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

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6           **Junwei Yu**

7           Graduate Student

8           School of Economics and Management

9           China University of Geosciences

10          Wuhan 430074, China

11          Email: [junwei8712319@vip.qq.com](mailto:junwei8712319@vip.qq.com)

12  
13          **Guangmin Wang**

14          Professor

15          School of Economics and Management

16          China University of Geosciences

17          Wuhan 430074, China

18          Email: [wgm97@163.com](mailto:wgm97@163.com)

19  
20          **Kara M. Kockelman,**

21          **(Corresponding author)**

22          Professor, and E.P. Schoch Professor in Engineering

23          Department of Civil, Architectural and Environmental Engineering

24          The University of Texas at Austin

25          Phone: 512-471-0210

26          Email: [kkockelm@mail.utexas.edu](mailto:kkockelm@mail.utexas.edu)

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**1 ABSTRACT**

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

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

## 1 INTRODUCTION

2 The Panama Canal is one of the most important shipping canals in the world, in terms of impacts  
3 on the global economy. It shortens the distance between the Pacific and Atlantic Ocean. 43% of  
4 traded value between Asia (including China, Japan and the Far East) and U.S. East Coast Ports in  
5 2007 (versus just only 11.3% in 1999) (1). The Panama Canal Authority found the Canal had  
6 reached its maximum capacity in 2006 and predicted that an unexpanded canal would see just  
7 23% of market trading between the Asia-U.S. East Coast Ports in 2025 if something did not  
8 change (2). As more and more global cargo is transported by post-Panamax ships (each holding  
9 4,000-5,000 twenty-foot equivalent units (TEUs)) that is larger than the Panamax ships (which  
10 carry 3,400-4,500 TEUs, the size limits for ships travelling through the Panama Canal), more and  
11 more ships can't pass the original Panama Canal locks. And the Authority found that post-  
12 Panamax vessels would account for more than 48% of global shipping fleet in TEU in the future.  
13 (1). These reasons prompted the Canal expansion through a construction of a third set of locks  
14 (2) to meet the increasing demand.

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

33 This paper uses the random utility-based multiregional input-output model (RUBMRIO)  
34 to explore which regions and types of product are affected most by the recent expansion of the  
35 Panama Canal as the U.S. exports to Asia. The RUBMRIO model considers 3,109 counties (all  
36 50 states, except for Hawaii and Alaska) trade pattern, across 20 sectors and two transportation  
37 modes (railway and truck), at 106 export-zone centroids. The RUBMRIO model originates from  
38 input-output model (10) that describes linkages between industries, and between producers and  
39 consumers. Following development of the IO model, many methods have been extended to  
40 develop IO model. Isard (11) developed IO model to interregional IO model (IRIO), Chenery  
41 (12) and Moses (13) utilized the IO model to apply into multi regions input-output model  
42 (MRIO). de la Barra (14) and Cascetta et.al (15) used the Land Use Transportation Interaction  
43 (LUTI) model integrated with random utility maximization (RUM) and IO model to generate the  
44 RUBMRIO model. Then the RUBMRIO was widely credited by Kockleman et al. to simulate  
45 Texas (16-18) and U.S. (19)'s trade, transportation and industrial production. The model is driven  
46 by export demands and measured in utility units and base on expected minimum transportation  
47 cost. The Texas-level RUBMRIO model was applied for 254 counties trade patterns, across 18  
48 social-economic sectors, with the U.S-level RUBMRIO model being developed for 3,109

1 counties trade patterns, across 20 social-economic sectors. These applications predicted trade and  
 2 location choices resulting from a variety of scenarios (variation in transportation cost, time, and  
 3 export demands).

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

## 15 **DATA SETS AND METHODS**

### 16 **Data Source**

17 The RUBMRIO model requires four main data: export demands, relative technical coefficients,  
 18 origin and mode choice parameters and time and cost to travel between origin and destination. The  
 19 best available freight data are from the U.S. Department of Transportation's Freight Analysis  
 20 Framework (FAF<sup>3</sup>) (20) database, the 2007 U.S. Commodity Flow Survey (CFS) (21), and the  
 21 IMPLAN industry code (24). FAF<sup>3</sup>'s data is based on 123 domestic regions, 8 foreign regions  
 22 across 43 known and 1 unknown commodity class, 8 different FAF modes, 3 freight flows (import  
 23 flows, domestic flows, export flows) and 3 measures (tons, ton-mile, values). The export flows'  
 24 measured by values are easily converted into utility. The origin and mode choices parameters,  
 25  $\lambda^m, \beta^m, \gamma^m$  are estimated based on the nested logit model. Then, using these parameters and data,  
 26 the RUBMRIO model is applied to predict the production change. The commodities data class  
 27 from the CFS database relied on the 43 two-digit Standard Classification of Transported Goods  
 28 (SCTG) and the North American Industry Classification System (NAICS), FAF<sup>3</sup> used the 43-two  
 29 digit SCTG as well, shown in Table 1.  
 30

31 **TABLE 1 Description of Economic Sectors in U.S. Application of the RUBMRIO**  
 32 **Model(19)**  
 33

	<b>Commodity Class</b>	<b>IMPLAN</b>	<b>NAICS</b>	<b>SCTG</b>
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	--	--	--

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

### 6 **Data of Trucking Travel Cost**

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

1 that fuel costs are the largest cost of vehicle-based grouping. The report (22) notes the fuel cost is  
2 easily affected by the fuel price. Therefore the fuel price is important for motor carrier costs.

3 **TABLE 2 Average Marginal Costs per Mile, 2008-2014 (22)**  
4

<b>Motor Carrier Costs</b>	<b>2008</b>	<b>2009</b>	<b>2010</b>	<b>2011</b>	<b>2012</b>	<b>2013</b>	<b>2014</b>
<b>Vehicle-based</b>							
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
<b>Driver-based</b>							
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
<b>TOTAL</b>	<b>\$1.65</b>	<b>\$1.45</b>	<b>\$1.55</b>	<b>\$1.71</b>	<b>\$1.63</b>	<b>\$1.68</b>	<b>\$1.70</b>

5  
6 EIA 2015 (23) shown fuel prices decreasing throughout the year, thus reducing the fuel  
7 cost per mile. According to report (22), the driving wages and drive benefits per mile in 2015 is  
8 assumed as \$0.46 and \$0.16. Since the equipment is constant from 2008 to 2014, the cost of the  
9 equipment is the average from 2008 to 2014. However, the fuel cost has consistently had the  
10 biggest influence on marginal costs during this time, accounting for 35% of the total cost per  
11 mile, with the other truck wear-out cost and driver pay respectively share of 30% and 35%  
12 respectively. Asche, et.al 's (24) proposed the relationships between the crude oil price ( $p_c$ ) and  
13 the diesel price ( $p_d$ ) at time ( $t$ ) is

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

14  
15 Equation 1 (24), where  $\alpha$  means a constant term (the log of a proportionality coefficient)  
16 that captures differences in the levels of the prices and  $\beta$  gives the relationship between the  
17 prices. The analysis is based on quarterly price series of crude oil and diesel price (25; 26)  
18 January 2008 to November 2014. All oil prices are be in US dollar per gallon. Cointegration  
19 analysis is used to infer causal long-run relationships between nonstationary time series. The  
20 Johansen test (27) is employed to allow for hypothesis testing on the parameters in the  
21 cointegration vector and exogeneity tests. Then the tool—Eviews 6.0 (28) (a statistical package  
22 for Windows, developed by Information Handling Services) can use the time series data to get  $\alpha$   
23 and  $\beta$ .

24 Before conducting any econometric analysis, the time series properties of the data must

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

$$7 \quad \ln P_{ct} = 1.01 \ln P_{at} - 0.65 \quad (2)$$

8 We then address the issue of whether crude oil and diesel prices are proportional, i.e.  
 9 whether the relative prices are constant. In the reduced system the likelihood ratio test(29) an  
 10 approximation is distributed as  $\chi^2(2)$  and gives a test statistic of 2.007641 with a P-value of  
 11 0.1603, which values is larger than the significance of 0.05. Hence, all the prices are  
 12 proportional, which the  $\exp(\alpha)$  is 0.52.

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

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

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

### 31 **Model Procedures**

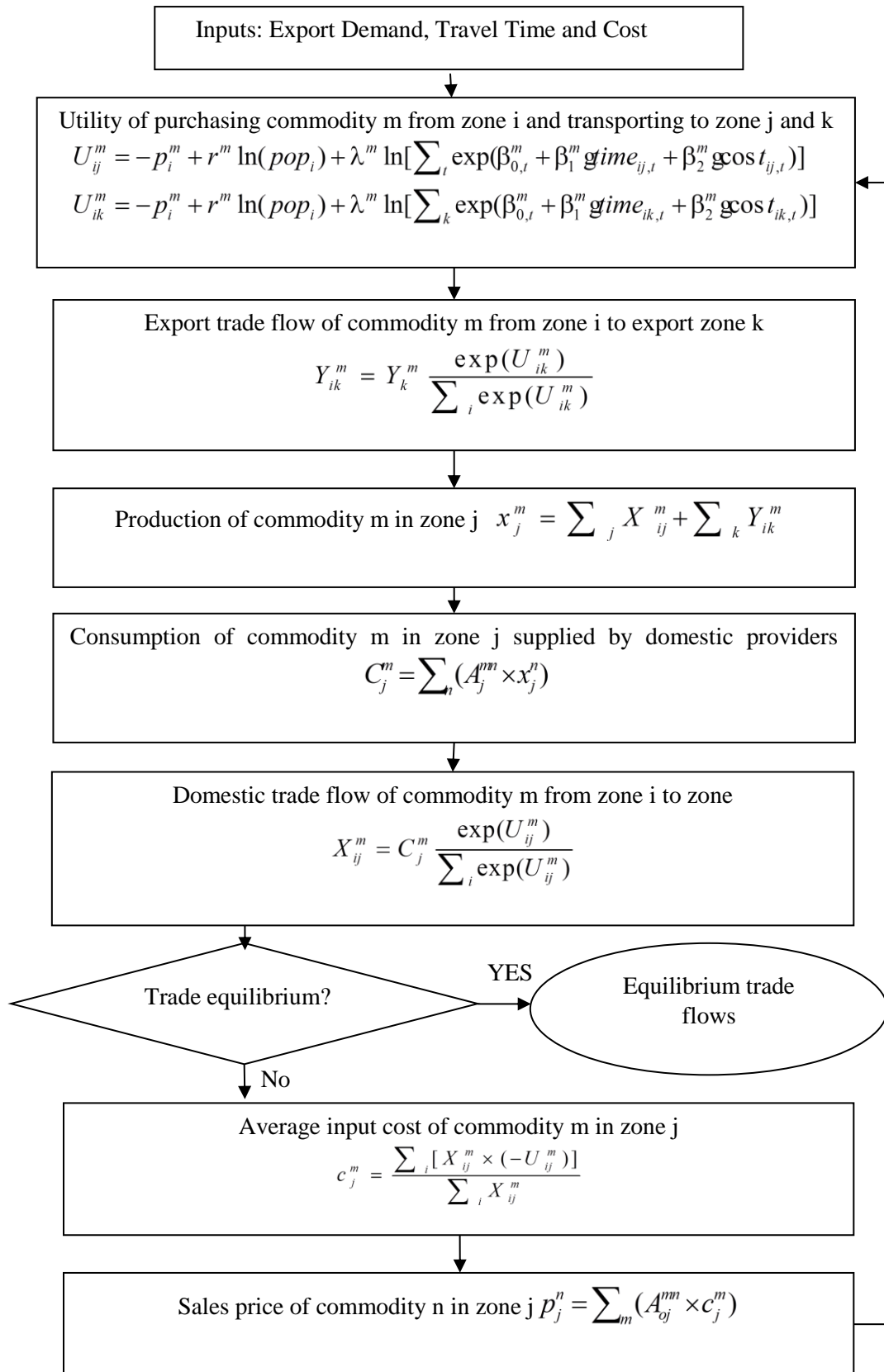
32 The RUBRMIO algorithm procedure is shown in Figure 1, and relative variables have been defined  
 33 in Table 2. The trade model begins by assuming the sale prices are at zero across production zones  
 34 and commodity types. The export and domestic production zone sales' prices, transport costs,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

1 **TABLE 2 Variable Definitions**  
2

<b>Variables</b>	<b>Definitions</b>
$U_{ij}^m$	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.
$\gamma^m$	The parameter reflects producer's attraction to an origin zone's size and prominence
$\lambda^m$	The parameter determines the effect of transportation of the utility and trade flow between all zone pairs.
$\beta^m$	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".

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**FIGURE 1 RUBMRIO structure and solution algorithm.**

## 1 SCENARIOS AND RESULT ANALYSIS

### 2 Scenarios

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

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

$$27 \text{ Total production increase percent in each county} = \frac{\text{change in total production flow}(\$)}{\text{origin total production flow}(\$)} =$$

$$28 \frac{\sum_m x_i^{m'} - \sum_m x_i^{m^0}}{\sum_m x_i^{m^0}} \quad (3)$$

### 30 Result Analysis

#### 31 *Scenario Affected Most in Term of Production Change*

32 Du and Kockelman (19) argued that if the production technologies hold constant, the U.S.  
 33 total production and consumption levels would be changeable. The output results list 3,109  
 34 counties’ production under the case of these 11 scenarios. Between Scenario 1 and Scenario  
 35 2, national total production and consumption levels nationally held constant, while national  
 36 total production and consumption rises quickly between Scenario 2 and Scenario 3. Over the  
 37 next 8 scenarios, the national total production and consumption levels remain stable. The  
 38 result manifests when Houston’s ports increase the export demand by 10%-20%, as the  
 39 production of 3,109 counties will increase abruptly, then keep stabilizing in the following 4-  
 40 11 scenarios. The results suggest that Scenario 3 is affected most when LA/LB export  
 41 demands shift to Houston via highway and/or railway.

#### 42 *States Affected Most in Term of Production Change*

43 As mentioned in the first part of this study, the expansion of the Panama Canal will  
 44 significantly decrease the West Coast congestion on routes and increase East/Gulf Coast  
 45 congestion. When analysing the freights varying from 10% to 20%, some states’ total

1 production change significantly as the expanded Panama Canal. 3,109 counties' (located  
 2 geographically in different states) total increase in production (by percent) can indicate each  
 3 state's average production increase as a result of this expansion. Meanwhile, Table 3 exhibits  
 4 15 states with largest rise in term of production change from 4.11% to 2.75%. Houston's port  
 5 is at the beginning of IH35 and other export ports in Texas, which is close to the Gulf Coasts.  
 6 The production of states grows significantly as expected, because they are geographically  
 7 nearby Texas or along Interstate Highway 35 (a major north-south Interstate Highway in the  
 8 central U.S.) The results also suggests those states located closer to the highway increase in  
 9 production based on the total trade with nearby states. Unexpectedly, 2 states—Oregon,  
 10 Marine-- located far away from the IH20, IH35, IH95, IH40, IH70 and IH80 exhibit a large  
 11 increase in production. Perhaps these states can trade with other regions easily because of  
 12 owing large ports such as Portland (OR), and Gulf of Maine(NH) and so on (32),  
 13 respectively. In addition, these states suggested that these counties located in Southwest,  
 14 Midwest, and Northwest should improve their technology and widen their traffic  
 15 infrastructure to meet the potential freight flows congestion. In the following section, fifteen  
 16 states were selected as the objects to find counties affected most in terms of commodity  
 17 production percent in scenario 3. In Table 3 IH70 IH80, two corridors cross Illinois and Ohio,  
 18 IH20, IH35, IH40, three important corridors cross Texas, these corridors' junction or parallel  
 19 counties have potential congestion or some industry production change.

20

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

23

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%	--	--	--

24

25 *Illinois' Counties affected most in term of commodity production change*

26 In Figure 2, purple, yellow and, green account large proportion of the highlighted area.

27 According to the legend, we can conclude the commodity 4 (Food, Beverage and Tobacco

28 Product Manufacturing), commodity 5 (Petroleum and Coal Product Manufacturing) and

29 commodity 9 (Machinery Manufacturing) increase in production change significantly. Du

30 and Kockelman(19) mentioned export demands for commodity 4 and commodity 5 had the

31 greatest impacts based on foreign export demands. In this paper Illinois' commodity 4 and 5

1 have the same trend with the Du and Kockelman(19)'s results. However, commodity 9 has a  
 2 significant impacts since it is the second manufacturing industries in 2006 (refer to Wikipedia  
 3 Illinois States Manufacturing). Table 4 reveals Illinois' ten counties' range (five top increase  
 4 and decrease counties). In the table, Pope, Knox, Pike, Pulaski and Kane's commodity 4, 5  
 5 and 9 have significant rise. Especially, in the case of Pope, whose commodity 5 and 9 rise  
 6 6.85% and 5.74%, which suggest commodity 5 and 9 are sensitive to the Panama Canal  
 7 expansion. In Figure 4, it's shown that Pope and Knox are located the border of two states,  
 8 which may easily be sensitive to the Panama Canal expansion for trade. With the project  
 9 completed, counties, such as Pope, Knox, Pike and others, should improve their production  
 10 technology in commodity 5 and 9. As shown in table 4, commodity 5 and 9 decrease in  
 11 production significantly in some counties (Winnebago, Woodford, Williamson, Adams and  
 12 Morgan). These counties' government shouldn't enhance production technology in  
 13 commodity 5 and 9. The five increase counties in production of each commodity should  
 14 improve their technology about these commodities and widen their local infrastructures to  
 15 meet the potential increase travel flow. Five decrease counties in production of each  
 16 commodity should reduce their corresponding industry.

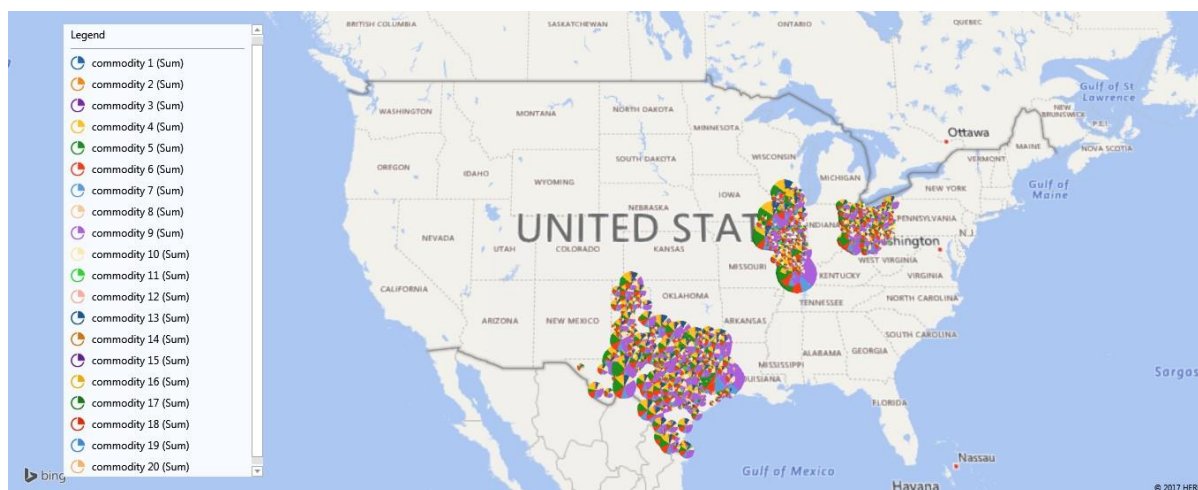
#### 17 *Texas' counties affected most in term of commodity production change*

18 In Texas, commodity 4, 5, 6 (Chemicals, Plastics and Rubber Product Manufacturing),  
 19 7(Primary Metal Manufacturing) and 9 are witnessed increasing or decreasing significantly.  
 20 In Figure 2, 20 commodities have been displayed, it's evident that commodity 4, 5 and 9  
 21 share in the largest production increase. Commodity 4 and 5 affected largest respectively  
 22 have similar trend with 3,109 counties in nation level. Commodity 9 presents Machinery  
 23 Manufacturing which is Texas' fourth largest export sector in 2013(33). Commodity 9 should  
 24 improve its industry technology to meet the increasing export demands due to the Panama  
 25 Canal expansion. Commodity 6 is the second largest export sector in 2013, which should  
 26 expand commodity 6 output to meet the increasing export demands. Commodity 7 is the fifth  
 27 largest output sector in 2013, which will be affected positively when the Panama Canal  
 28 expansion is finished. Top five increase counties' (Tyler, Trinity, Upshur, Colin, Comal)  
 29 share a positive increase in commodity 4, 5, 6, 7 and 9, while top five decrease counties'  
 30 (Ector, Montague, Morris, Erath) present negative increase in commodity 4, 5, 6, 7 and 9.  
 31 These counties should expand or reduce their volumes in these commodity 4, 5, 6, 7 and 9.  
 32

#### 33 *Ohio' counties affected most in term of commodity production change*

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

47  
 48 **FIGURE 2 Illinois, Texas and Ohio state increase and decrease in 20 commodity**  
 49 **production when 20 Percent of LA/LB's export demand divert to Houston.**



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**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%
<b>Legend</b>		Minimum value		No change		Maximum value

1

## 2 CONCLUSIONS

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

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

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