PREDICTING EFFECTS OF THE PANAMA CANAL EXPANSION ON U.S. COUNTIES' PRODUCTION USING THE RANDOM UTILITY-BASED INPUT-OUTPUT MODEL

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ABSTRACT
The paper estimates the effect of the Panama Canal expansion on commodities manufactured in the U.S. and exported to Asia, based on a Random Utility-based Multiregional Input-Output (RUBMRIO) model. 11 scenarios are used to describe shifts in export demands from the Port of Long Beach/Los Angeles, in California to Houston, Texas, using the nation's Commodity Flow Survey database and Freight Analysis Framework version 3 (FAF^3). The results reveal a lot of counties have a strong increase in production (20%) from such a Canal-related shift. Several important interstate corridors across 15 states are predicted to demonstrate the largest increase. Illinois, Texas and Ohio are expected to see the three of the 15 states increases, in their Food, Beverage and Tobacco Products Manufacturing, in their Petroleum and Coal Product Manufacturing and in their Machinery Manufacturing, respectively. These three states may do well to begin investing in their production processes to meet these added freight flow demands, as result of the Panama Canal's recent expansion.

Keywords: Panama Canal expansion, trade modeling, freight movement, spatial input-output models

INTRODUCTION

The Panama Canal is one of the most important shipping canals in the world, in terms of impacts on the global economy. It shortens the distance between the Pacific and Atlantic Ocean. 43% of traded value between Asia (including China, Japan and the Far East) and U.S. East Coast Ports in 2007 (versus just only 11.3% in 1999) (*1*). The Panama Canal Authority found the Canal had reached its maximum capacity in 2006 and predicted that an unexpanded canal would see just 23% of market trading between the Asia-U.S. East Coast Ports in 2025 if something did not change (*2*). As more and more global cargo is transported by post-Panamax ships (each holding 4,000-5,000 twenty-foot equivalent units (TEUs)) that is larger than the Panamax ships (which carry 3,400-4,500 TEUs, the size limits for ships travelling through the Panama Canal), more and more ships can't pass the original Panama Canal locks. And the Authority found that post-Panamax vessels would account for more than 48% of global shipping fleet in TEU in the future. (*1*). These reasons prompted the Canal expansion through a construction of a third set of locks (*2*) to meet the increasing demand.

In June 2016, the Panama Canal Expansion project was completed, and doubled the capacity of the original Panama Canal (from 5,000 to 13,000-14,000 TEUs) (*3*). With the Canal handling post-Panamax vessels, Costa and Rosson (*4*) predict the expansion Canal reduce costs by up to $860 per TEU from Gulf Coast and East Coast Ports to China. As the Panama Canal offering lower costs, the U.S. Maritime Administration (*5*) is difficult to estimate the potential changes in the volume and commodity mix of trade flows product in U.S. inland regions. However, some models have been predicted different results. CanagaRetna (*6*) predicts a significant rise in volume of U.S. goods moving through the Mexico Gulf Coast and East Coast Ports to Asia. Costa and Rosson (*4*) used a spatial price equilibrium model to predict that Canal expansion will shift U.S. cotton export flows from West Coast Ports to Gulf and Atlantic Ports. Costa and Rosson (*4*) also predicts that the new Canal will reduce maritime shipping costs from the U.S. East Coast Ports to Asia by 28%, reflecting cost structure, transit time, and the Canal tolls (as compared to the Intermodal Option). Baird et.al (*7*) predict California's grain exports to Asia slowing, relative to growth in Gulf od Mexico Ports exports. Vorotnikova and Devadoss (*8*) develop a world dairy trade model to witness that the expansion is positive for the West Coast and the Gulf Coast on the dry milk and butter trade export to Asia. Knight (*9*) argues that the Panama Canal expansion plays an important role in decreasing trade between the West Coast and Asia, and increasing trade between the Gulf/East Coast and Asia.

This paper uses the random utility-based multiregional input-output model (RUBMRIO) to explore which regions and types of product are affected most by the recent expansion of the Panama Canal as the U.S. exports to Asia. The RUBMRIO model considers 3,109 counties (all 50 states, except for Hawaii and Alaska) trade pattern, across 20 sectors and two transportation modes (railway and truck), at 106 export-zone centroids. The RUBMRIO model originates from input-output model (*10*) that describes linkages between industries, and between producers and consumers. Following development of the IO model, many methods have been extended to develop IO model. Isard (*11*) developed IO model to interregional IO model (IRIO), Chenery (*12*) and Moses (*13*) utilized the IO model to apply into multi regions input-output model (MRIO). de la Barra (*14*) and Cascetta et.al (*15*) used the Land Use Transportation Interaction (LUTI) model integrated with random utility maximization (RUM) and IO model to generate the RUBMIO model. Then the RUBMRIO was widely credited by Kockleman et al. to simulate Texas (*16-18*) and U.S. (*19*)'s trade, transportation and industrial production. The model is driven by export demands and measured in utility units and base on expected minimum transportation cost. The Texas-level RUBMRIO model was applied for 254 counties trade patterns, across 18 social-economic sectors, with the U.S-level RUBMRIO model being developed for 3,109 counties trade patterns, across 20 social-economic sectors. These applications predicted trade and location choices resulting from a variety of scenarios (variation in transportation cost, time, and export demands).

As mentioned previously, the Panama Canal expansion will switch the West Coast Ports freight arrival point to the Gulf Coast Ports. In this paper Los Angles and Long Beach (LA/LB) and Houston port are selected as the typical export ports to Asia from West Coast Ports and the Gulf Coast Ports respectively, as LA/LB and Houston are two of the top ten contained ports in U.S. The application will proceed as the following steps. Step 1, LA/LB will shift its export demands to Houston from 0% to 100% in 11 scenarios to find a scenario in which 3,109 counties' production change significantly overall. Step 2, in the significant scenario we will search for some states, whose average productions vary the most. Step 3, under the same scenario we will figure out which regions and commodities are affected most by production changes. Lastly, the paper concludes with a discussion of application results and recommendations for future studies.

DATA SETS AND METHODS

Data Source

The RUBMRIO model requires four main data: export demands, relative technical coefficients, origin and mode choice parameters and time and cost to travel between origin and destination. The best available freight data are from the U.S. Department of Transportation's Freight Analysis Framework(FAF^3) *(20)* database, the 2007 U.S. Commodity Flow Survey (CFS) (*21*), and the IMPLAN industry code *(24)*. FAF^3's data is based on 123 domestic regions, 8 foreign regions across 43 known and 1 unknown commodity class, 8 different FAF modes, 3 freight flows (import flows, domestic flows, export flows) and 3 measures (tons, ton-mile, values). The export flows' measured by values are easily converted into utility. The origin and mode choices parameters, λ^m,β^m ,γ^m are estimated based on the nested logit model. Then, using these parameters and data, the RUBMRIO model is applied to predict the production change. The commodities data class from the CFS database relied on the 43 two-digit Standard Classification of Transported Goods (SCTG) and the North American Industry Classification System (NAICS), FAF^3 used the 43-two digit SCTG as well, shown in Table 1.

TABLE 1 Description of Economic Sectors in U.S. Application of the RUBMRIO Model(*19*)

Commodity Class		IMPLAN	NAICS	SCTG
1	Agriculture, Forestry, Fishing and Hunting	1-19	11	1
2	Mining	20-30	21	10-15
3	Construction	34-40	23	--
4	Food, Beverage and Tobacco Product Manufacturing	41-74	311,312	2-9
5	Petroleum and Coal Product Manufacturing	115-119	324	16-19

6	Chemicals, Plastics and Rubber Product Manufacturing	120-152	325, 326	20-24
7	Primary Metal Manufacturing	170-180	331	32
8	Fabricated Metal Manufacturing	181-202	332	33
9	Machinery Manufacturing	203-233	333	34
10	Computer, Electronic Product and Electrical Equipment Manufacturing	234-275	334, 335	35,38
11	Transportation Equipment Manufacturing	276-294	336	36,37
12	Other Durable & Non-Durable Manufacturing	75-114, 153-169, 295-304	313-316, 327, 321-323, 337	25-31, 39
13	Miscellaneous Manufacturing	305-318	339	40,41,43
14	Transportation, Communication and Utilities	31-33, 332-353	22,48,49,51	--
15	Wholesale Trade	319	42	--
16	Retail Trade	320-331	44,45	--
17	FIRE (Finance, Insurance and Real Estate)	354-366	52,53	--
18	Services	367-440	54-56, 61,62, 71,72,81,92	--
19	Household	--	--	--
20	Government	--	--	--

Note: This table provides the corresponding sector code in different data sources, which is used in the U.S. studies. IMPLAN stands for Impact Analysis for Planning, NAICS stands for North America Industrial Classification System, and SCTG stands for Standard Classification of Transported Goods. Household and government are both treated as industrial sectors that buy from and sell to other sectors.

Data of Trucking Travel Cost

The calculation of travel time and cost are based on the corresponding transport distances from zone i to zone j (or export zone k) by mode t. To get $time_{ij,t}$ and $cost_{ij,t}$, assumptions made by Du and Kockelman (*19*) about railway price per mile, the truck freight speed, railway freight speed and delay time were employed. However, travel cost is also sensitive to the expense for trucks. Based on Analysis of the Operational Costs of Trucking from the year 2008 to 2014 (*22*), the average marginal costs per mile will decrease in 2015. In Table 2, the average marginal costs per mile were divided into two general groupings: vehicle-based and driver-based. It is evident that fuel costs are the largest cost of vehicle-based grouping. The report (*22*) notes the fuel cost is easily affected by the fuel price. Therefore the fuel price is important for motor carrier costs.

TABLE 2 Average Marginal Costs per Mile, 2008-2014 (*22*)

Motor Carrier Costs	2008	2009	2010	2011	2012	2013	2014
Vehicle-based							
Fuel Costs	$0.63	$0.40	$0.49	$0.59	$0.64	$0.64	$0.58
Truck/Trailer Lease or Purchase Payments	$0.21	$0.26	$0.18	$0.19	$0.17	$0.16	$0.22
Repair & Maintenance	$0.10	$0.12	$0.12	$0.15	$0.14	$0.15	$0.16
Truck Insurance Premiums	$0.06	$0.05	$0.06	$0.07	$0.06	$0.06	$0.07
Permits and Licenses	$0.02	$0.03	$0.04	$0.04	$0.02	$0.03	$0.02
Tires	$0.03	$0.03	$0.04	$0.04	$0.04	$0.04	$0.04
Tolls	$0.02	$0.02	$0.01	$0.02	$0.02	$0.02	$0.02
Driver-based							
Driver Wages	$0.44	$0.40	$0.45	$0.46	$0.42	$0.44	$0.46
Driver Benefits	$0.14	$0.13	$0.16	$0.15	$0.12	$0.13	$0.13
TOTAL	$1.65	$1.45	$1.55	$1.71	$1.63	$1.68	$1.70

EIA 2015 (*23*) shown fuel prices decreasing throughout the year, thus reducing the fuel cost per mile. According to report (*22*), the driving wages and drive benefits per mile in 2015 is assumed as $0.46 and $0.16. Since the equipment is constant from 2008 to 2014, the cost of the equipment is the average from 2008 to 2014. However, the fuel cost has consistently had the biggest influence on marginal costs during this time, accounting for 35% of the total cost per mile, with the other truck wear-out cost and driver pay respectively share of 30% and 35% respectively. Asche, et.al 's (*24*) proposed the relationships between the crude oil price (p_c) and the diesel price (p_d) at time (t) is

$$\ln P_{ct} = \alpha + \beta \ln P_{dt} \qquad (1);$$

Equation 1 (*24*), where α means a constant term (the log of a proportionality coefficient) that captures differences in the levels of the prices and β gives the relationship between the prices. The analysis is based on quarterly price series of crude oil and diesel price (*25; 26*) January 2008 to November 2014. All oil prices are be in US dollar per gallon. Cointegration analysis is used to infer causal long-run relationships between nonstationary time series. The Johansen test (*27*) is employed to allow for hypothesis testing on the parameters in the cointegration vector and exogeneity tests. Then the tool—Eviews 6.0 (*28*) (a statistical package for Windows, developed by Information Handling Services) can use the time series data to get α and β.

Before conducting any econometric analysis, the time series properties of the data must be investigated. Augmented Dickey–Fuller (ADF, in statistics and econometrics, an ADF tests the null hypothesis that that a unit root is present in a time series sample) tests suggest that all prices are stationary in the first difference. Then the Johansen test are performed to obtain the maximum Eigen value test and the trace test, which suggests there are only one cointegration vector within the two variables and the long relationship between two variables. After analysing the significance, we can get a stable equation (2)

$$\ln P_{ct} = 1.01 \ln P_{dt} - 0.65 \quad (2)$$

We then address the issue of whether crude oil and diesel prices are proportional, i.e. whether the relative prices are constant. In the reduced system the likelihood ratio test(*29*) an approximation is distributed as $\chi^2(2)$ and gives a test statistic of 2.007641 with a P-value of 0.1603, which values is larger than the significance of 0.05. Hence, all the prices are proportional, which the exp(α) is 0.52.

Due to the diesel prices being proportional to the crude oil prices, it's easy to compute the diesel prices in 2015 with the known crude oil prices. The start of the year experienced high crude oil prices in 2015 when it reached $1.42 per gallon in June before falling steadily all through the year. The final recorded crude oil price of the year was in fact the lowest price for the year at $0.89 per gallon.

There is a long-standing relationship between the crude oil prices and diesel prices. This assumes fuel costs per mile are proportional to diesel prices per gallon from 2008 to 2015, which is represented by the averages of all fuel/diesel prices from 2008 to 2014 (Table 1). When applying Equation 1, average fuel costs are computed, which significantly decreased in 2015. It is true in the specialized sector where carriers accounted for the highest cost of specialized equipment when expanding or replacing fleets.

With these data mentioned above, the marginal cost per mile equals to $1.48 in 2015. GIS software-TransCAD 4.0(*30*) provides a 3,109×3,109 county-to-county matrix to compute the travel costs and times, based on the shortest inter-county network distances for highway and railway modes. TransCAD have highway network and railway network, so the shortest-path routes can be estimated. Besides the travel times and costs in details are computed based on Du & Kockelman's assumptions (*19*).

Model Procedures

The RUBRMIO algorithm procedure is shown in Figure 1, and relative variables have been defined in Table 2. The trade model begins by assuming the sale prices are at zero across production zones and commodity types. The export and domestic production zone sales' prices, transport costs, times and native population index are used to calculate the trade utility. The export flows (demands) in the model, are distributed in different productive zones (based on the relative export utilities of competing supplier and modes). The domestic demands and trade flows between origins to destinations are both driven by export demands. Export demands and intermediate production are summed by other sectors and counties, equal to the production in each county. The total consumption of each commodity at each iteration, across each zone, are calculated by the total production of each commodity multiplied with each corresponding technical coefficient (considering the import and leakage situation). Average input costs are calculated as a flow-weighted average of utilities coupled by original technical coefficient to work out new sales prices. The new sales prices estimate feedback for a new iteration until stable trade flows arise, achieving model equilibrium (set the relative errors at 1%).

TABLE 2 Variable Definitions

Variables	Definitions
U_{ij}^{m}	Utility of purchasing one unit of sector m's goods from region i for use as input in region j.
U_{ik}^{m}	Utility of purchasing one unit of sector m's goods from region i for use as export from region k.
Y_{ik}^{m}	The dollar value of foreign export trade flow of commodity m from zone i to export zone k.
X_{ij}^{m}	The dollar value of domestic trade flow of commodity m from zone i to zone j.
$time_{ij,t}$	The travel time from zone i to zone j by mode t.
$cost_{ij,t}$	The travel cost from zone i to zone j by mode t.
x_{i}^{m}	The total production commodity m in zone i.
C_{j}^{m}	The total consumption of commodity m in zone j supplied by domestic zones (including local provider in zone j).
c_{j}^{m}	The weighted average input cost of commodity m from all zones (include zone j) in zone j.
p_{j}^{n}	The sales price of commodity n in zone j.
γ^{m}	The parameter reflects producer's attraction to an origin zone's size and prominence
λ^{m}	The parameter determines the effect of transportation of the utility and trade flow between all zone pairs.
β^{m}	The parameters represent the sensitivity of travel times and costs of the two alternative modes (highway and railway) in the lower level of the nested logit model
$A_{0,j}^{mn}$	The m * n matrix reflects the productive technology of all zones, for needs across all industries.
A_{j}^{mn}	The m * n matrix that reflects the productive technology of all zones, with Regional Purchase Coefficients (RPCs) to account for "leakages".

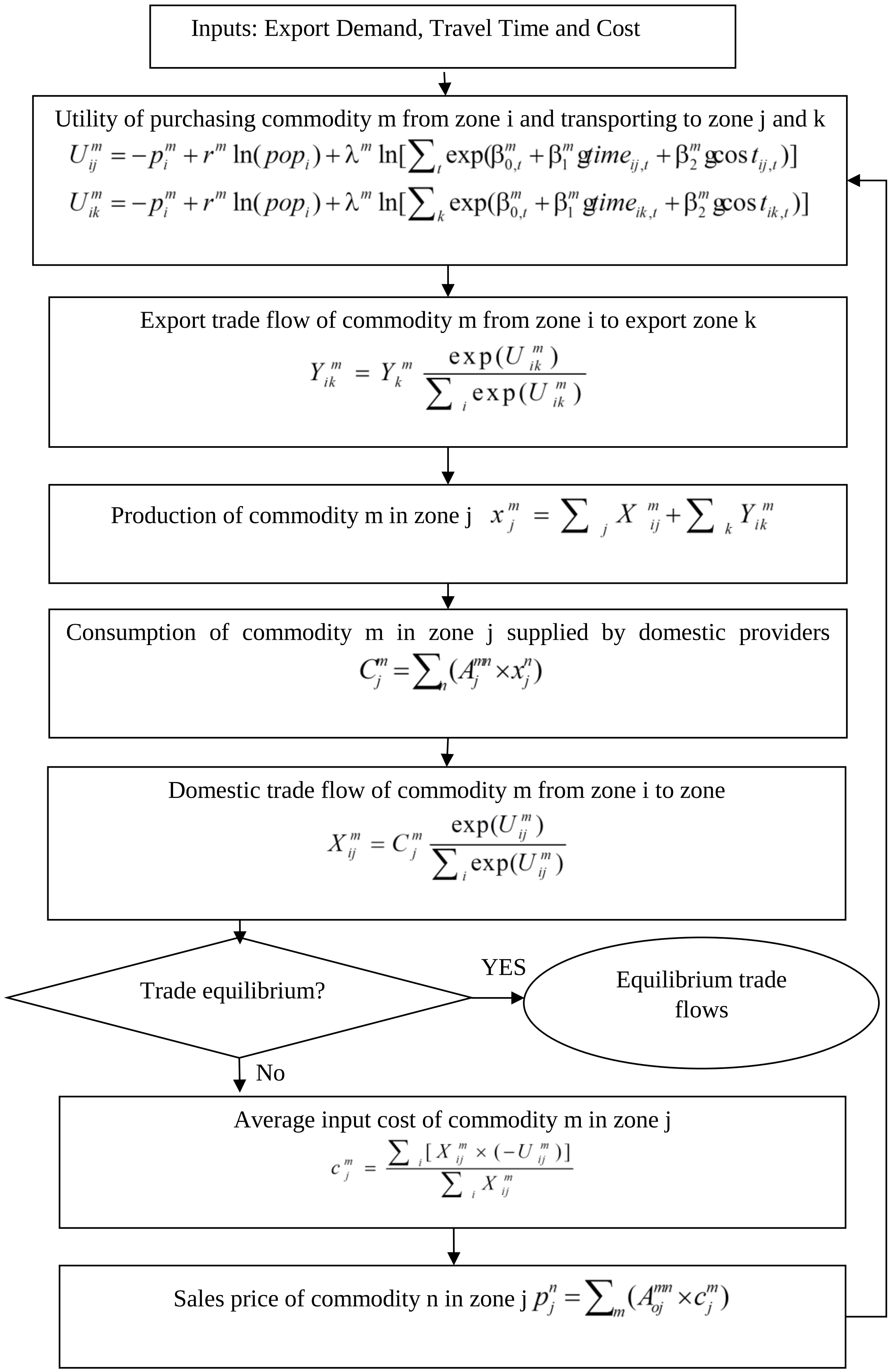

FIGURE 1 RUBMRIO structure and solution algorithm.

SCENARIOS AND RESULT ANALYSIS

Scenarios

Freight exported from the West Coast is diverted to the East/Gulf Coast because of the Panama Canal expansion. However, the estimated results of the volume vary in different models. Many models predicted 20%-30% cargo will shifted from the West Coast to Gulf Coast, but the Panama Canal Authority think the rate of the diversion relies on the Panama Canal toll (*31*). In the RUBMRIO model, export demands shift from LA/LB selected as the typical ports in West Coast to Houston in the Gulf Coast. 11 different scenarios have proceeded similar to the following description. The primary scenario is the criteria to analysis the production in U.S. without the expansion of the Panama Canal. The following 10 scenarios are formulated to obtain results from the Panama Canal expansion effect on the volume diversion. In the first scenario LA/LB have the 100% volume of the export demands. Then, the original amount of export demands of Houston will get the added export demands which is 10% of the base export demands of LA/LB. Each scenario will shift export demands of LA/LB to Houston by 10% (Figure 4). Until export demands of LA/LB reach zero, the shift between the two ports stops.

When analysing the result of the 3,109 counties, x_j^n is set as the total production of commodity n in zone j and the sum of domestic and export flows "leaving" zone i (though must also heads to zone i industries and customers). Each scenario's iteration reaches model equilibrium, RUBMRIO open-source code will put out all counties' total production and 20 commodities' total production. After finishing the next scenario, the new procedure will calculate all counties' total production (all new) and 20 commodities total production. Using Equation 1, the change in each county's total production share was calculated as indicators of the traffic volume variation and the local technology development. According to data, the production change was abrupt between Scenario 2 and Scenario 3. Therefore, the 3,109 counties or states' production flows change will be analysed under the case of Scenario 3.

$$\text{Total production incease percent in each county} = \frac{\text{change in total production flow(\$)}}{\text{origin total production flow(\$)}} = \frac{\sum_m x_i^{m'} - \sum_m x_i^{m^0}}{\sum_m x_i^{m^0}} \qquad (3)$$

Result Analysis

Scenario Affected Most in Term of Production Change

Du and Kockelman (*19*) argued that if the production technologies hold constant, the U.S. total production and consumption levels would be changeable. The output results list 3,109 counties' production under the case of these 11 scenarios. Between Scenario 1 and Scenario 2, national total production and consumption levels nationally held constant, while national total production and consumption rises quickly between Scenario 2 and Scenario 3. Over the next 8 scenarios, the national total production and consumption levels remain stable. The result manifests when Houston's ports increase the export demand by 10%-20%, as the production of 3,109 counties will increase abruptly, then keep stabilizing in the following 4-11 scenarios. The results suggest that Scenario 3 is affected most when LA/LB export demands shift to Houston via highway and/or railway.

States Affected Most in Term of Production Change

As mentioned in the first part of this study, the expansion of the Panama Canal will significantly decrease the West Coast congestion on routes and increase East/Gulf Coast congestion. When analysing the freights varying from 10% to 20%, some states' total production change significantly as the expanded Panama Canal. 3,109 counties' (located geographically in different states) total increase in production (by percent) can indicate each state's average production increase as a result of this expansion. Meanwhile, Table 3 exhibits 15 states with largest rise in term of production change from 4.11% to 2.75%. Houston's port is at the beginning of IH35 and other export ports in Texas, which is close to the Gulf Coasts. The production of states grows significantly as expected, because they are geographically nearby Texas or along Interstate Highway 35 (a major north-south Interstate Highway in the central U.S.) The results also suggests those states located closer to the highway increase in production based on the total trade with nearby states. Unexpectedly, 2 states—Oregon, Marine-- located far away from the IH20, IH35, IH95, IH40, IH70 and IH80 exhibit a large increase in production. Perhaps these states can trade with other regions easily because of owing large ports such as Portland (OR), and Gulf of Maine(NH) and so on (*32*), respectively. In addition, these states suggested that these counties located in Southwest, Midwest, and Northwest should improve their technology and widen their traffic infrastructure to meet the potential freight flows congestion. In the following section, fifteen states were selected as the objects to find counties affected most in terms of commodity production percent in scenario 3. In Table 3 IH70 IH80, two corridors cross Illinois and Ohio, IH20, IH35, IH40, three important corridors cross Texas, these corridors' junction or parallel counties have potential congestion or some industry production change.

TABLE 3 Fifteen States with Largest Rise in Total Production when 20 Percent of LA/LB's Export Demand Divert to Houston.

State	Cross Interstate corridors	Increasing production percent	State	Cross Interstate corridors	Increasing production percent
Illinois	IH70 IH80	4.11%	**Ohio**	IH70 IH80	3.09%
South Carolina	IH20	3.66%	**Kansas**	IH35	3.08%
Indiana	IH70	3.60%	**New Hampshire**	IH95	3.00%
Florida	IH95	3.39%	**Oklahoma**	IH35	2.84%
Oregon	-	3.36%	**Maine**	-	2.81%
Iowa	IH80	3.35%	**Louisiana**	IH20	2.79%
Texas	IH20 IH35 IH40	3.34%	**Tennessee**	IH40	2.75%
Arkansas	IH40	3.21%	--	--	--

Illinois' Counties affected most in term of commodity production change

In Figure 2, purple, yellow and, green account large proportion of the highlighted area. According to the legend, we can conclude the commodity 4 (Food, Beverage and Tobacco Product Manufacturing), commodity 5 (Petroleum and Coal Product Manufacturing) and commodity 9 (Machinery Manufacturing) increase in production change significantly. Du and Kockelman(*19*) mentioned export demands for commodity 4 and commodity 5 had the greatest impacts based on foreign export demands. In this paper Illinois' commodity 4 and 5 have the same trend with the Du and Kockelman(*19*)'s results. However, commodity 9 has a significant impacts since it is the second manufacturing industries in 2006 (refer to Wikipedia Illinois States Manufacturing). Table 4 reveals Illinois' ten counties' range (five top increase and decrease counties). In the table, Pope, Knox, Pike, Pulaski and Kane's commodity 4, 5 and 9 have significant rise. Especially, in the case of Pope, whose commodity 5 and 9 rise 6.85% and 5.74%, which suggest commodity 5 and 9 are sensitive to the Panama Canal expansion. In Figure 4, it's shown that Pope and Knox are located the border of two states, which may easily be sensitive to the Panama Canal expansion for trade. With the project completed, counties, such as Pope, Knox, Pike and others, should improve their production technology in commodity 5 and 9. As shown in table 4, commodity 5 and 9 decrease in production significantly in some counties (Winnebago, Woodford, Williamson, Adams and Morgan). These counties' government shouldn't enhance production technology in commodity 5 and 9. The five increase counties in production of each commodity should improve their technology about these commodities and widen their local infrastructures to meet the potential increase travel flow. Five decrease counties in production of each commodity should reduce their corresponding industry.

Texas' counties affected most in term of commodity production change

In Texas, commodity 4, 5, 6 (Chemicals, Plastics and Rubber Product Manufacturing), 7(Primary Metal Manufacturing) and 9 are witnessed increasing or decreasing significantly. In Figure 2, 20 commodities have been displayed, it's evident that commodity 4, 5 and 9 share in the largest production increase. Commodity 4 and 5 affected largest respectively have similar trend with 3,109 counties in nation level. Commodity 9 presents Machinery Manufacturing which is Texas' fourth largest export sector in 2013(*33*). Commodity 9 should improve its industry technology to meet the increasing export demands due to the Panama Canal expansion. Commodity 6 is the second largest export sector in 2013, which should expand commodity 6 output to meet the increasing export demands. Commodity 7 is the fifth largest output sector in 2013, which will be affected positively when the Panama Canal expansion is finished. Top five increase counties' (Tyler, Trinity, Upshur, Colin, Comal) share a positive increase in commodity 4, 5, 6, 7 and 9, while top five decrease counties' (Ector, Montague, Morris, Erath) present negative increase in commodity 4, 5, 6, 7 and 9. These counties should expand or reduce their volumes in these commodity 4, 5, 6, 7 and 9.

Ohio' counties affected most in term of commodity production change

In Ohio, commodities 4, 5, 6, 7 and 9 have significant increase in Figure 2, especially commodities 4, 5, and 9 have large increase. Du and Kockelman(*19*) noted that the commodities 4, 5 had greatest impact, so Ohio has a similar trend with the rest of the nation. However, commodity 9 also have a greatest impact because of the Panama Canal expansion. Commodity 9 in Ohio accounted for 8.4% to 9.7% from 2013 to 2016(*34*), which is the leading export industry in Ohio. As the Panama Canal expansion is accomplished, commodity 9 should see a significant increase, the production technology in commodity 9 should be improved to meet the increase. In Table 4 lists the five greatest increases and decreases in county from commodity 4 to commodity 9. In the table, commodity 9 range from 2.59% to -2.55%. Counties Ashtabula, Butler, Clark, Ashland and Allen don't need to improve their technology in commodities 4, 5, 6, 7 and 9 due to the Panama Canal expansion, while counties Warren, Vinton, Wyandot, Van and Union should enhance their technology in commodities 4, 5, 6, 7 and 9 to meet the increase.

FIGURE 2 Illinois, Texas and Ohio state increase and decrease in 20 commodity production when 20 Percent of LA/LB's export demand divert to Houston.

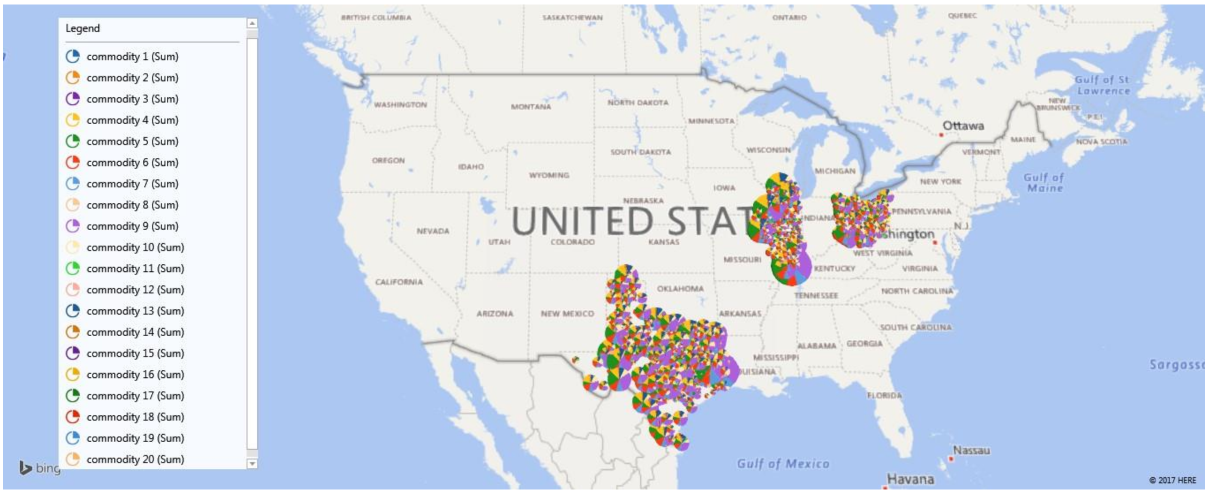

TABLE 4 Illinois, Texas and Ohio State with Five Largest Increase and Decrease in Different Commodity Production when 20 Percent of LA/LB's Export Demand Diverted to Houston.

States	Counties	Commodity 4	Commodity 5	Commodity 6	Commodity 7	Commodity 9
Illinois	Pope	2.82%	6.85%	1.84%	2.12%	5.74%
Illinois	Knox	1.72%	2.84%	1.03%	1.38%	3.81%
Illinois	Pike	1.25%	1.88%	0.86%	0.77%	2.78%
Illinois	Kane	1.01%	1.02%	0.77%	0.74%	1.63%
Illinois	Richland	0.90%	0.88%	0.85%	0.45%	1.37%
Illinois	Adams	-0.52%	-0.18%	-0.52%	-0.22%	-0.74%
Illinois	Morgan	-0.45%	-0.18%	-0.51%	-0.23%	-0.60%
Illinois	Williamson	-0.79%	-0.58%	-0.71%	-0.41%	-1.68%
Illinois	Woodford	-0.90%	-0.74%	-0.78%	-0.51%	-2.11%
Illinois	Winnebago	-1.41%	-1.61%	-1.03%	-0.88%	-3.88%
Texas	Tyler	1.68%	5.85%	1.03%	1.94%	4.82%
Texas	Trinity	1.83%	4.77%	1.37%	1.75%	4.74%
Texas	Upshur	1.08%	2.97%	0.71%	1.13%	3.29%
Texas	Upton	0.96%	2.48%	0.62%	1.00%	2.90%
Texas	Collin	0.92%	1.83%	0.76%	0.71%	3.19%
Texas	Motley	-1.02%	-1.27%	-0.67%	-0.65%	-3.07%
Texas	Morris	-1.01%	-1.32%	-0.64%	-0.66%	-3.15%
Texas	Montague	-0.87%	-1.35%	-0.50%	-0.64%	-3.18%
Texas	Wilbarger	-0.89%	-1.40%	-0.45%	-0.76%	-2.85%
Texas	Ector	-1.28%	-2.45%	-0.81%	-1.10%	-5.44%
Ohio	Warren	0.68%	1.58%	0.52%	0.55%	2.59%
Ohio	Vinton	0.46%	1.43%	0.33%	0.45%	2.13%
Ohio	Wyandot	0.39%	1.19%	0.28%	0.41%	1.50%
Ohio	Van	0.41%	0.85%	0.34%	0.34%	1.50%

Ohio	Union	0.34%	0.55%	0.31%	0.24%	1.12%
Ohio	Ashtabula	-0.52%	-0.27%	-0.49%	-0.25%	-0.86%
Ohio	Butler	-0.49%	-0.29%	-0.46%	-0.25%	-0.87%
Ohio	Clark	-0.88%	-0.80%	-0.65%	-0.51%	-1.47%
Ohio	Ashland	-0.94%	-0.85%	-0.67%	-0.55%	-2.19%
Ohio	Allen	-0.97%	-0.96%	-0.66%	-0.59%	-2.55%

Legend	Minimum value				No change				Maximum value

CONCLUSIONS

The paper uses the RUBMRIO model to find which regions and commodities are affected most by the Panama Canal expansion. When the Panama Canal expansion is finished, the West Coast Ports will shift their export demands to the Gulf/East Coast Ports. With this, 11 scenarios are examined to describe the export demands diversion. Los Angeles/Long Beach (LA/LB) representing the West Coast Ports shifts its export demands to Houston representing the Gulf Coast Ports by 10% in every scenario. The results suggest that when LA/LB shifts its 20% export demands to Houston, 3,109 counties in production and consumption have an abrupt increase or decrease. Fifteen states see the largest increase in average production, and these states have several important interstate corridors within their borders. Specially three states: Illinois, Texas and Ohio which have two important corridors across their lands. The three states present commodity 4, 5 and 9 have a significant increase in production when LA/LB diverts its export demands to Houston by 20%.

This paper explores the trade diversion between the West Coast Ports and the Gulf Coast Ports trade diversion. Future studies may simulate a shift in the West Coast export demands to the East Coast Ports (e.g. New York). The dynamic and extended RUBMRIO model (*17; 18*) can predict which regions and commodity will be most affected in next 20 years because of the Panama Canal expansion. The Panama Canal is a mega project in the world, this paper seeks to explore only commodities manufactured in the U.S. and exported to Asia. However, Asia is one of the largest export regions in the world and, the potential expenses saved could have a significant effect on the trade from Asia to U.S. (*9*). Future research may also explore the effect on the trade from Asia to U.S., and then find out which region or commodities are affected most in Asia.

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