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Estimation Method of Port Cargo Volume Considering Changes in Social and Economic Conditions using a Dynamic SCGE Model

Abstract

A large amount of investment is channeled into the development of ports, which are vital to international trade. It is essential to make decisions based on estimates of the amount of infrastructure development required for future trade. Therefore, a highly accurate estimation of future port cargo volume based on potential changes in various social and economic conditions is required.

For this reason, the purpose of this study is to establish a port cargo volume estimation method that reflects changes in various conditions. This study utilized a spatial computable general equilibrium (SCGE) model, which can estimate the economic impact caused by changes in GDP, population, labor, tariff rates, transport costs, and the real effective exchange rate.

In this estimation, the port cargo volume in 2011 was set as the starting point and changes in social and economic conditions between 2012 and 2017 were used as shocks to the model. As a result, the estimated value accurately reproduced Japan's actual port cargo volume in 2017. These results indicate that future volumes can be projected using this method and that we will be able to utilize the estimation result as an index for judging the pace of future port development in Japan.

Keywords: *port investment, maritime trade, marine transportation cost, ship type, tariff rate, Dynamic GTAP model*

1. Introduction

A large amount of investment, including subsidies, is spent on the development of ports, which are a part of the social infrastructure vital to international trade. It is essential to make well-informed decisions regarding future investment that are based on accurate estimations of the infrastructure development required for future trade. Overdevelopment reduces port profitability, while a lack of development leads to inefficiency due to chronic congestion. Therefore, it is necessary, from the standpoint of facilitating trade and accelerating economic activity, to accurately estimate future port cargo volume based on changes in various social and economic conditions.

Based on this background, the purpose of this study is to establish a port cargo volume estimation method that reflects changes in social and economic conditions. The purpose of this paper is to report the results of this research.

In previous estimations of port and facility plans, statistical methods (*e.g.*, various regression methods) based on historical data were often used to estimate port cargo volume and container throughput. This method had a problem in that it is greatly affected by the characteristics of the historical data. In this context, previous studies developed a trade coefficient prediction model based on input-output analysis. However, there was a problem in that the future social structure (*e.g.*, declining population and labor) of Japan was not explicitly considered by the model. To overcome these problems, this study utilizes a SCGE model, which is used globally to calculate the impact of international trade policy. This model is structured to reflect changes in the gross domestic product (GDP), the population and the number of workers, tariff rates by free trade agreements (FTAs) and economic partnership agreements (EPAs), transport costs, and the real effective exchange rate. Since the SCGE model is a long-term model and don't have monetary units, there are problems in that the nominal exchange rate cannot be directly handled, and the calculation results are affected by the data structure used for the initial equilibrium.

The SCGE model is a model that can analyze the influence of economic entities such as households and producers on the market through multiple regions and sectors and can also analyze ripple effects on other sectors. In addition, since the dynamic SCGE model is used in this study, it is possible to consider the pace of the accumulation of capital. Moreover, since the model used in this study can explicitly handle the international transportation sector, the decrease in marine transportation costs due to the increase in ship sizes of many ship types (container ship, bulk ship, tanker, *etc.*) in the sector was also considered.

In the estimation of port cargo volume, the 2011 volume was set as the initial equilibrium (starting point) and changes in GDP, population, labor, tariff rates, exchange rate, and marine transport margins from 2012 to 2017 were used as shocks to the model. As a result, the estimated value accurately reproduced Japan's actual port cargo volume in 2017.

This result indicates that the future port cargo volume can be estimated using this method and that there is a possibility that the estimation result can be used as an index for judging the future development pace of ports in Japan.

This paper is organized as follows. Section 1 is an introduction. Section 2 is a literature review. Section 3 describes the details of the model used in this study, the data used, and the shocks input into the model. Section 4 shows the results of the calculations of import and export cargo volume by sector and by partner country. Section 5 discusses the results and Section 6 concludes.

2. Literature Review

There are existing data that forecasts trade values or port cargo volumes as follows. The World Trade Organization (WTO) provides forecasts of worldwide trade values for the following year regularly. The WTO (2018) also provided forecasts of real trade growth by country and region through the year 2030. Sea Europe (2018) provided forecasts of world trade volume by type of cargo through 2035. Drewry (2019) periodically forecasts up to five years of port cargo volumes. In Japan, the Japan External Trade Association (JFTC, 2019) estimates Japanese trade value by commodity for the following year and Nittsu Research Institute and Consulting (2019) also forecasts trade value and cargo volume by transport mode for the following year.

In the academic field, from a methodological viewpoint, the estimation methods used in the literature include the gravity model, econometric models using regression analysis and time series techniques and data, and models that take into account the structure of the economy and industry.

According to Andersson *et al* (2008), gravity models have been an important tool for studying trade based on distance between any two countries for a considerable length of time. Earlier work during the 1960s, such as that of Isard (1960), Tinbergen (1962), Pöyhönen (1963), Leontief and Strout (1963) and Linneman (1966), represent the classical studies in the field. The relationship between international trade and trade costs has traditionally been estimated using gravity models of trade, which relate bilateral trade flows to the incomes and populations of trading partners and the geographical distance between them. Among more recent research, Bensassi (2014) focused on the use of more accurate proxies for transport costs, such as freight rates, infrastructure, or customs procedures. Limao and Venables (2001) analyzed the dependency of trade and transport costs on geographical and infrastructure variables and estimated the elasticity of trade with respect to transport costs. Wilmsmeier and Hoffmann (2008) confirmed the general positive correlation between distance and freight rates in principle. However, statistically speaking, distance explains only one-fifth of the variance in the freight rate. In the gravity model, it is estimated considering the positional relationship and other indicators related to trade.

Among the econometric analyses, Seabrooke *et al* (2003) identified the economic indicators affecting cargo throughput in Hong Kong and carried out a regression analysis to predict cargo growth. Zhang *et al* (2005) used regression analysis to examine the contribution of growth— namely, gross industrial product value and foreign direct investment into the region—to container throughput in the Pearl River Delta region of China. Veenstra and Haralambides (2001) contributed to the literature of forecasting seaborne trade flows by showing that the multivariate autoregressive time series model can be used to produce long-term predictions. Rashed *et al* (2017) applied different univariate time series approaches, the autoregressive integrated moving average (ARIMA) model, the ARIMA-intervention model, and the ARIMAX model with leading economic indicators. Hoffmann *et al* (2019) considered five separate components of the effects on trade of sailing distances and direct (air) distances and the GDP of 142 trading partners. They then applied the quasi-maximum likelihood method to estimate the parameters of a dynamic panel data model. The above survey of the literature demonstrates that econometric analyses are mainly based on historical time series data.

The gravity model is a method that is easy to intuitively understand because positional relationship (distance), which is an index that is easy to imagine, is set as the main variable. Although there are various mathematical calculation methods, econometric analysis is also intuitively acceptable because it is based on past performance. However, these calculation methods cannot take into account changes in economic and industrial structures. A computable general equilibrium (CGE) models are excellent models for considering the structure of the economy and industry. The SCGE model extends the CGE analysis range from one region to multiple regions.

The CGE and SCGE models are used as an important tool in policy analysis. These models have been widely adopted by many countries and international organizations, such as the World Bank and the International Trade Organization. In previous times, to analyze the impact of differential income tax policy on the United States (US) national economy, Shoven and Whalley (1972) developed a CGE model. Dixon and Rimmer (1998) applied the MONASH model to the Australian economy. Recently, the SCGE model has been more widely used for policy analyses of various aspects of national and regional economies. Devarajan *et al* (2011) used a CGE model to study South African tax policies. Naranpanawa and Arora (2014) built a single-country multi-regional SCGE model to study the link between trade liberalization and regional disparities in India. Zhang *et al* (2018) analyzed, under the Belt and Road initiatives, the impact of a further reduction in the Chinese import tariff rate on major economic indicators using a CGE model.

Looking at the application of the SCGE models on cargo volume prediction, Lee *et al* (2011) estimated the seaborne cargo volumes resulting from an FTA between Taiwan and China. A similar study exists in Japan by which the change in trade volume due to the effects of EPAs and port policy was calculated (Higaki *et al*, 2008, Kadono *et al*, 2005)

The contribution of these studies to the literature is the further development of an estimation method for port cargo volume utilizing a dynamic SCGE model. Many previous studies have focused on calculating trade value with the CGE and SCGE models as an indicator for the evaluation of policy. A few studies have used the SCGE model to estimate the volume of trade; however, there are no examples that have utilized a dynamic SCGE model to estimate trade volume. The greatest feature of the dynamic SCGE model, especially as compared with the static SCGE model, is its reproduction of the pace of economic change. Static SCGE models basically do not have any temporal scale. On the other hand, the dynamic SCGE model does exhibit instability in terms of its convergent calculations, so more proficiency in its calculation settings, procedures, and model parameters, *etc.* is required. The procedure developed in this study is unique for considering various socio-economic factors in forecasting.

3. Methods

3.1 Calculation Model

The CGE model enables a multi-sectoral analysis of the mutual influences of economic agents, such as households and producers, on markets. The CGE model allows an analysis of the ripple effects on other sectors that cannot be handled by partial equilibrium analysis, which only analyzes the mutual influence of economic agents in a single sector. The SCGE model extends the scope of analysis to multiple regions. With the static CGE/SCGE model, it is difficult to clearly incorporate real economic activity such as savings, investment, and capital accumulation into the model. However, a dynamic CGE/SCGE model has the advantage in that items that are difficult to capture with a static CGE/SCGE model can be clearly incorporated. In addition, if it is a dynamic CGE/SCGE model, it is possible to consider calculation results in each term (e.g. result of two year-by-year) up to the final result.

The SCGE model used in this study is "Dynamic GTAP Model (GDyn)" developed by Global Trade Analysis Project (GTAP). GDyn was developed as an extension of the standard GTAP Model for the purpose of comparative static analysis.

The GTAP Model—developed by the World Trade Analysis Center, which was established in 1992 and led by Professor Hartell of Purdue University in the US—was created to evaluate the impact of international trade on countries around the world. The GTAP Model is an SCGE model widely used for the evaluation of policy. Currently, in addition to the GDyn which was extended to dynamics, the GTAP-E model incorporates the relationship between the environment and energy into the standard GTAP Model in order to evaluate greenhouse gas reduction policies, and the GMig2 model allows for the migration of labor.

The GDyn can explicitly account for the dynamic effects of changes in production factors (such as population and labor), investment, and capital accumulation over time. A number of prerequisites—such as a completely competitive market, production technologies of constant returns, and differentiation of tradable commodities by production area (Armington assumption); as well as frames, such as an accounting definition that describes the general equilibrium, equations based on the optimal behavior of consumers and producers, and market equilibrium—which are features of the standard GTAP Model (general SCGE model features), are also inherited by the GDyn. The GDyn introduces international capital transfers between regions through foreign direct investment; capital accumulation and capital income, which generated by international capital transfers are endogenous in the model. Figure 1 shows the whole structure of GDyn.

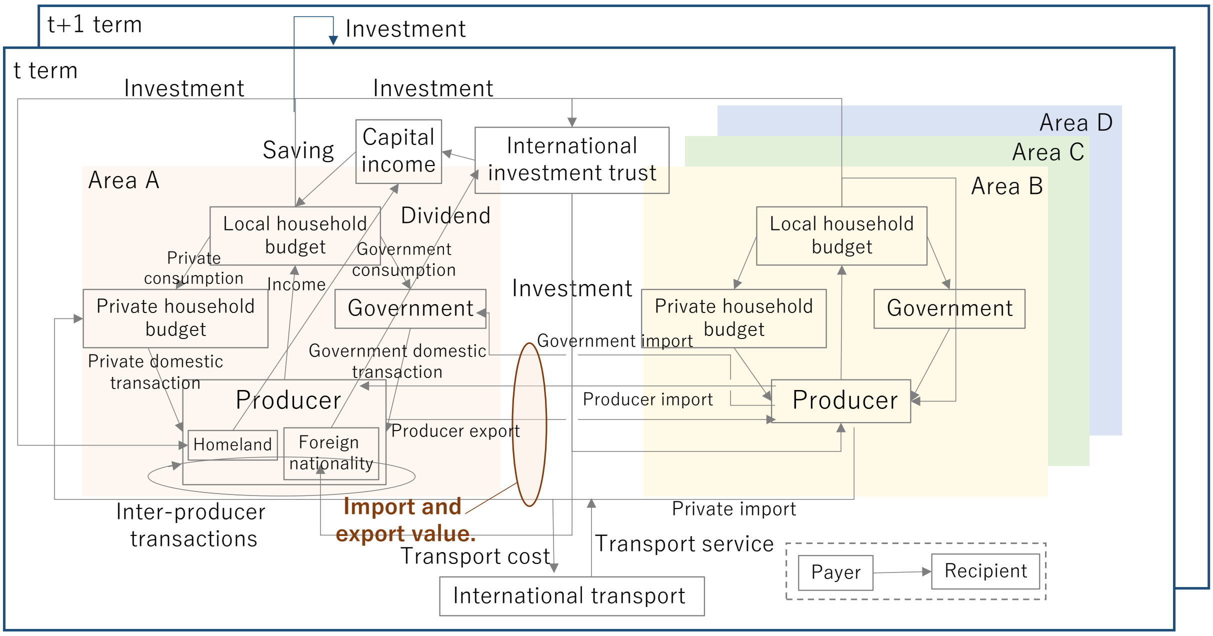


Figure 1 – Structure of Dynamic GTAP Model (GDyn).

The structure of production in the GDyn is illustrated in Figure 2.

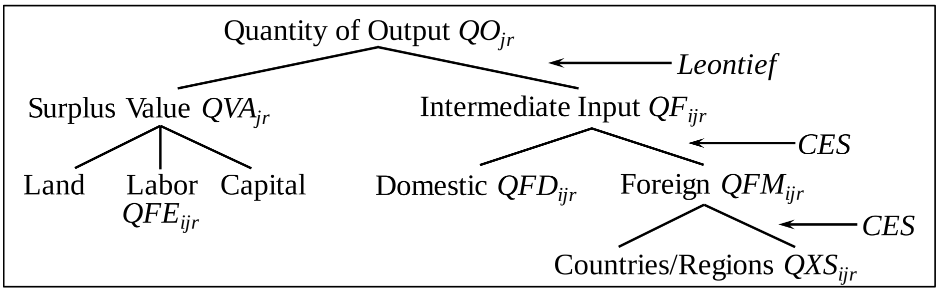


Figure 2– Production Functions of the GTAP Model.

In Figure 2, intermediate input of *i* commodity of *j* sector in *r* country: QF_{ijr} is expressed as a composite of domestic and international goods using a constant elasticity of substitution (CES)-type production function as shown below in Formula (1):

$$QF_{ijr} = e^{afa_{ijr}^{t}} \left[d_{Dijr} QFD_{ijr}^{\frac{1-\sigma_{Di}}{\sigma_{Di}}} + d_{Mijr} QFM_{ijr}^{\frac{1-\sigma_{Di}}{\sigma_{Di}}} \right]^{\frac{\sigma_{Di}}{1-\sigma_{Di}}} \tag{1}$$

where, QFD_{ijr}, QFM_{ijr}: international and domestic intermediate input of *j* sector in *r* country, d_{Dijr}, d_{Mijr}: international and domestic share of *i* goods in *r* country, *j* sector, σ_{Di}: CES between international and domestic goods. In the same way, input of intermediate goods : QFM_{ijr} is expressed as a composite among international goods by a CES-type production function. The CES of the GTAP Model is set by sector and is common among countries/regions.

3.2 Usage Data

In this paper, the GTAP database, specifically Version 9 for the year 2011, was used as the initial equilibrium data. Changes in population, labor, tariffs, international maritime transport costs, and the real effective exchange rate from 2012 through 2017 are the shocks to the model. The rate of change in Japan's import/export volume from 2011 to 2017 was calculated. The cargo volume in 2017 is estimated by applying the calculated rate of change in import/export volume to Japan's import/export cargo volume in 2011.

For the purpose of estimating Japan's import/export trade volume and considering matters that may have a significant impact on Japan's imports and exports the original data of 141 countries were aggregated and 40 countries/regions were set as shown in Table 1, by considering the amounts of trade, concluding or scheduling economic partnerships, and anticipated future expansion of trade.

Table 1 – Setting Countries and Regions.

Area	Code	Countries / Regions	
Northeast Asia	1	JPN	Japan
	2	CHN	China
	3	HKG	China, Hong Kong SAR
	4	TWN	China, Taiwan Province of China
	5	KOR	Republic of Korea
	6	xnea	Rest of Northeast Asia
Southeast Asia	7	IDN	Indonesia
	8	MYS	Malaysia
	9	THA	Thailand
	10	SGP	Singapore
	11	PHL	Philippines
	12	VNM	Viet Nam
	13	BRN	Brunei Darussalam
	14	LAO	Lao People's Democratic Republic
	15	KHM	Cambodia
	16	xsea	Rest of Southeast Asia
Other Asia	17	IND	India
	18	xsas	Rest of South Asia
	19	SAU	Saudi Arabia
	20	ARE	United Arab Emirates
	21	xme	Rest of Middle East
North America	22	USA	United States of America
	23	CAN	Canada
	24	MEX	Mexico
South America	25	BRA	Brazil
	26	CHL	Chile
	27	PAN	Panama
	28	xsam	Rest of South America
Europe	29	DEU	Germany
	30	FRA	France
	31	GBR	United Kingdom
	32	NLD	Netherlands
	33	RUS	Russian Federation
	34	xnee	Rest of Northern and Eastern Europe
	35	ITA	Italy
	36	ESP	Spain
	37	xewe	Rest of Southern and Western Europe
Oceania	38	OCEANIA	Oceania
Africa	39	AFRICA	Africa
ROW	40	ROW	Rest of the World

The GTAP's 57 sectors have been consolidated into 36 sectors, as shown in the table 2. The table also shows the types of vessels by sector, as set forth below in Section 3.3.4, "International sea transportation costs."

Table 2 – Setting of sectors used in the calculation and corresponding ship types

GTAP No.	Description	Aggregated No.	Aggregated item	Aggregated code	Vessel type
1	Paddy rice	1	Paddy rice	pdr	Container
2	Wheat	2	Wheat	wht	General Cargo
3	Cereal grains nec	3	Cereal grains nec	gro	Dry Bulk Carrier
4	Vegetables, fruit, nuts	4	Vegetables, fruit, nuts	v_f	Container
5	Oil seeds	5	Crops nec	ocr_n	Container
6	Sugar cane, sugar beet				
7	Plant-based fibers				
8	Crops nec				
9	Bovine cattle, sheep and goats, horses	6	Animal products nec	ap_n	Container
10	Animal products nec				
11	Raw milk				
12	Wool, silk-worm cocoons				
13	Forestry	7	Forestry	frs	General Cargo
14	Fishing	8	Fishing	fsh	General Cargo
15	Coal	9	Coal	coa	Dry Bulk Carrier
16	Oil	10	Oil	oil	Crude Oil Tanker
17	Gas	11	Gas	gas	Gas Tanker
18	Minerals nec	12	Minerals nec	omn	Ore Carrier
19	Bovine meat products	13	Meat products nec	omt_n	Container
20	Meat products nec				
21	Vegetable oils and fats	14	Vegetable oils and fats	vol	General Cargo
22	Dairy products	15	Food products nec	ofd_n	Container
23	Processed rice				
24	Sugar				
25	Food products nec				
26	Beverages and tobacco products	16	Beverages and tobacco products	b_t	Container
27	Textiles	17	Textiles	tex	Container
28	Wearing apparel	18	Wearing apparel	wap	Container
29	Leather products	19	Leather products	lea	Container
30	Wood products	20	Wood products	lum	Container
31	Paper products, publishing	21	Paper products, publishing	ppp	Container
32	Petroleum, coal products	22	Petroleum, coal products	p_c	Oil Products Tanker
33	Chemical, rubber, plastic products	23	Chemical, rubber, plastic products	crp	Container
34	Mineral products nec	24	Mineral products nec	nmm	Container
35	Ferrous metals	25	Ferrous metals	i_s	General Cargo
36	Metals nec	26	Metals nec	nfm	Container
37	Metal products	27	Metal products	fmp	Container
38	Motor vehicles and parts	28	Motor vehicles and parts	mvh	Container and PCC
39	Transport equipment nec	29	Transport equipment nec	otn	General Cargo
40	Electronic equipment	30	Electronic equipment	ele	Container
41	Machinery and equipment nec	31	Machinery and equipment nec	ome	Container
42	Manufactures nec	32	Manufactures nec	omf	Container
43	Electricity	33	Construction, electricity	cde_n	-
44	Gas manufacture, distribution				
45	Water				
46	Construction				
47	Trade	34	Transport, communication, trade	ttt_n	-
48	Transport nec				
49	Water transport				
50	Air transport				
51	Communication				
52	Financial services nec	35	Finance, insurance, service	fis_n	-
53	Insurance				
54	Business services nec				
55	Recreational and other services				
56	Public Administration, Defense, Education, Health	36	Administration, Defense, Education	pde_n	-
57	Dwellings				

3.3 Setting the Shock Applied to the Model
Changes in population, labor, tariffs, international maritime transport costs, and the real effective exchange rate from 2012 to 2017 were given as shocks to the model.

If a shock has an abnormal value, the risk that the simulation does not converge increases. For this reason, to flatten shocks, shocks are aggregated for three years and given as one term.

3.3.1 Population and Labor force
The population change rate in the calculated countries/regions was set from the United Nations (UN) population estimation database “World Population Prospects (WPP): The 2017 Revision.”

Changes in labor were set as changes in the working-age population from the UN population estimation database “World Population Prospects (WPP): The 2017 Revision.”

3.3.2 GDP
Changes in the GDP growth rate of calculation countries/regions were set from the International Monetary Fund database “World Economic Outlook Database 2019 April.”

GDP is an endogenous variable by default in the GDyn but is replaced with an exogenous variable, which is the total factor productivity of each country, in order to give the rate of change in GDP as an exogenous shock.

3.3.3 Tariff rate
Since the initial equilibrium data is set to 2011, changes in the tariff rate by economic partnerships went into effect between 2011 and 2017, such as the Japan-India EPA, were countries as shown in the Table 3 (JPN-IND cell).

The calculation process for tariff reduction is as follows.

(1) Compile import value of each commodity by harmonized system (HS) code to importing countries/regions in 2011 and 2017 using the UN’s “Comtrade Database.”

(2) Compile the tariff rates of each commodity to importing countries/regions in 2011 and 2017 using the “Market Access Map (MAcMap)” of the International Trade Center.

(3) Calculate tariff amounts for each commodity in 2011 and 2017 based on the compiled import values and tariff rates (HS codes are HS 2007 in 2011 data and HS 2017 in 2017 data).

(4) Aggregate import values and tariff amounts in 2011 and 2017 for each of the 36 sectors and recalculate the tariff rates for each sector.

(5) Calculate the rate of change in tariff rates through 2017 using the 2011 figures as the tariff rates for the year when the EPA came into effect.

(6) All tariff reductions relating to Japan have been calculated, while other countries have calculated one case and applied it to all cases for practical convenience. The colored cells in the table 3 are inputs to the model.

Table 3 – Activated Economic Partnership Agreements between 2011 and 2017.

Country / Region	JPN	CHN	HKG	TWN	KOR	IDN	MYS	THA	SGP	PHL	VNM	BRN	LAO	KHM	IND	SAU	ARE	USA	CAN	DEU	NLD	GBR	FRA	ITA	ESP	RUS	BRA	CHL	PAN	MEX
JPN	＼														◎ (11/8)															
CHN		＼			◎ (15/12)																									
HKG			＼																									◎ (14/10)		
TWN				＼					◎ (14/4)																					
KOR		◎ (15/12)			＼						◎ (15/12)							◎ (12/3)	◎ (15/1)	◎ (15/12)										
IDN						＼																								
MYS							＼								◎ (11/7)													◎ (12/2)		
THA								＼																				◎ (15/11)		
SGP				◎ (14/4)					＼							◎ (13/9)	◎ (13/9)													
PHL										＼																				
VNM					◎ (15/12)						＼															◎ (16/10)		◎ (14/1)		
BRN												＼																		
LAO													＼																	
KHM														＼																
IND	◎ (11/8)						◎ (11/7)								＼															
SAU									◎ (13/9)							＼														
ARE									◎ (13/9)								＼													
USA					◎ (12/3)													＼											◎ (12/10)	
CAN					◎ (15/1)														＼	◎ (17/9)									◎ (13/4)	
DEU					◎ (15/12)														◎ (17/9)	＼										
NLD																					＼									
GBR																						＼								
FRA																							＼							
ITA																								＼						
ESP																									＼					
RUS											◎ (16/10)															＼				
BRA																											＼			
CHL			◎ (14/10)				◎ (12/2)	◎ (15/11)			◎ (14/1)																	＼		
PAN																		◎ (12/10)	◎ (13/4)										＼	◎ (15/7)
MEX																													◎ (15/7)	＼

Legends

◎ ･･･Effective, (Year / Month)･･･Effective date

Data Source: JETRO (2018).

3.3.4 International sea transportation costs

In order to set the reduction in sea transportation costs, we performed the calculation using the following procedure.

(1) First, we set the types of vessels that carry maritime cargos in each of 36 sectors (*see* Table 2) considering trade values of containerized/non-containerized cargos in Japan's trade statistics. For non-containerized cargo transportation, the correspondence between sectors and ship types was set in consideration of the characteristics of cargo items (sectors) (*e.g.* 11. gas: gas tanker, 12. Minerals nec: ore carrier). However, for "28. Motor vehicles and parts," it is assumed that finished motor vehicles are transported by pure car carriers (PCC) and parts are transported by container ship.

(2) We compiled the trends of the upsizing of vessels of each type listed in Table 2. For cargo carrier excluding container ship, we obtained all ship data for the target ship types in 2011 and 2017 from the IHS "Sea-web Ships database" and calculated the average ship size rate of change for each vessel type as shown in Table 4.

For container ships, we calculated the average ship size in 2011 and 2017 using the 2011 and 2017 editions of "World Container Transport and Service Status" (NYK Line) considering container shipping routes.

(3) We calculated the sea transportation costs based on the average ship size for each ship type from 2011 to 2017 calculated above, by using the calculation formula for sea transportation by container ship and cargo carrier excluding container ship in the "Cost Benefit Analysis Manual for Port Projects in Japan." These results are indicated in Table 4 and 5.

Table 4 – Changes in Average Vessel Size and Transportation Cost of Cargo Carrier Excluding Container Ship.

Vessel type	Average vessel size （DWT）		Sea tranportation cost (Yen/DWT/Day)	
	2011	2017	2011	2017
Crude Oil Tanker	145,235	152,615	37	36
Ore Carrier	236,763	273,896	28	26
Vehicles Carrier(PCC)	64,616	72,652	59	56
Dry Bulk Carrier	66,658	71,716	58	56
General Cargo	5,055	4,941	281	285
Gas Tanker	26,924	32,645	98	88
Oil Products Tanker	13,076	12,291	151	157

Table 5 – Changes in Transportation Costs of Container Ships.

Container route		Sea tranportation cost（Yen/TEU）	
		2011	2017
East-West	East Asia / Europe	91,676	84,862
	East Asia / North America	93,217	88,222
	Europe / North America	80,840	76,539
	East Asia / Middle East / South Asia	-	73,534
North-South	Europe / Middle East / South Asia	151,501	140,234
	East Asia / Latin America	123,444	112,316
	East Asia / Oceania	115,275	104,186
	East Asia / Africa	150,390	135,654
	Europe / Latin America	118,754	108,997
	Europe / Africa	74,860	69,464
	North / Latin America	152,110	145,417
	Other	101,022	88,730
Within the region	East Asia	71,476	63,098
	Far East / Middle East / South Asia	28,080	24,663
	Europe / Mediterranean (including North Africa)	31,756	29,198
	Other areas	175,963	159,191
Other		135,815	129,579

(4) Finally, we entered the (reduction) rate of change of sea transportation costs as a shock to the model. In the sector setting, GTAP's transportation sectors (48.Transport nec, 49.Water transport, 50.Air transport) were aggregated into one item (34.Transport, communication, trade) in this study (*see* Table 2), so when inputting the data into the model, considering the ratio of sea transportation modes as shown in Table 6.

Table 6 – Transportation Rates by Mode for Each Commodity.

	Land	Sea	Air
1 pdr	0.768	0.195	0.037
2 wht	0.275	0.643	0.082
3 gro	0.170	0.735	0.094
4 v_f	0.571	0.356	0.073
5 ocs	0.240	0.696	0.064
6 a_p	0.492	0.347	0.161
7 frs	0.285	0.673	0.042
8 fsh	0.285	0.251	0.464
9 coa	0.106	0.871	0.023
10 oil	0.117	0.857	0.026
11 gas	0.654	0.323	0.023
12 omn	0.076	0.806	0.118
13 omp	0.524	0.425	0.051
14 vol	0.324	0.653	0.024
15 ofp	0.464	0.484	0.051
16 b_t	0.395	0.549	0.057
17 tex	0.359	0.530	0.111
18 wap	0.343	0.477	0.180
19 lea	0.318	0.539	0.144
20 lum	0.437	0.534	0.030
21 ppp	0.396	0.500	0.104
22 p_c	0.115	0.866	0.019
23 crp	0.299	0.532	0.169
24 nmm	0.430	0.460	0.110
25 i_s	0.351	0.575	0.073
26 nfm	0.285	0.482	0.232
27 fmp	0.386	0.471	0.143
28 mvh	0.469	0.473	0.058
29 otn	0.265	0.428	0.307
30 ele	0.166	0.290	0.544
31 ome	0.284	0.410	0.306
32 omf	0.236	0.560	0.204

3.3.5 Exchange rates

GDyn used in this study, like most other CGE models, is a real model, so all figures are treated as real values with no monetary units. Therefore, there is no nominal exchange rate that can be directly linked to those observed in the foreign exchange markets.

In the actual economy, however, it is well known that exchange rates have a significant impact on trade value and volume. The exchange rate of Japanese yen (¥) to the US dollar ($) has varied substantially over the long term, for example, in 2011 it was ¥80 per $1 and ¥121 per $1 in 2015. Thus, the exchange rate is one of the most important settings for estimating port cargo volume. The GDyn includes a real effective exchange rate mechanism as the market price index of primary factors for each region, the “pfactor” variable. We set the value of "pfactor" to the rate of change of the real exchange rate from 2011 (initial equilibrium), with a pass-through rate of 30%.

(1) Pass-through Rate

It is generally thought that the price of traded goods varies due to fluctuations in the exchange rate. For example, it is considered that an appreciation in the yen represents an increase in the price of products exported from Japan to overseas markets, and, conversely, a reduction in the price of products imported from overseas to Japan. The degree of this effect, that is, the exchange rate elasticity of the rate of change in traded goods prices, is called the pass-through rate. If the rate of change of the exchange rate is 100% added to the price of traded goods, the pass-through rate is 100%, and, conversely, if the change in the exchange rate does not affect the price of tradable goods at all, the pass-through rate is 0%. Many previous study have indicated the pass-through rate have been decreased in recent years, therefore, in this study, the pass-through rate was set to 30%, with reference to data from Japan’s Ministry of Economy, Trade and Industry (METI) (2013).

(2) Real Effective Exchange Rate

Japan’s real effective exchange rate was set from “the effective exchange rate index” in the Bank of Japan’s database. The nominal exchange rate refers to the exchange rate of a bilateral currency at the market rate. For example, $1 is expressed as ¥100, and ¥1 is expressed as $0.01. The former is called the nominal exchange rate in yen and the latter in dollars. The nominal exchange rate includes price fluctuations, and the exchange rate that excludes the effect of price fluctuations is called the real exchange rate. Also, in order to see the competitiveness of one’s own currency in the global market as a whole, it is necessary to look not only at the bilateral relationship with a certain currency but also at the plurality of currencies. The effective exchange rate is calculated by weighting the exchange rates between all target currencies and the Japanese yen based on the importance of trade amounts. The real effective exchange rate is an exchange rate that takes into account both the real exchange rate and the effective exchange rate. Trends in Japan's real exchange rates are shown in Figure 3.

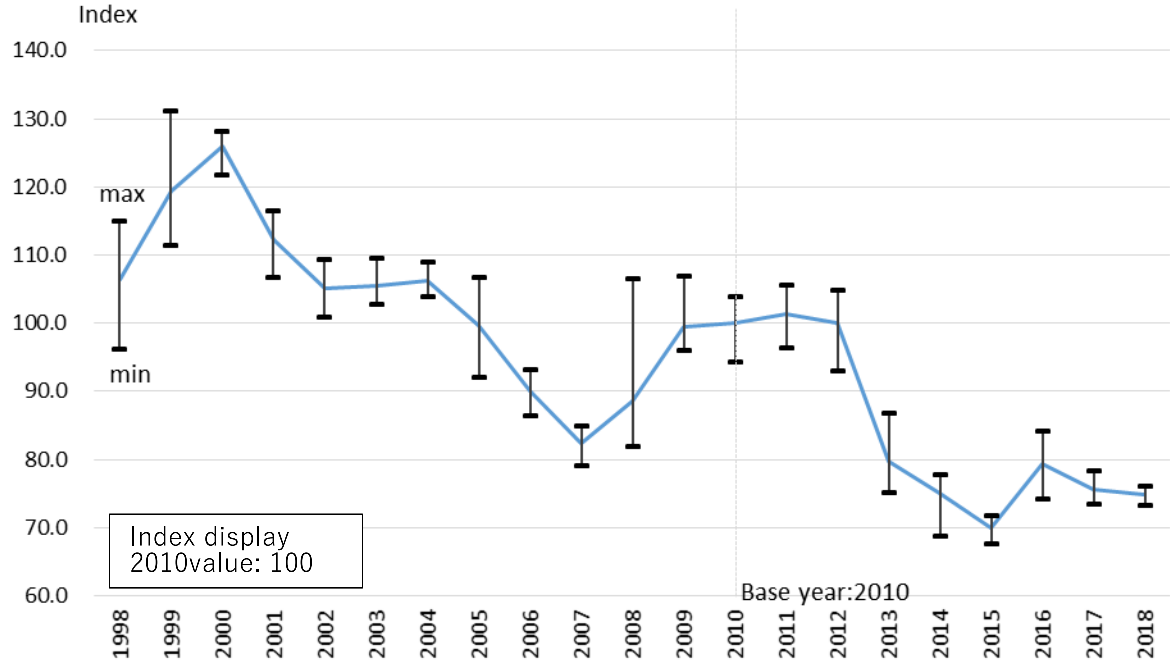


Figure 3 – Fluctuations in Japan's Real Effective Exchange Rate.

Source: BANK OF JAPAN (2019).

The change rate of "pfactor" as 10% of the fluctuation of the real effective exchange rate, because the value rate of imported goods among whole trading goods in Japan is about 30% (input-output table, Ministry of Internal Affairs and Communications), and "pfactor" is calculated by multiplying pass-through rate by rate of imported goods.

4. Calculation Results

Calculations using the GDyn yielded the percentage change in import and export volume by sector between 2012 and 2017. By applying this rate of change in imports and exports to the actual maritime cargo volume in 2011 from Japan's port statistics, export and import volumes by sector in 2017 were calculated. The cargo volumes in the port statistics are tabulated using freight ton (FT), which is shipping ton established by the weight/measure method. To calculate the actual cargo volume in 2011 and 2017, the conversion table between 81 items of the port statistics and 36 sectors of this study was arranged based on HS codes ([36 Sectors]-[HS Code]-[Port Statistics 81 Items]).

Figure 4 shows the 2017 calculation results of port cargo volume, together with the 2017 results, by sector. For exports, the correlation coefficient was 0.9979. For imports, coal, oil, gas, and minerals had slightly higher than calculated values, but had a correlation coefficient of 0.9992. Both exports and imports were very applicable.

Figure 5 shows results by trading partner. Although the US and China was low fit, the correlation coefficient for exports was 0.9678. Regarding imports, the calculated value for Africa was higher than the actual value, but the correlation coefficient was 0.9131. The results by trading partner were also very applicable to both exports and imports.

Figure 6 shows the results of container volume. Container volume of *i* commodity: $Vcon_i$ was calculated by formula (2).

$$Vcon_i = Vall_i \times R_i \tag{2}$$

where, $Vall_i$: whole maritime cargo volume of *i* commodity, R_i: containerized rate of *i* commodity in FT by Japan's port statistics. The calculation results shown in Figure 6 were in 81 items in Japan's port statistics using containerized rate in 2011. The results of container volume were also very applicable to both export and import.

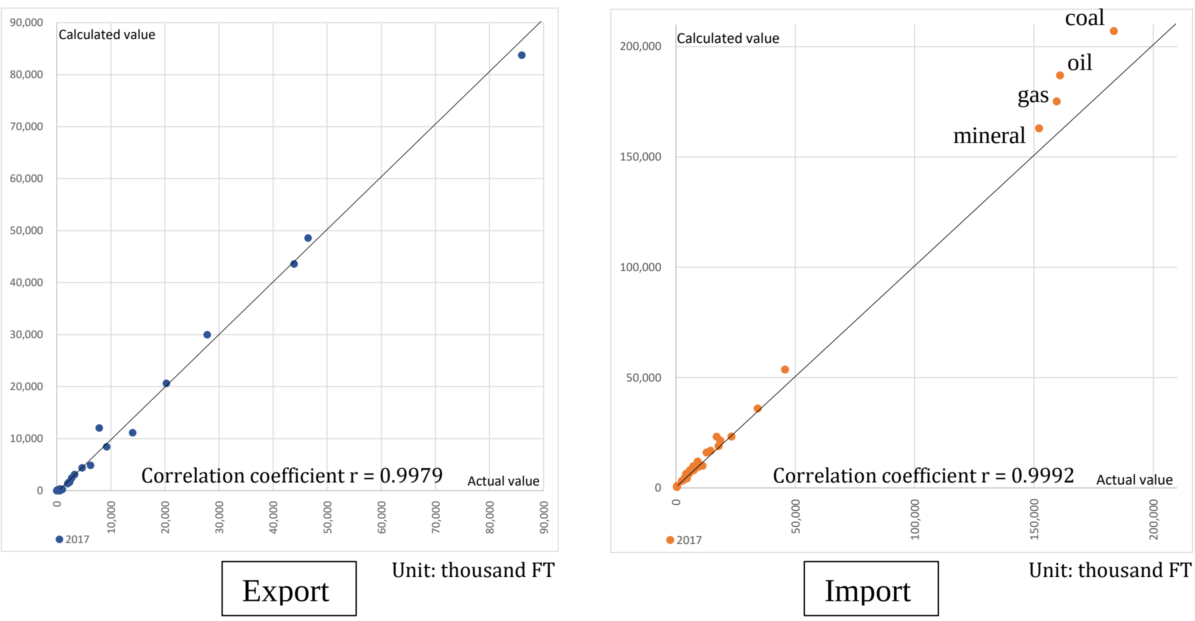
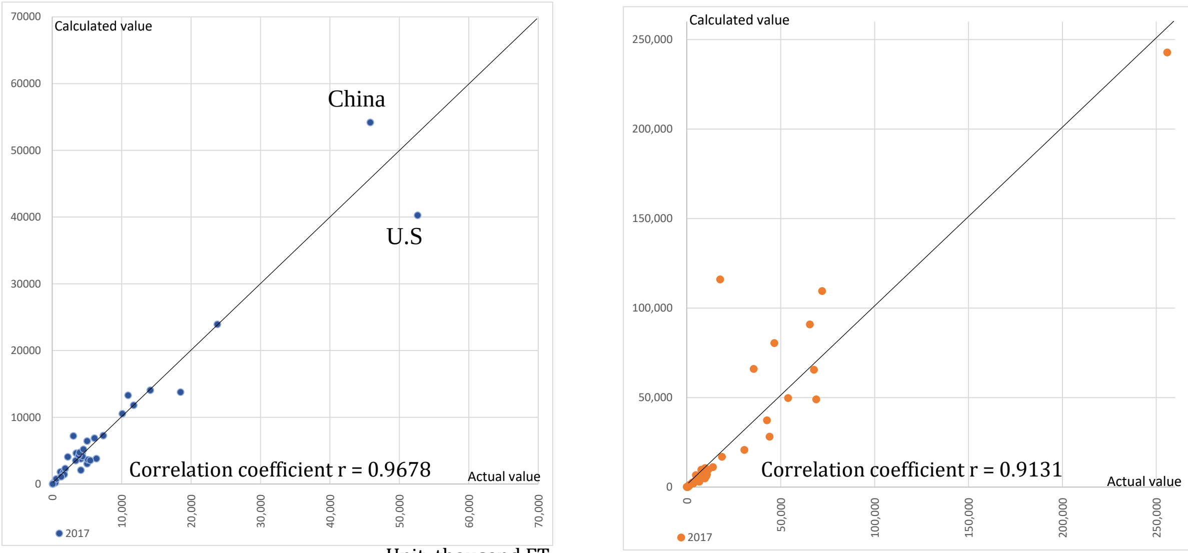


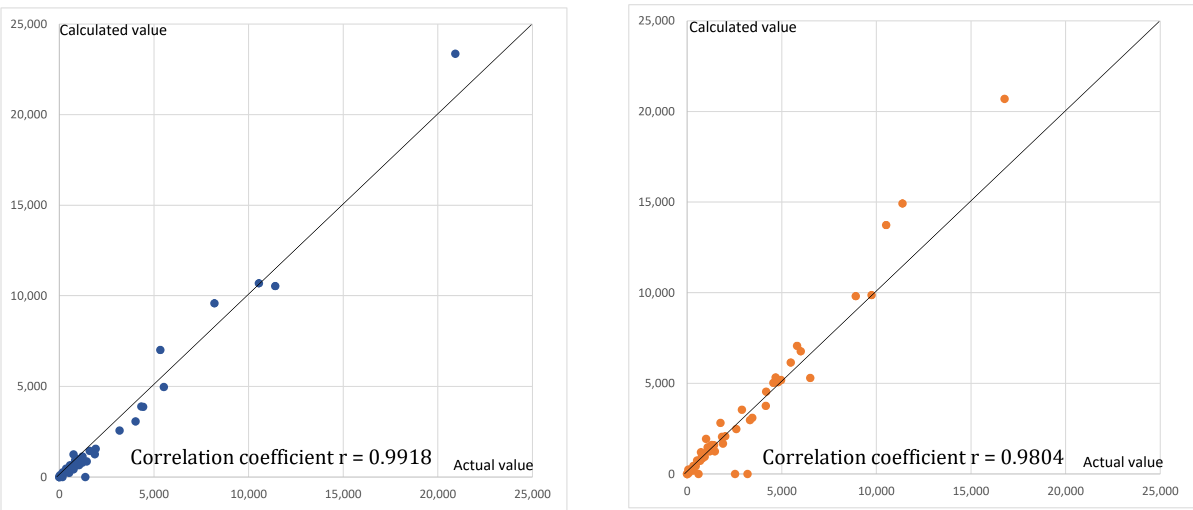
Figure 4 – Calculation Results by Sector.



Unit: thousand FT Unit: thousand FT

Export Import

Figure 5 – Calculation Results by Trading Partner.



Unit: thousand FT Unit: thousand FT

Export Import

Figure 6 – Calculation Results of Container Volume.

5. Discussion

The purpose of this study was to examine a method for estimating Japan's import/export port cargo volume, taking into account various social and economic changes. This model estimates Japan's import/export port cargo volume by incorporating changes into the social and economic condition of the population, labor, GDP, tariff rates, transport margins, and the real exchange rate into the models, which resulted in a high level of reproducibility.

These results indicated that the future port cargo volume can be estimated using this method and that there is a possibility that the estimation result can be used as an index for judging the development pace of Japanese ports in the future. However, the estimation method should consider various social and economic factors influencing future port cargo volume. For example, the population has been decreasing and the aging rate is increasing in Japan. The Japanese government now promotes the acceptance of foreign workers in various fields as a countermeasure to deficiencies in the work force. In terms of EPAs (*see* Table 7), the Trans-Pacific Partnership Agreement took effect in 2018, the Japan-EU EPA came into effect in 2019, and the Regional Comprehensive Economic Partnership, that includes Japan, China, India, Australia and ASEAN countries, is under negotiation. On the other hand, the "trade war" between the US and China is also under negotiation and the United Kingdom (UK) withdrew from the European Union (EU) in 2020. Many of over 10,000 twenty-foot equivalent (TEU) mega-container ships are still under construction and the commission of these ships has a cascading effect, which means the knock-on effect of enlarging ships. The US President Trump made comments about a high dollar exchange rate many times. These factors have an impact on trade values and port cargo volumes. The proposed method in this study is able to deal with all of these issues.

However, this study did not have a long-term verification, the duration was only six years, because of a lack of data. In order to judge the development pace of port infrastructure, long-term estimates are needed, meaning 10 to 15 years in the future. Therefore, long-term trial estimation is still needed in order to verify and improve the accuracy of the estimation. The accuracy of the base data is another issue. The base year of the estimations in this study was 2011, the various economic indicators in Japan were unstable due to the Great East Japan Earthquake, and Japan's input-output data was estimated using 2009 data. The GTAP database Version 10 features 2014 data, so using this data could improve this problem.

The challenge in expanding this study and applying it to future estimates is in how to ensure the certainty of each socio-economic factor used as a shock. In this study, actual values were provided to the model as shocks. However, in future estimations, it will be necessary to set future values such as long-term GDP, labor migration, the effects of EPAs and protectionism on tariff rates, changes in the exchange rate, and the long-term trends of enlarging ships. In addition, change in energy composition is another difficult issue. Many developed countries, such as the EU countries, are aiming to decrease their carbon dioxide (CO_2) emissions drastically by utilizing natural energy sources such as solar power, wind power, geothermal power, and biomass. The US became the top oil producing country in 2018 by a surge of shale oil production and has increased exports to Canada, China, and the UK, and other countries. These changes in energy consumption directly impact port cargo volume. The substitution of electric sources should be accounted for by the model in some way. These issues cannot be addressed in only one manner, thus estimation using various scenarios is required to utilize the estimation results in making policy regarding the ports.

Table 7 – Status of Economic Partnership Agreements at 2018

Country / Region	JPN	CHN	HKG	TWN	KOR	IDN	MYS	THA	SGP	PHL	VNM	BRN	LAO	KHM	IND	SAU	ARE	USA	CAN	DEU	NLD	GBR	FRA	ITA	ESP	RUS	BRA	CHL	PAN	MEX
JPN	＼	□			□											□	□		◎ (18/12)			○ (18/7)								
CHN	□	＼													▲	□	□		▲										□	
HKG			＼							○ (17/11)																				
TWN				＼																										
KOR	□				＼											□	□										□		○ (18/2)	□
IDN						＼																						○ (17/12)		
MYS							＼									▲	▲		○ (18/3)			□								○ (18/3)
THA								＼										▲	▲											
SGP									＼										◎ (18/12)			○ (14/10)					□			◎ (18/12)
PHL			○ (17/11)							＼								▲	▲			□								
VNM											＼								○ (18/3)			○ (15/12)								○ (18/3)
BRN												＼										□								
LAO													＼						▲			□								
KHM														＼								□								
IND		▲													＼	□	□		□			□				▲				
SAU	□	□			□		▲								□	＼						□								
ARE	□	□			□		▲								□		＼					□								
USA								▲		▲								＼	○ (18/11)		□									○ (18/11)
CAN	◎ (18/12)						○ (18/3)	▲	◎ (18/12)	▲	○ (18/3)		▲		□			○ (18/11)	＼								▲			
DEU																				＼										
NLD																					＼									
GBR	○ (18/7)						□		○ (14/10)	□	○ (15/8)	□	□	□	□	□	□	□				＼				▲	□			
FRA																							＼							
ITA																								＼						
ESP																									＼					
RUS					▲										▲						▲					＼				
BRA					□				□													□					＼			
CHL						○ (17/12)																						＼		
PAN		□			○ (18/2)																								＼	
MEX					□		○ (18/3)		◎ (18/12)		○ (18/3)							○ (18/11)												＼

◎ ･･･Effective, (Year / Month)･･･Effective date

○ ･･･General agreement (not effective), (Year / Month)･･･Agreement date

□ ･･･In negotiations

▲ ･･･Conceptual phase

･･･TPP

Data Source: JETRO (2018).

6. Conclusions

The purpose of this study was to establish a port cargo volume estimation method that reflects changes in various social and economic conditions, such as GDP, population, the tariff rate, *etc*.

We set a starting point of 2011 for calculations and changes in GDP population, number of labors, tariffs, international maritime transport costs, and the real effective exchange rate from 2012 to 2017 were shocks to the model, and the rate of change in Japan's import/export volume from 2011 to 2017 was calculated. The change in tariff rates was caused by EPAs that went into effect during the period between 2011 and 2017 and transport costs were impacted by enlarging ship sizes corresponding to the defined sectors.

The calculation results by sector show that the correlation coefficient is 0.9979 for exports and 0.9992 for imports. By trade partner country, the correlation coefficient was 0.9678 for exports and 0.9131 for imports. For container volume, the correlation coefficient was 0.9918 for exports and 0.9804 for imports. The estimation results had very good reproducibility to actual volumes.

This study's estimation method is unique for utilizing a dynamic SCGE model. No previous study has used the same method. Although dynamic SCGE models do feature instability in convergent calculations, this study proposed a procedure for getting relevant calculations despite this shortcoming.

These results indicate that future volumes can be estimated using this method, and that this estimation result can be utilized as an index for judging the development pace of ports in Japan. However, this study does not have long-term verification, the duration was short term. For judging the development pace of port infrastructure, long-term estimates are required, namely 10 to 15 years in the future. Therefore, long-term trial estimation is still needed to verify and improve the accuracy of the estimates by this model. We will tackle this issue continuously.

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