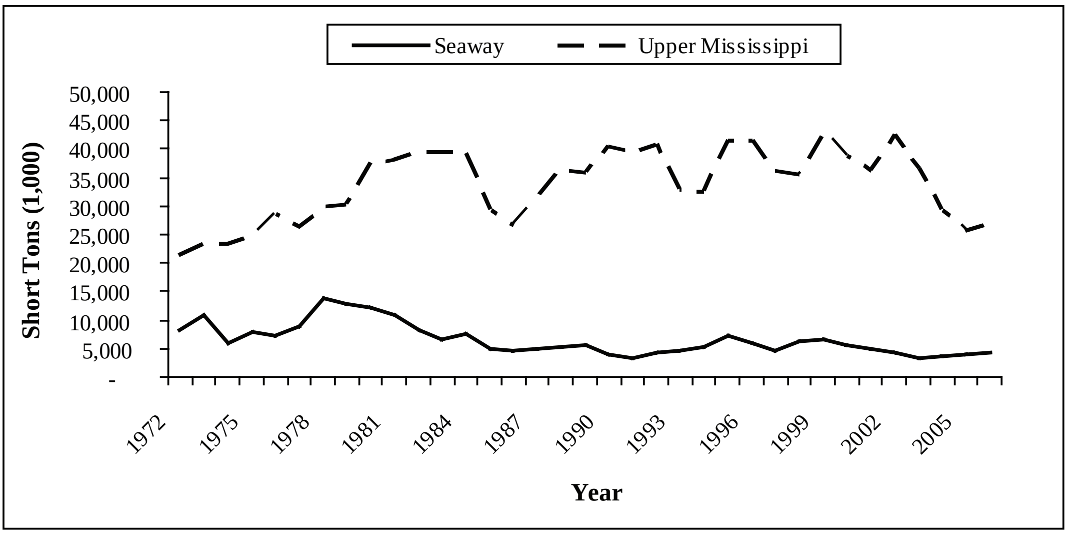
Source: U.S. Department of Agriculture, Agricultural Marketing Service, Federal Grain Inspection Service, *Grains Inspected and/or Weighed for Export by Region and Port Area*. (USDAa various years).

United States Gulf grain ports on the lower Mississippi River are estimated to have historically received about 90% of their corn and soybeans by barge. It is estimated that the Illinois River and upper Mississippi River (above St. Louis) carry about half of the corn and one-third of the soybeans exported through the lower Mississippi port area (USDA 2004), a port area handling up to

70% of U.S. corn and soybean exports (USDAa various years). Because of the efficiency of barge transportation on the upper Mississippi and Illinois Rivers, strong competition was likely offered to the Great Lakes' important Duluth/Superior and Lake Michigan grain ports, since these grain ports' hinterlands would appear to overlap with the upper Mississippi and Illinois' Rivers grain-drawing area in the major grain producing regions of Illinois, Iowa, Minnesota and Wisconsin. Further, Railroad Waybill data shows important quantities of corn, soybeans and wheat in Minnesota, Iowa and the Dakotas shipped to Pacific ports, thus suggesting additional overlap between Pacific, Gulf and Great Lakes port hinterlands (U.S. Department of Transportation various years). In addition, the Atlantic coast ports and associated hinterland are in proximity to the Toledo port area and the Ohio River, a tributary of the Mississippi River system, which may compete for grain that could be routed to Atlantic coast ports.

An examination of U.S. export grain flows via the Seaway and the upper Mississippi and Illinois Rivers show markedly different shipment patterns occurring during the period between 1972 and 2006 (St. Lawrence Seaway Management Corporation various issues) (USACE 2004) (Figure 3). During the 1970s, total U.S. grain exports via the Seaway and the Illinois and upper Mississippi Rivers were erratic but trending upward. However, subsequent to the 1980s, the fortunes of the two transport arteries were altered, with grain movement on the upper Mississippi and Illinois Rivers trending upward while U.S. Seaway traffic commenced its downward trek.

Figure 3: U.S. Grain Traffic Via St. Lawrence Seaway and Upper Mississippi (1972-2006)

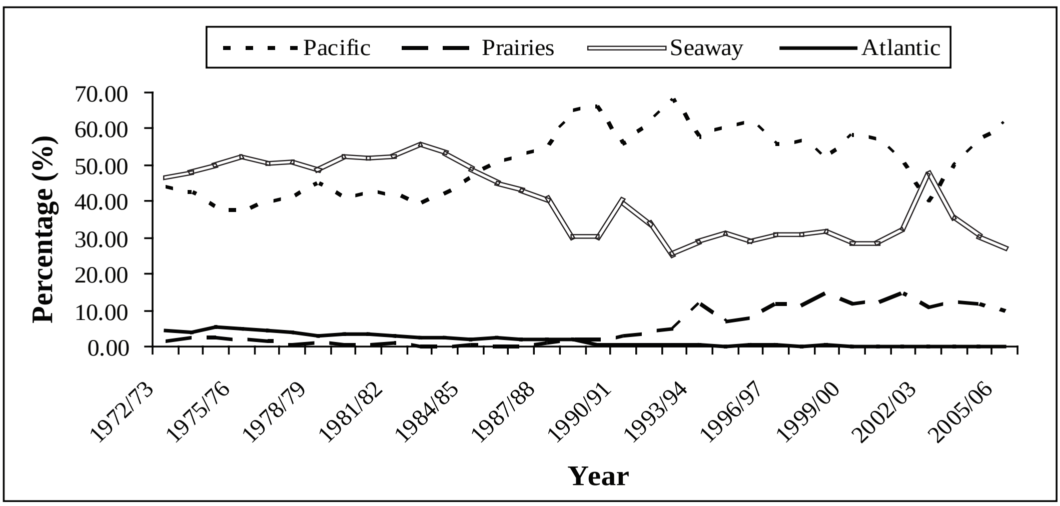


Source: Seaway traffic is from St. Lawrence Seaway Management Corporation. *Traffic Report*, (various years). Upper Mississippi traffic is from U.S. Army Corps of Engineers. *Final Integrated Feasibility Report for UMR-IWW System Navigation Feasibility Study.* 2004. Recent upper Mississippi grain traffic was supplied by John Carr, Rock Island District, U.S. Army Corps of Engineers, Rock Island, Illinois.

United States grain inspection data show U.S. port areas typically serve world importing regions that are in nearest proximity to the U.S. port area (USDAb various issues). For example, during the years 2005-2007, about 73% of U.S. grain exports exiting the St. Lawrence Seaway were destined for countries that border the Mediterranean Sea (North Africa/South Europe/the Middle East), with the remainder destined for north Europe (19%), Africa (3%), South and Central America (3%) and East Asia (1%). Conversely, about 90% of the grain exiting Pacific ports was destined for East and Southeast Asia, while the Middle East (4%) and Africa (2%) received much of the remaining outflow. United States Gulf ports tend to serve most world importing regions, with primary destinations being East and Southeast Asia (40%), South and Central America (28%), countries bordering the Mediterranean Sea (14%), other African nations (8%), northern Europe (5%) and the Middle East (4%) (USDAb various issues). Therefore, the least-cost routing of grain from U.S. surplus regions often involves port areas that are comparatively close to the importing world region. Thus, if a particular world region experiences a change in demand for U.S. and Canadian grain, selected port flows could be affected.

The portion of Canadian grain exports transiting each port area or sector fluctuated during the study period (1972-2006), with the St. Lawrence Seaway responsible for over 50% of grain exports during the 1970s and early 1980s, trending downward thereafter to comprise about 30% of annual outflow since 1990 (Figure 4) (Canadian Grain Commission various years). In contrast, the share of exports by Canada's Pacific coast ports increased from about 40% in 1972-1984 to approximately 60% since 1990. Also, of increasing importance is the Prairies sector, which includes wheat exports to the U.S., an activity that has expanded with the advent of the North American Free Trade Agreement (Canadian Grain Commission various years, Canada Grain Council various years). As noted, transportation rates may influence grain routing through port areas. Therefore, it is hypothesized that deregulation of U.S. railroads (Staggers Rail Act of 1980), and possibly other transportation modes in the U.S. and Canada, may have altered relative efficiencies regarding logistic/transportation systems serving various port areas that provided incentive to alter various port volumes and utilized modes. The introduction of unit and shuttle trains subsequent to the Staggers Act has made for increasingly efficient rail transportation of grain from Minnesota, Iowa, Nebraska and the Dakotas to distant Pacific Northwest ports and may be a force that partially explains increased tonnage through the Pacific Northwest grain ports.

Figure 4: Canada Grain Exports Via Various Port Sectors (1972-2007)



Source: Canadian Grain Commission, Canadian Grain Exports (various years), and Canada Grain Council, Online Statistical Handbook (various years).

Doan et. al. (2006) explain that Canada's changing rail grain regulatory policy and a relocation of the geographic pricing point for grain have been important forces influencing the routing of Canadian grain. Since the mid-1980s, Canadian grain transportation policy has evolved from a fixed rate structure (Crow's Nest rates based on an agreement between a railroad and Canadian government in 1897) to one where market forces became increasingly central to rate determination. The Crow's Nest Pass Agreement of 1897 established, in perpetuity, rates on east bound grain movements. The Crow's Nest rates were an important force linking the grain-surplus prairies to the export grain market, but over time the fixed rate covered an ever-smaller fraction of rail costs, creating financial losses for the railroads. The Western Grain Transportation Act (WGTA) of 1983 (effective 1984) was the first step in reforming Canada's rail grain transportation. It allowed rail rates to increase gradually, required the Canadian government to provide a subsidy to railroads to cover some of their rail costs, and had producers pay about 30% of the grain transportation costs. However, by the mid-1990s, the producers' share of the transportation cost had increased to 50%, and the government subsidy to railroads had been reduced. Provisions of the WGTA allowed for subsidization of rail rates for grain but not for processed grain products. As a result, regional grain economies were distorted, since grain processors found it advantageous to locate outside of the grain-producing region. In 1995, the WGTA was repealed and replaced by the Budget Implementation Act, which eliminated government payments to railroads and the associated regional rail rate distortions and required grain shippers to pay full rail transportation costs. Facing higher rail grain transportation costs to export locations, grain production increasingly shifted to feed grains, livestock production and specialty crops. Further, the 1989 Free Trade Agreement with the United States encouraged feed grain and livestock production, further deterring grain exports in the early 1990s.

An additional factor potentially impacting the routing of Canadian grain occurred in 1995, when the port used to calculate transportation charges to producers (termed the pricing point) was moved eastward from Thunder Bay to Montreal. This increased transportation charges on eastbound grain shipments from the grain-surplus prairies (Doan et al. 2006).

The review of historic information on geographic grain flows suggests several hypothesis regarding reasons for declining grain exports via the Seaway. These include the relocation of world grain import regions for U.S. and Canadian grains, changing grain transportation policies and grain handling costs on various transportation corridors, and conceptually changing grain production patterns in port hinterlands, which may alter port flows.

REVIEW OF LITERATURE

Makus and Fuller (1987) examined how shifts in location of the United States' foreign grain demands may redirect export grain flows away from traditional transportation corridors and port areas. A multi-period, cost-minimizing spatial model including corn, grain sorghum, soybean and three classes of wheat (hard, soft, durum) were featured in a model that included 165 domestic production regions, 85 domestic demand regions, 16 U.S. port areas, 43 barge-loading locations on two major inland waterways (Mississippi River and tributaries, Columbia-Snake system) and 24 foreign demand regions. The surplus grain producing regions were linked to grain-deficit regions, ports and barge-loading locations by applicable truck and rail rates, while barge rates connected barge-loading sites to port areas and barge-unloading sites that were connected by truck and rail rates to applicable grain-deficit regions. Ship rates linked the U.S.' 16 port areas to the 24 foreign demand regions. The spatial model was calibrated to represent region production and consumption patterns in the early 1980s and then systematically foreign demand for U.S. grain was redistributed among world demand regions to observe the change in domestic grain flows to various port areas. Of particular interest was the scenario that redistributed demand away from Europe and the former USSR to Asia. These analyses indicated an 80% reduction in European and Soviet Union grain demands would reduce U.S. corn and wheat flows through the Great Lakes by about 25%, suggesting that relocated world grain demands can influence U.S. port area flow patterns.

Hazem Ghonima (1991) examined trends in St. Lawrence Seaway traffic and offered discussion for the observed decline in grain, coal, iron ore and general cargo traffic – the primary products transported via the Seaway. Ghonima (1991) notes Seaway traffic in the first navigation season (1959) was about 19 million metric tons (MMT) (Montreal-Lake Ontario section), with cargo growing steadily to reach an all-time record of 57.5 MMT in 1977. With regard to U.S. grain exports via the Seaway, Ghonima believes Western Europe's decline in demand for U.S. grain is a central force behind the downward trend in Seaway grain traffic, as is the Staggers Railroad Act of 1980, which contributed to the efficiency of transporting grain by rail. Interestingly, in a more recent presentation, Ghonima (2004) suggests that U.S. Seaway grain traffic is favorably influenced by steel imports into the Great Lakes because of the backhaul opportunity offered to grain.

Ghonima (1991) observed that Canadian grain shipments through the Seaway depend on world grain demand, primarily in Europe, Soviet Union, North Africa and the Middle East, and increasingly grain demand was shifting to Asia, thus unfavorably influencing Seaway traffic. Further, weather and the Western Grain Transportation Act of 1983 were cited as forces impacting Canadian Seaway grain traffic. Drought was thought to unfavorably influence exports, and the Western Grain Transportation Act may have deterred Seaway exports because of higher rates on eastbound rail shipments to Lake ports along with relatively low ship rates on shipments from Canada's Pacific coast. More recently, Ghonima (2004) cited the (1) disappearance of Canadian grain exports to the former USSR in early the 1990s as an important force influencing Canadian Seaway grain traffic and (2) the development of unit trains and high throughput elevators with additional grain cleaning capacity at Quebec City (export facility on St. Lawrence Seaway) as a force unfavorably impacting Seaway traffic.

A study by Transport Canada (2007) and other agencies including the U.S. Army Corps of Engineers entitled *Great Lakes St. Lawrence Seaway Study* examined a variety of issues pertaining to the Great Lakes/St. Lawrence Seaway system, including economic importance, environmental considerations, infrastructure and policies (Transport Canada 2007). The study estimates annual transportation cost savings of the Great Lakes/St. Lawrence Seaway to be $2.65 billion. The report also offered potential reasons for the observed downtrend in Seaway grain traffic. They note a variety of forces as responsible for the trend, including the decline in demand for North American grain in Europe, domestic transportation legislation and technological developments, Canada's Pacific coast port developments, increasing competitiveness in rail rate structures, rationalization of railroad infrastructure and associated implementation of unit trains and high-volume inland terminals.

Taylor and Roach (2005) examined the transportation "cost penalty" of closing the St. Lawrence Seaway to international shipping. The study focused on Seaway commerce in 2002 that was attributed to ocean-going vessels. Based on collected handling and transportation costs in 2002, the annual transportation cost penalty of closing the Seaway was estimated at $54.9 million.

A committee selected by the Transportation Research Board (2008) of the National Research Council and the National Academy of Sciences was charged with identifying and exploring options for Great Lakes shipping that would (1) enhance the potential for global trade in the region and (2) eliminate further introduction of non-indigenous aquatic species into the Lakes by vessels transiting the Seaway. The committee concluded that closing the Seaway to transoceanic shipping would be a high-risk alternative and would potentially affect the region's trade opportunities. Ultimately, the committee concluded that the preferred strategy for reducing the risk of introducing ship-vectored aquatic invasive species into the Great Lakes was technological innovations that kill the organism while in the ship's ballast water (Transportation Research Board 2008).

ANALYSIS

A myriad of forces may offer explanation for the declining role of the St. Lawrence Seaway as a grain export artery. This analysis focuses on (1) changing import levels by selected world grain import regions, (2) domestic transportation legislation, (3) domestic grain production levels, and (4) steel imports transiting the Seaway.

Model Specification

The general form of the estimated equations explaining Canadian and U.S. grain exports via the St. Lawrence Seaway were as follows:

(1) $q_{ct} = f(qe_{cit}, qp_{ct}, qs_t, T_t)$

where q_{ct} is the annual quantity of grain and oilseeds exported through the St. Lawrence Seaway by country c in year t, qe_{cit} is the quantity of grain and oilseeds exported by country c to world grain import region i in year t, qp_{ct} is the quantity of grain produced by country c in year t, qs_t is quantity of manufactured iron and steel imported via the St. Lawrence Seaway in year t, and T_t is a variable representing domestic transportation legislation. Ultimately it was necessary to remove the qp_{ct} variable (country grain production) from the U.S. and Canadian models because of endogeneity and collinearity problems. This is discussed more completely in the following Empirical Analysis section.

An equation is estimated for Canadian grain and oilseed exports transiting the Seaway and another equation for U.S. exports. Quantity of grain and oilseeds annually exported by a country to a particular world grain import region (qe_{cit}) represents those grains and oilseeds typically transiting the Seaway, and annual grain production in each country (qp_{ct}) is for those types of grain and oilseeds that typically transit the Seaway. The quantity of manufactured iron and steel annually imported via the Seaway is represented as qs_t, and typically it is destined for U.S. ports. Domestic transportation legislation (T_t) in the Canadian equation is represented by a dummy variable that reflects those time periods when the legislation is in place and in the U.S. equation as a continuous rail grain rate variable.

In general, a positive relationship is expected between the quantity of grain and oilseeds exported via the Seaway (q_{ct}) and import levels of an importing world region (qe_{cit}), except when port hinterlands overlap and tend to take grain supplies from a competing port hinterland, in which case a negative relationship may be found between q_{ct} and qe_{cit}. A positive relationship is also expected between Seaway grain traffic (q_{ct}) and the quantity of grain and oilseeds produced in the country (qp_{ct}) and steel imports via the Seaway (qs_t). High grain export levels are expected to be associated with increased grain production (qp_{ct}) and vice versa, however the qp_{ct} variable, as noted above, had to be dropped from both models because of endogeneity and collinearity problems created with its inclusion in the models. Steel imported through the Seaway is largely destined for U.S. ports, and because the steel-carrying vessels seek backhauls of grain, a positive relationship is expected between steel imports and U.S. grain exports through the Great Lakes. It is posited that deregulation of U.S. railroads (Stagger Rail Act of 1980) unfavorably affected U.S. Seaway traffic, as did Canada's Western Grain Transportation Act of 1983, which increased export rate levels above those of the preceding Crow's Nest era.

Data

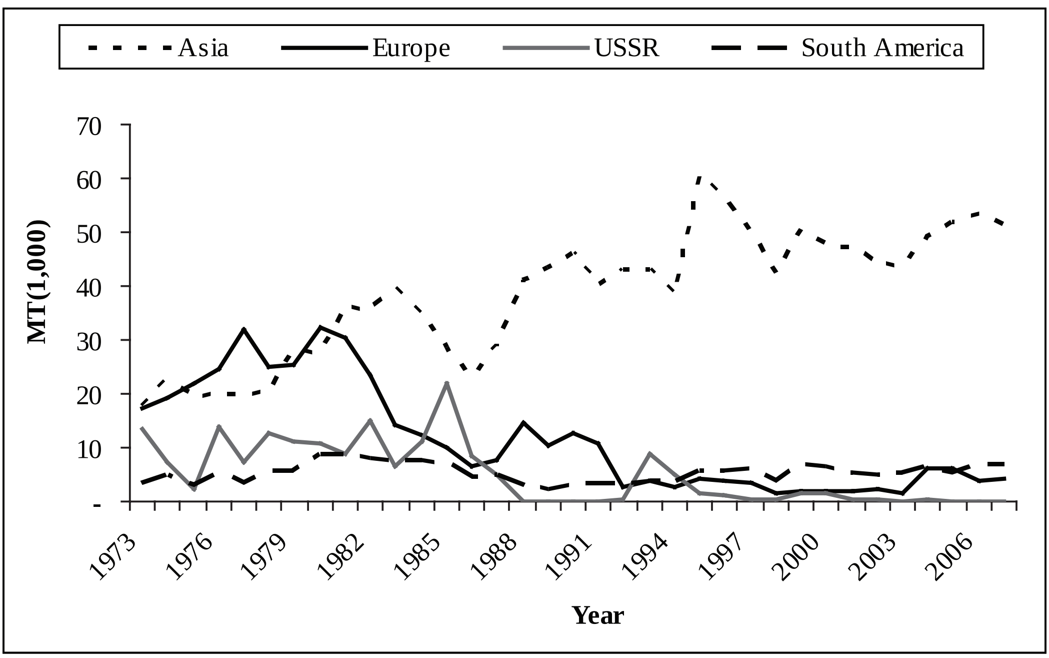
The dependent variable in the estimated Canadian St. Lawrence Seaway grain export equation is the annual quantity of Canadian grain and oilseeds (1,000's metric tons) transiting the St. Lawrence Seaway for 1972/73-2005/06 (Canadian Grain Commission various years, Canada Grain Council various years). Information on Canada's annual exports of grain and oilseeds to world grain import regions were segregated to include (1) Europe and former USSR, (2) Asia and Oceania, (3) Africa and the Middle East, and (4) Western Hemisphere nations. Information on annual Canadian grain and oilseed production was obtained from the Canada Grains Council, Online Statistical Handbook. Annual production was collected for Canadian wheat, barley, canola, flaxseed, rye and oats for 1972/73-2005/06. Data on annual imports of manufactured iron and steel transported via the St. Lawrence Seaway were taken from St. Lawrence Seaway Management Corporation (various years) website. Information on Canadian grain transportation policy was obtained from Doan, Paddock and Dyer (2006), Nolan and Drew (2002), and Schmitz, Highmoor and Schmitz (2002).

The dependent variable in the estimated U.S. Seaway equation was the annual quantity (1,000's metric tons) of U.S. grain and oilseed exports transiting the St. Lawrence Seaway. These data came from the annual Seaway Traffic Reports and were collected for 1972-2006 (St. Lawrence Seaway Management Corporation various issues). Data on U.S. grain exports to world regions were obtained from USDA's *Production, Supply and Distribution Database* (USDAc various years). The world regions include: North Africa, Asia, Europe, former USSR, the Middle East, South America, Caribbean and North America. See USDA website for countries comprising each world region (USDAc). Data on U.S. grain and oilseed production came from the USDA's National Agricultural Statistical Service (USDA 2007). Data on annual imports of manufactured iron and steel transported via the St. Lawrence Seaway was from the St. Lawrence Seaway Management Corporation website (various years), and U.S. transportation legislation was incorporated through a railroad rate index. Numerous studies have been conducted to examine the effects of the Staggers Rail Act and the resulting deregulation, and results have consistently found a decrease in grain rates as a result of deregulation (Babcock et al. 1985, Bitzan 1994, Fuller et al. 1987, McDonald 1989). It is expected that the declining real grain rail rates in the post-Staggers era had an unfavorable impact on Seaway grain traffic.

Based on counsel from the U.S. Department of Transportation (2009) a real railroad rate index was computed as a proxy for rail grain rates during the study period with the Rail Freight Farm Products rate index (USDA 2009), a nominal rate index collected by the Bureau of Labor Statistics, and the implicit price deflator from the U.S. Department of Commerce (2009). The Rail Freight Farm Products index was selected since a rail grain rate index was not available for the 35-year study period, and grain rates comprise a significant portion of the Rail Freight Farm Products index. The Rail Freight Farm Products rate index was converted to revenue/ton-mile values with data from the Association of American Railroads (2007) and deflated with the implicit price deflator to yield a proxy of a real rail grain rate index. The resulting rail rate index increased from 1972 to 1981-1982 and then declined about 20% during the post-Staggers era.

Figure 5 relates U.S. grain exports to selected importing world regions during recent decades (USDAc various years). United States exports to Europe peak in 1980-81 and then decline, yielding a temporal export profile that approximates U.S. exports transiting the Seaway. Europe was often the principal destination for U.S. grain exports until the early 1980s, when Asia began to dominate

Figure 5: U.S. Grain Exports to World Demand Regions (1973-2007)

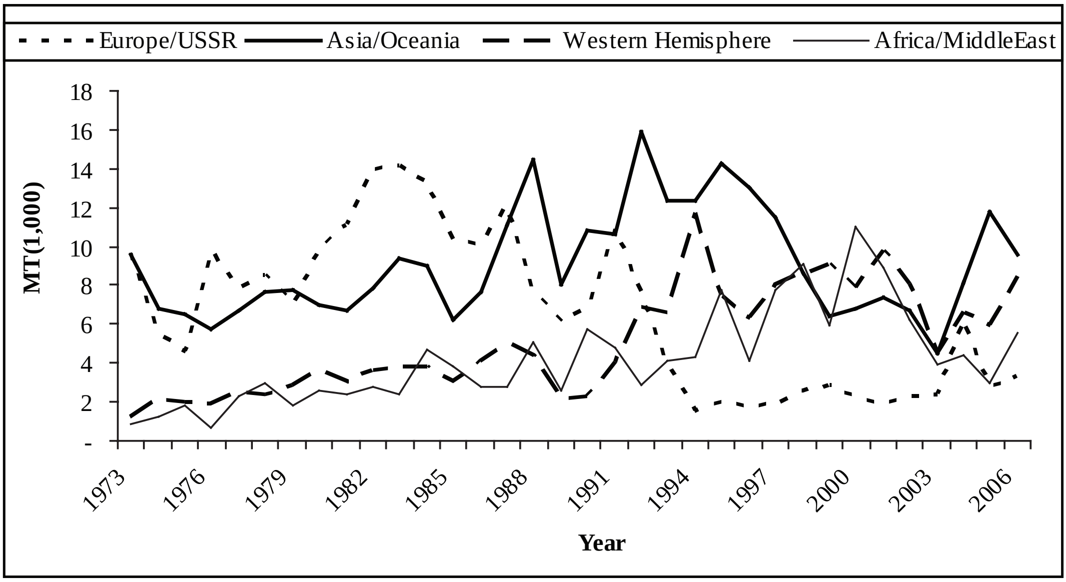


Source: U.S. Department of Agriculture, Agricultural Marketing Service, Federal Grain Inspection Service. *Grains Inspected and/or Weighed for Export by Port Region and Country of Destination.* (USDAb various years).

as the primary destination. Grain exports to Asia showed strong growth throughout the study period, peaking at 61 MMT in 1995 and averaging about 52 MMT in recent years. United States exports to the former USSR were highly erratic during the study period, ranging from zero to 22 MMT in 1985.

Canadian grain exports to various world import regions (Figure 6) reveal some similarity to U.S. export patterns, with the exports to Europe and former Soviet Union peaking at 14.4 MMT in the early 1980s prior to trending downward to average about 2.4 MMT since 1993 (Figure 6) (Canadian Grain Commission various years, Canada Grain Council various years). Canadian grain exports to Asia and Oceania grew until the early 1990s to peak at 14.9 MMT prior to averaging downward to about 9.0 MMT during the past decade. Canadian grain exports to Africa, the Middle East and other Western Hemisphere regions have shown an erratic upward trend until the current decade, when a downturn is evidenced.

Figure 6: Canadian Grain Exports to World Demand Regions (1973-2007)



Source: Canadian Grain Commission, Canadian Grain Exports (various years), and Canada Grain Council, Online Statistical Handbook (various years).

Empirical Analysis

Initial model specifications included the following independent variables in each country's Seaway grain export equation: (1) a country's annual exports of grain and oilseeds to various world import regions, (2) a country's grain production, (3) manufactured iron and steel imports via the Seaway, and (4) selected variables to represent domestic transportation policies. Grain production was ultimately dropped from the analysis. Although a country's grain production was initially considered as an explanatory variable in the U.S. equation, the variable creates endogeneity problems as determined by Granger causality testing (Greene 2002) and was not included in the final model. Further, including the grain production variable in the U.S. equation induces collinearity problems. In particular, when total grain production is added to the U.S. equation, the average Variance Inflation Factor (VIF) is increased to 5.54 from 2.92, while the largest VIF becomes 15.41 instead of 5.69 (Belsey, Kuh, and Welsch 1980). Even though the Canadian grain production did not induce collinearity problems in the Canadian equation, it rendered the coefficients biased and inconsistent and therefore was not included. The endogeneity of this variable was confirmed with Granger causality testing (Greene 2002), where all regressors significantly explained the variation in Canada's total grain production with a calculated p-value smaller than 0.006.

The U.S. and Canadian equations were estimated with ordinary least squares, and none of the presented models have statistical problems beyond a tolerable level. Specifically, it is concluded that the residuals obtained from both equations are independent, homoscedastic and accurately described by a normal distribution. Independence was studied by testing for autocorrelation with Portmanteau (Q) test statistics up to six lags (Ljung and Box 1978). None of the Portmanteau statistics-associated p-values were smaller than 0.23 for the U.S. equation and 0.82 for the Canadian equation. Therefore, the analysis failed to provide evidence of significant autocorrelation. Homoscedasticity could not be rejected using a Breusch-Pagan/Cook-Weisberg's test, which yielded a p-value of 0.81 for the U.S. equation and 0.15 for the Canadian equation (Breusch and Pagan 1979, Cook and Weisberg 1983). Normality was not rejected by a Shapiro-Wilks' test, with an associated p-value of 0.59 for the U.S. equation and 0.18 for Canadian equation (Shapiro and Wilks 1965). Although the data display considerable volatility, none of the observations drive the estimation results. Cook's distances were computed for each observation in both equations. Cook's D statistics were within the [9.9×10^{-6}, 0.295] interval for the U.S. equation, whereas they were in the [5.7×10^{-5}, 0.33] interval for the Canadian equation, proving to be too small to be considered influential observations (Cook 1977). Collinear relationships were studied using Variance Inflation Factors (VIF). Although the average VIF was 2.92 for the U.S. equation, none of the individual VIFs were larger than 6. The average VIF for the Canadian equation was 1.92, with the largest VIF equaling 2.80 (Belsey, Kuh and Welsch 1980). None of the accumulated sums of residuals cross the confidence bands to suggest structural breaks in either the presented U.S. or Canadian equation (Brown, Durbin and Evans 1975), and Granger causality testing (Greene 2000) shows endogeneity is not a problem in either equation.

U.S. Seaway Equation. Table 1 defines the variables in the selected U.S. Seaway equation, Table 2 is a statistical summary of these variables and Table 3 presents the estimation results. In addition, USDA grain inspection data (USDAb various years) show that over 98% of the U.S. wheat exports to the former USSR between 1972 (first year of analysis) and the fall of the Soviet Empire in 1991 were from ports other than the Great Lakes, and in many crop years there were no U.S. wheat exports to the former USSR from the Great Lakes. Therefore, it seemed prudent to subtract wheat exports from the other grain exports to the former USSR. Further, segregating wheat out of the USSR variable overcame a multi-collinearity problem that existed with its inclusion.

Table 1: Definition of Variables in U.S. St. Lawrence Seaway Grain Export Equation

Variables	Definitions
$EUROPE_i$	U.S. Grain Exports to Europe in year *i* (1,000 metric tons)
$ASIA_i$	U.S. Grain Exports to Asia in year *i* (1,000 metric tons)
$SOUTH\ AMERICA_i$	U.S. Grain Exports to South America in year *i* (1,000 metric tons)
$STEEL_i$	Steel Imports via St. Lawrence Seaway in year *i* (1,000 metric tons)
RTM_i	Real Rail Farm Product Revenue/Ton-Mile in year *i* (cents/ton-mile)
$SLS\text{-}US_i$	U.S. Grain Exports via Seaway in year *i* (1,000 metric tons)
$USRWHT_i$	U.S. Grain Exports to USSR (except wheat) in year *i* (1,000 metric tons)

All variables included in the model shown in Table 3 were significant with the estimated equation having an Adj-R^2 of 0.78. Interestingly, two of the four world importing region variables were found to have positive signs (EUROPE, SOUTH AMERICA), while Asia (ASIA) and the former USSR (USRWHT) had negative signs. This suggests that the declining imports of U.S. grain by Europe was central to the decline in Seaway grain traffic, while the growth in exports to Asia tended to offer increased competition to western Great Lakes grain ports through expansion of Gulf and Pacific grain port hinterlands. Further, the analysis shows that the erratic purchase pattern of

Table 2: Summary of U.S. St. Lawrence Seaway Equation Variables

Variables	Unit	Mean	Standard Deviation	Min	Max
ASIA	1,000 Metric Tons	38,476.71	11,997.35	17,764.00	60,878.00
EUROPE	1,000 Metric Tons	11,538.17	9,818.75	1,469.00	32,388.00
SLS-US	1,000 Metric Tons	5,831.77	2,522.77	2,690.00	13,509.00
SOUTH AMERICA	1,000 Metric Tons	5,409.80	1,744.24	2,334.00	8,891.00
STEEL	1,000 Metric Tons	3,908.77	1,120.50	2,085.00	6,909.00
RTM	Cents/Ton-Mile	2.48	0.209	2.07	2.85
USRWHT	1,000 Metric Tons	3,157.83	3,947.68	-	15,800.00

the former USSR and the substantial size of these purchases may have expanded the hinterland of Gulf ports at the expense of selected Great Lake ports. Analysis shows that a 1,000 metric ton (MT) decrease in European imports would reduce Seaway grain traffic by 120.9 MT (-1,000 MT x 0.1209 = -120.9 MT), and a similar increase in Asian imports would reduce Seaway traffic by 162.6 MT (+1,000 MT x -0.1626 = -162.6 MT) (Table 3). The comparatively large coefficient associated with the South America variable (0.9485) suggests the importance of the Great Lakes as a source of South America's grain imports from the United States, i.e., a 1,000 MT increase in U.S. grain imports by South America will increase Seaway flow 948.5 MT (+1,000 MT x 0.9485 = 948.5 MT).

Table 3: Summary of U.S. St. Lawrence Seaway Equation

Variables	Coefficients	t-statistic	P-Value
INTERCEPT	-5555.654	-1.63	0.11
ASIA	-0.1626	-4.01	0.00
EUROPE	0.1209	3.59	0.00
USRWHT	-0.4404	-4.22	0.00
SOUTH AMERICA	0.9485	5.72	0.00
RTM	4390.386	3.20	0.01
STEEL	0.3965	1.80	0.08
Number of Obs	35		
Adj-R^2	0.78		

The proxy for real rail grain rates during the study period (RTM) has the expected positive sign and is statistically significant, indicating that the decline in rates during the post-Staggers period tended to decrease Seaway traffic. In the post-Staggers era (1981-2006), the estimated real rate decreased 0.45 cents/ton-mile, effecting a decline in U.S. Seaway grain traffic of 1.975 MMT (-0.45 x 4390.38 = -1,975.67 MT). Another transportation related variable (STEEL) measures the effect of steel imports into the Great Lakes on backhauls of U.S. Seaway grain. The coefficient associated with the STEEL variable (p = 0.08) indicates that an increase in manufactured iron and steel imports into the Great Lakes of 1,000 MT will increase U.S. Seaway grain exports of grain by 396.5 MT (+1,000 MT x 0.3965 = 396.5 MT).

Canadian Seaway Equation. Table 4 defines variables included in the Canadian Seaway equation. Table 5 is a statistical summary of variables included in the Canadian equation, and Table 6 presents the estimated equation. All variables included in the Canadian equation are highly significant with the estimated equation explaining about 87% of variation (Adj.-R^2) in annual Canadian Seaway grain traffic.

Canadian grain exports to Europe and the former USSR, Asia and Oceania, Africa and the Middle East, and the Western Hemisphere are significant and with the expected positive signs (Table 6).

Europe, the former USSR, Asia and Oceania have been important destinations for Canadian grain. However, exports to these regions peaked in 1982-1992, with subsequent declines in recent years that analyses suggest have been a force behind the decline in Canadian Seaway grain flow. Importantly, the analysis shows that a 1,000 MT decline in grain exports to Europe and the former USSR decreased Seaway flow 814.6 MT (-1,000 MT x 0.8146 = -814.6 MT), while a similar decline in exports to Asia and Oceania lowered Seaway exports a more modest 214.7 MT. Since the majority of Canada's grain exports to Asia and Oceania exit through the Pacific Coast, the general downtrend in Canada's grain exports since the 1990s may have been partially captured with the Asia/Oceania variable. Canadian exports to the Western Hemisphere, Africa and the Middle East have generally trended upward over the study period, thus contributing to increased Seaway flow. Further, the analysis shows the Western Grain Transportation Act of 1983, which is included as a binary variable extending from 1984-1994, has a negative sign as expected (Ghonima 2004), suggesting this legislation reduced annual Seaway grain flow about 1.26 MMT.

Table 4: Definition of Variables in Canadian St. Lawrence Seaway Grain Export Equation

Variables	Definitions
EUROPE/USSR_i	Canada Grain Exports to Europe and USSR in year *i* (1,000 metric tons)
ASIA/OCEANIA_i	Canada Grain Exports to Asia and Oceania in year *i* (1,000 metric tons)
$\text{WESTERN HEMISPHERE}_i$	Canada Grain Exports to West Hemisphere in year *i* (1,000 metric tons)
$\text{AFRICA/MIDDLE EAST}_i$	Canada Grain Exports to Africa and Middle East in year *i* (1,000 metric tons)
SLS-CANADA_i	Canada Grain Exports via Seaway in year *i* (1,000 metric tons)
WGTA	Binary Variable for Western Grain Transportation Act (1 = 1984-1994)

Table 5: Summary of Canadian St. Lawrence Seaway Equation Variables

Variables	Unit	Mean	Standard Deviation	Min	Max
AFRICA/MIDDLE EAST	1,000 Metric Tons	4,204.46	2,469.06	698.18	10,982.10
ASIA/OCEANIA	1,000 Metric Tons	9,081.51	2,804.91	4,477.04	15,889.80
EUROPE/USSR	1,000 Metric Tons	6,614.63	3,981.56	1,564.84	14,143.40
SLS - CANADA	1,000 Metric Tons	9,500.38	2,685.13	5,572.10	16,167.60
WESTERN HEMISPHERE	1,000 Metric Tons	5,132.76	2,705.10	1,267.66	11,633.90
WGTA (DUMMY)	1,000 Metric Tons	0.29412	0.4624973	-	1.00

Table 6: Summary of Canadian St. Lawrence Seaway Equation

Variables	Coefficients	t-statistic	P-Value
INTERCEPT	165.9502	0.18	0.86
EUROPE/USSR	0.8146	14.15	0.00
ASIA/OCEANIA	0.2147	3.01	0.01
WESTERN HEMISPHERE	0.2875	2.79	0.01
AFRICA/MIDDLE EAST	0.2117	2.15	0.04
WGTA	-1,255.1180	-3.01	0.01
Number of Obs	34		
Adj R^2	0.87		

Findings and Implications of Findings

The findings of this study support many of the hypotheses forwarded by Ghonima (1991, 2004) and others as explanation for declining grain traffic on the St. Lawrence Seaway. Canada's grain exports to Europe and the former USSR were statistically important, as was the Europe variable in the U.S. equation that shows declining grain exports to the European region is central to understanding the decline in Seaway grain traffic. For example, during the decade of the 1980s, U.S. grain exports to Europe declined nearly 20 MMT, which is estimated to have reduced U.S. Seaway grain traffic about 2.42 MMT (-20 MMT x 0.1209 = -2.42 MMT). In the U.S. equation, grain imports by the former USSR were included as a separate variable whose estimated coefficient was negative. This suggests the erratic and often large grain purchases by the former USSR tended to decrease Seaway grain traffic, because the Gulf port hinterland expanded at the expense of competing hinterlands associated with Great Lake grain ports. Similarly, the Asia variable in the U.S. equation had a negative sign, which indicates the large and growing exports to Asia during the study period likely extended the hinterland of the Pacific and Gulf grain ports into portions of the Great Lake's grain port areas. In the Canadian equation, grain shipments to the Western Hemisphere were found to be a statistically important determinant of Seaway grain traffic: a substantial portion of the nations in the Western Hemisphere grouping are located in the Caribbean, South America and Mexico, nations that receive most of their Canadian grain imports by water. In contrast, U.S. grain imports from Canada are largely overland.

The analysis indicates that the decline in real grain rates following the Staggers Act reduced U.S. Seaway grain traffic. Interestingly, the important growth in U.S. grain exports via Pacific grain ports during the study period was coincident with rail deregulation (Staggers Rail Act) and the introduction of unit and shuttle trains that ultimately linked regions formerly in the Great Lakes hinterland (Minnesota, Iowa, the Dakotas) to the Pacific Northwest grain ports. Further, the analysis suggests that U.S. grain was a backhaul for steel imports into the Great Lakes, and Canada's Western Grain Transportation Act of 1983 had a negative influence on that country's grain exports via the Seaway.

Since the analysis suggests declining imports of North American grain by Europe is central to the observed decline in Seaway grain traffic, efforts were made to learn about the erosion of this demand. The decline in Europe's demand for North American grain is explained largely by the European Union's (EU) agricultural policies, technology, expansion of the EU and preferential trade agreements. Grain production in Western Europe has climbed steadily over the past 40 years due to a combination of new technology, high prices and income support provided by the Common Agricultural Policy (CAP) of the European Union. The CAP was designed to equalize farm and non-farm income and increase food self-sufficiency. This was accomplished through guaranteed farm prices at high levels, protective tariffs and export subsidies for excess production (USDA 2001).

EU self-sufficiency in grains increased from 86% in 1969 to 118% in 1990. Interestingly, the European Union became self-sufficient in wheat production in 1978 and self-sufficient in coarse grain (corn) production in 1984, which are periods when Seaway grain traffic turned abruptly downward (USDA 2001). The EU has become a grain exporter for over two decades as a result of subsidies offered through the Common Agricultural Policy. The success of the European Union and the Common Agricultural Policy is evidenced by its growth. Currently the EU includes 25 members that comprise much of Europe. The European Union also features preferential trading agreements that create a mosaic of tariffs, quotas and import restrictions that vary among preferred agricultural trading partners. The U.S. and Canada are two of only nine countries that have no preferential access to the European Union (Cochrane and Seeley 2004).

Further, it is likely the dissolution of the Soviet Union and the market-oriented reforms in former Soviet republics (15 nations resulting from the fall of the USSR in December 1991) that generated important quantities of grain exports from Russia, Ukraine and Kazakhstan, which have influenced the competitiveness of U.S. and Canadian grain in the Mediterranean region, an important import region for North American grain. For example, by 2000 the old Soviet Federation, primarily the Ukraine and Kazakhstan, were exporting an average of 13.3 MMT of wheat per year (Liefert, Liefert, Seeley and Allen 2004).

SUMMARY

Completion of the St. Lawrence Seaway in 1959 facilitated the introduction of harmful, non-indigenous aquatic species into the Great Lakes through the ballast water of international carriers. A variety of solutions have been proposed to this externality, with some advocating closure of the St. Lawrence Seaway to curtail the further introduction of invading species. Because the Seaway is an export grain artery for important grain producing regions of Canada, the U.S. Midwest and north Plains, agricultural interests have voiced concern about closure of the Seaway. The purpose of this study was to develop an understanding of the forces responsible for the decline in U.S. and Canadian grain traffic on the Seaway and offer conjecture regarding the likely reversal of these forces.

The analysis indicates relocation of world demands for North American grain is central to explaining the decline in St. Lawrence Seaway grain flow. Based on the Canadian and U.S. Seaway equations, Europe's decline in demand for Canadian and U.S. grain had an important influence on Seaway grain tonnage, and the demise of the Soviet Union and its demand for Canadian grain also unfavorably affected Seaway grain traffic. Asian imports of North American grain also had an important effect on Seaway tonnage. The U.S. equation suggests U.S.' substantial and continuous growth in grain exports to Asia negatively influenced U.S. Seaway exports. It is believed that the growth in Asian demand for U.S. grain expanded Gulf and Pacific Northwest grain port hinterlands at the expense of Great Lake port hinterlands, and the expansion of the Pacific Northwest hinterland was partially facilitated by rail deregulation (Staggers Rail Act of 1980) and the introduction of increasingly efficient train service that linked Minnesota, Iowa, and the Dakotas to Pacific Northwest ports. The analysis shows the declining real rail grain rates following the Staggers Rail Act in 1980 were statistically important and had a negative influence on Seaway grain traffic, as did Canada's Western Grain Transportation Act of 1983.

The decline in demand for North American grain in Europe is largely a result of the European Union's agricultural policies that have encouraged domestic grain production through increased subsidization of production agriculture, expansion of the EU to include grain-exporting countries in Eastern Europe, and preferential trade agreements that exclude Canada and the United States. Further, the demand for grain in the Mediterranean region (south Europe/north Africa/the Middle East) may be increasingly met by Ukraine, Russia, Kazakhstan and other grain-exporting countries that resulted from adoption of market-oriented reforms after the fall of the Soviet empire. Therefore, expanding world competition may also offer some explanation for declining traffic on the Seaway.

It is difficult to ascertain with certainty the relative continuing nature of forces that have affected a downturn in Seaway grain traffic. Clearly, the agricultural policy of the EU could be reversed, but it is unlikely since the same general policy has been in place over 40 years. In addition, it is unlikely that there would be changes in transportation policies that reverse efficiency gains of North American railroads and the apparent increased competitiveness they offer to Seaway grain traffic. Therefore, an immediate reversal in trends believed to be responsible for the observed downtrend does not seem imminent. However, one cannot conclude that closure of the Seaway to ocean travel would be inconsequential to North American grain shippers. Some have argued that economic growth in Africa and South America portends increased grain exports via the Seaway, and analysis suggests a positive relationship between Seaway grain flows and North American exports to these world regions. Further, even though the Seaway is not a dominant grain transport artery, it represents an alternate route that may prove to be of substantial value in case of a national emergency or catastrophic event (e.g. Hurricane Katrina).

The Transportation Research Board (2008) study concludes that closing the Seaway to transoceanic shipping would be an impractical solution to introduction of aquatic invasive species into the Great Lakes. The report indicates that shifting Seaway cargoes to other modes could well have an adverse environmental impact, including increased fuel use, greenhouse gas emissions, accidents and noise. Further, the study notes closing the Seaway could lead to reprisals by trading partners of the United States and Canada, and closing of the Seaway for a prolonged period could raise concerns about the financial viability of transportation assets that may have value in the future.

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