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An Assessment of the Impacts on the International Container Transport and the World Economy Resulting from the 2014/15 U.S. West Coast Port Disruption

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Abstract The development of global supply chains has progressed as a result of reduced transport costs and lead times associated with the expansion of the global container trade. However, this extensive, highly efficient, just-in-time supply chain system is vulnerable in the face of various disasters, and maritime transport and port operations face the risk of stagnation induced not just by natural disasters but also by man-made disasters such as strikes, explosive accidents and so on. Against this background, a review of the 2014/15 U.S. West Coast port disruptions was conducted to assess its impact on the international container transport and the world economy. The findings of the study indicated that the disruption induced an additional two weeks of transportation lead time between the United States and East Asian countries. Direct losses were estimated at above US\$7 billion and overall losses, including indirect losses, were estimated within a range of US\$10 to 13 billion. In addition, a procedure is proposed for reducing the economic impacts of the stagnation of maritime transport and port operations on world trade.

Key words Supply Chain; Container Transport; Man-Made Disaster; Port Disruption; Economic Impact.

1. INTRODUCTION

The transportation of 58 containers from Port Newark to Port Houston in *Ideal-X*, the world's first container ship, in 1956 marked the onset of modern maritime container transport. Approximately 60 years later, maritime container transport has evolved into an integral part of

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economies and contemporary trade, globally. In the 1950s, it was not possible for consumer goods produced in Asian and African countries to reach markets in the United States and Europe. The reason was that the cost of transport over a distance of 10,000 km was too high relative to their production costs. In addition, shippers did not have advance knowledge of the true day of arrival of their cargoes, because cargo handling for conventional ships was canceled on rainy days. However, following the introduction of a stable and inexpensive freight system, many companies ventured abroad, seeking a low-priced and high-quality work force. Consequently, China became a "factory" for the world.

Thus, global maritime container transport has evolved, enabling the advancement of global supply chains through the reduction of transport costs and lead time. An excellent example is provided by the transport of auto parts within the global car production system. As shown in **Figure 1**, a number of automakers are producing various brands in several countries, and the scale of production and procurement of these parts has become global. These auto parts are transported by ships, mostly within containers, between all areas except within North America.



Figure 1. The global trade flow in auto parts in 2015

The division of labor between production processes has been internationalized, and globalization has led to considerable growth in the trade of raw materials, parts, and capital goods between countries. In addition, a "just-in-time" production and delivery system has been introduced that enables the manufacture and delivery of required quantities of products on demand. However, this extensive, highly efficient, and cutting-edge supply chain system is vulnerable in the face of various disasters. In the aftermath of the Great East Japan Earthquake, the disruption in the supply of auto parts from Japan slowed down the global production of cars. For example, the production of cars in Toyota factories in North America decreased to 20% of ordinary production levels (**Figure 2**), indicating that the impacts of disasters spread worldwide throughout supply chains and that the pace at which they spread has been increasing. At the same time, the stagnation of transport can lead to an equivalent outcome.



Figure 2. Impact of the Great East Japan Earthquake on Toyota's production

Maritime transport and port operations, which play an important role in the global economy and trade, may be brought to a halt or become stagnant as a result of not only natural disasters but also man-made disasters (**Table 1**). Many countries and areas, including the U.S. West Coast ports, have been affected by strikes, and, in June 2017, it also occurred in Spain intermittently. The explosion accident at the Tianjin port fully shut down the port's operations and its restoration took approximately one month to complete, having a significant impact on the Chinese economy. In June 2017, cyberterrorist attacks targeting the global Maersk container terminals compelled their closure or led to manual operation at terminals within Europe and North America. Following the bankruptcy of Hanjin Shipping, which was formerly the seventh largest container shipping company in the world, the container ships operated by the company were obliged to wait in offshore areas or at ports, and the transport of many of their containers was cancelled on the way. In June 2017, the Persian Gulf countries, including Saudi Arabia, broke off diplomatic relations with Qatar, which was the largest LNG exporting country in the world, and prohibited the calling of Qatari registered ships. These examples illustrate how maritime transport and port operations may cease or become stagnant as a result of various disasters.

Against this background, a review of the case of the disruption of U.S. West Coast ports was conducted to assess its impact on the international container transport and the world economy. In this study, direct as well as overall economic losses caused by the disruption were assessed. In light of this assessment, a procedure for reducing the economic impacts of stagnation of maritime transport and port function on world trade was proposed.

Category		Disasters		
	Earthquakes	1995:Hanshin Awaji (Japan), 2004:Sumatra/Galle (Sri Lanka), 2010:Talcahuano		
Natural	and Tsunamis	(Chile), 2011:East Japan (Japan)		
Itaturui	Tropical Storms	2003:Busan (South Korea), 2005:Katrina-New Orleans (U.S.), 2008:Nargis/Yangon		
	Tiopical Storins	(Myanmar), 2012:Sandy-New York (U.S.), 2017:Harvey & Irma (U.S.)		
		2002:West Coast (U.S.), 2003:Busan (South Korea), 2003:Europe, 2007:Shenzhen		
	Labor Disputes	China), 2008:Cochin (India), 2010:Chittagong (Bangladesh), 2013:Nhava Sheva		
		(India), 2014/15:West Coast (U.S.), 2017:Spain, 2017:Jakarta (Indonesia)		
	Explosion	2010:Mumbai (India), 2010:Dalian (China), 2015:Santos (Brazil), 2015:Tianjing		
	Accidents	(China)		
M an-M ade	IT System	2013 New York (U.S.) 2017 Moarsk Terminals		
	Failures	2013. New Tork (0.5.), 2017. Wracisk Terminals		
	Bankruptcies of	1986 Unaited States Lines 2001 Chaoyang Shinning 2012 Sanko Steamshin		
	Shipping	2015:Global Maritime Investments, 2016:Haniin Shinning		
	Companies	2015.0100a Wartine investments, 2010.11anjin Shipping		
	Political Issues	1983-88:Tanker War, 2017:Qatar		

Table 1. Recent Disasters that have Influenced Maritime Transport and Port Operation	Fable 1. Rec	cent Disasters that	have Influenced	l Maritime Trans	port and Port O	perations
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2. LITERATURE REVIEW

A number of assessments of economic loss due to port shutdowns have been conducted. Among these is a widely quoted estimate by (Martin Associates 2001), who claimed that the 11-day lockout of West Coast ports would cost the U.S. economy US\$1.94 billion per day. However, (Hall 2004) contended that this was an overestimation, because the ratio of direct loss was only 4% and the indirect loss was calculated based on the assumption that all companies using ports were closed. (The Congressional Budget Office 2006) concluded that the direct loss incurred as a result of the West Coast port shutdown in 2002 ranged from US\$65 to US\$150 million per day.

(Haveman and Shatz 2006) discussed the impacts of terrorist attacks and countermeasures against them in the context of the vulnerability of the Los Angeles and Long Beach ports. They estimated that one year of reconstruction would lead to a loss of US\$45 billion for the U.S. economy. (Winterfeldt and Rosoff 2007), who similarly estimated losses from terrorist attacks on the Los Angeles and Long Beach ports inflicted with radiological dispersal devices ("dirty" bombs) calculated values within a range of US\$130 million to US\$100 billion. These figures applied to a shutdown in port operations for a period of 15 days to one year. (Park 2008) estimated that the same attack leading to a one-month shutdown would result in a loss to the global economy of US\$35.9 billion. (Funase et al. 2011) estimated that a closure period of one year for the Nagoya port would cost the Japanese economy JPY252.9 billion (approximately US\$2.2 billion, based on the exchange rate on August 28, 2017), and it would cost the global economy JPY794.3 billion (approximately US\$7.0 billion). (Southworth et al. 2014) reviewed various cases of port disruptions and conducted a specific case study of the Superstorm Sandy and Columbia River Closure. Based on their examination of the U.S. port system, (Trepte and Rice 2014) suggested that the major ports lack sufficient capacity to handle disruptions, with consequent significant economic impacts. (Lam and Su 2015) compiled and analyzed cases of port disruption in Asia. (Werling 2014) and (Martin Associates 2014) also estimated losses for the U.S. economy resulting from the impact of the 2014/15 U.S. West Coast port disruptions, which are the focus of the present study. Their estimates, ranging from US\$3.4 to 40.9 billion, were based on the assumption of a port shutdown period of 5 to 20 days prior to the occurrence of the disruption. In fact, West Coast port operations during this period did not stop, although they remained stagnant for a long period. In another study, (Novati et al. 2014) assessed the impacts of major port disruptions on the shipping networks that connect Europe and Southeast Asia.

The impacts of the closure of international waterways have also been studied. (Akimoto 2001) examined the structural weakness of chokepoints in Eurasian maritime areas such as the Malacca/Singapore Strait, the Sunda Strait, and the Lombok and Makassar Straits from the perspective of securing sea lanes. (Rimmer and Lee 2007) calculated the cost of using alternative routes to the Malacca/Singapore Strait. (The International Risk Governance Council 2011) selected and analyzed three possible high-impact events that would lead to the closure of the Malacca/Singapore Strait: the explosion of refineries, cyberattacks directed at ship control systems, and multiple collisions of large ships. They estimated that the Strait's closure for a period of one year would have an economic impact to the value of US\$18 billion.

Almost all of these earlier studies were based on the assumption that closure of ports and waterways would occur. Therefore, they did not consider cases in which the ports' functions remained partially active and stagnant. No studies are available in which the actual alternative routes used by shipping companies and cargo owners in cases of port disruption. This study addressed this gap through an analysis of an actual case study entailing the use of alternative routes under conditions of port disruption and presented a possible countermeasure.

In the practical field of business, the Asia-Pacific Economic Cooperation (APEC) focused on counter measures for terrorist attacks by the Secure Trade in the APEC Region (STAR) Initiative, and its tenth conference was held in Peru in 2016. Moreover, the world's seven major insurance companies, led by Risk Management Solutions Inc., have developed marine cargo catastrophe modeling to assess risks associated with maritime cargo.

3. U.S. WEST COAST PORT DISRUPTION

3.1 An Outline of the West Coast Ports and Labor-Management Negotiations

U.S. West Coast ports constitute important gateways not only for the United States but also for the East Asian region, specifically, Japan, South Korea, China, and Taiwan. There are two container transport routes between the United States and East Asia: those via the West Coast and East Coast ports. The West Coast route connects marine transport with inland rail and truck at West Coast ports, so this route is described as "intermodal." The East Coast route is exclusively for marine transport to and from East Coast ports and is therefore described as "all water." The West Coast route is the one chosen most often, with approximately 70% of container cargoes moving between the United States and East Asia. Major ports handling containers along the West Coast are Los Angeles, Long Beach, and the Northwest Seaport Alliance (NSA) comprising Seattle and Tacoma. Their container throughput rankings in the United States are first, second, and fifth, respectively.

At the West Coast ports, the International Longshore and Warehouse Union (ILWU), which primarily represents dock workers, and the Pacific Maritime Association (PMA), comprising

shipping companies and stevedores, have negotiated labor contracts from the time of the inception of the PMA in 1949. In recent decades, labor contract negotiations have occurred every six years. The negotiation held in 2002 resulted in an 11-day lockout. During this period, 29 West Coast ports fully ceased operations, and over 200 ships were kept waiting offshore. The lockout was ended through a Federal Court order originating from President Bush's appeal based on the Taft-Hartley Act (Labor Management Relation Act, 1947). The negotiation in 2008 was concluded in the absence of any major confusion. **Table 2** provides details regarding the 2014/15 negotiation. At the end of 2014, the offshore waiting time was extended, and it became necessary for shipping companies to add extra ships. President Obama decided to dispatch Peres to the scene, followed by the Secretary of Labor, because, as discussed in the next section, increasing stagnation of these ports was apparent in February of the following year. Consequently, the negotiation was concluded after a nine-month period of confusion.

Time		Occurrence		
Mid-May		Start of the negotiation		
2014	End of Jun	Deadline of the 2008 Contract		
2014	Late Oct	WU started slowdown (Announcement by PMA)		
	Late Dec	PMA stopped night work		
	Feb 4th	PMA proposed compromise to ILWU and released it		
2015	Feb 11th	PMA announced end of holiday work		
	Feb 17th	Start of the mediation by Peres Secretary of Labor		
	Feb 20th	Tentative Agreement		

Table 2. The sequence of events that occurred during the 2014/15 negotiations

3.2 Stagnation of Port Operations

The slowdown and suspension of night work led to a significant decline in the efficiency of cargo handling. **Figure 3** shows a change of the efficiency of container handling during the period of stagnation compared with that of the same month in 2013. ILWU denied that there was a slowdown, but the efficiency rate began to decrease at the Los Angeles and Long Beach ports in October and at the NSA ports in November. The average efficiency rate decreased to around 0.4 in January and February, indicating that the time required for container handling was 2.5 times above the time normally required.

The decrease in container handling efficiency resulted in lengthy offshore waiting times. From the shipping company's perspective, waiting was the only option for handling carrying containers, because the cargo handling work was carried out in the order of the arrival of ships. In other words, even if a container ship from East Asia reached the offshore area of the West Coast ports on time, the projected terminal of call was still occupied by the previous ship that should have departed several days ago. Moreover, the arriving ship had to join a long queue. On February 17, 2015 when Secretary Peres began mediation efforts, there were over 30 container ships waiting offshore of the Los Angeles and Long Beach ports.



Figure 3. Efficiency of container handling (time per box)

4. IMPACTS ON CONTAINER TRADE

4.1 Impact on Transportation Lead Times

The stagnation of port operations directly impacted on the container trade. The lengthy handling and offshore waiting times increased the transportation lead time for containers passing through the West Coast ports. **Figure 4** shows changes in transportation lead times from the Tokyo Bay ports to the U.S. West Coast ports. The blue bars represent offshore time, including offshore waiting, and the green bars represent average container handling times at the terminals. The average lead time, which was ordinarily approximately 12 days, rose to 26 days in February 2015. Thus, an additional two weeks was incurred for shipping. In March 2015, the average terminal time was restored to normal as a result of the tentative agreement reached on February 20. However, the time spent offshore did not decrease immediately, because considerably more time was required to resolve the problem of offshore waiting.



Figure 4. Lead time for container transport from Tokyo Bay ports to U.S. West Coast ports

4.2 A Case Study of Auto Parts

Japanese and Korean automakers produce a number of cars at their factories located in the United States. (MarkLines 2017) reported that in 2016, the U.S. market shares of Japanese car manufacturers, namely, Toyota, Honda, Nissan, and Subaru, according to the number of cars produced, were 14.0%, 9.3%, 8.9%, and 3.5%, respectively. The Korean automakers, Hyundai and Kia, occupied respective shares of 4.4% and 3.5% (MarkLines 2017). In the U.S. production factories of these Japanese and Korean companies, supplies of parts characterized by high functionality are sourced from the home countries. Approximately 20% of the destination states for these parts, both from Japan and Korea, are located in the American West and the remaining destinations are in the American Midwest and the South (**Figure 5**). However, the discharging ports for imported auto parts from these two countries differ. Almost all of the Japanese parts are imported via the West Coast ports, and about 40% of Korean parts are imported through the East Coast ports (**Figure 5**).



Figure 5. Destination states for auto parts and discharging ports in the United States

How then was the route for transporting auto parts from Japan and Korea to the United States altered by the West Coast port disruption? Possible alternative routes were the East Coast route and the air transport route. **Figure 6** shows a comparison of the proportions of usage of these three routes in normal circumstances (February 2014) and at the time of disruption (February 2015). Japanese automakers used air transport as an alternative, whereas Korean automakers mainly opted for the East Coast route. Thus, the choices of Japanese and Korean automakers differed regarding alternative routes. It is possible that this difference could be attributed to whether or not these automakers had used the East Coast route under ordinary circumstances. This is because it is generally very difficult to create a new transport route during a state of emergency and confusion. In addition, the press reported that Toyota and Honda were obliged to decrease their car production, and that Subaru had to charter four flights per month at a cost of JPY7.0 billion (US\$62 million) for urgent transportation of car parts. However, Hyundai did not face any serious problems in its car production, indicating that there is a valuable lesson to be



learned by shippers to manage the risk of stagnation of their supply chains.

Figure 6. Transport routes for Japanese and Korean car parts

5. DIRECT ECONOMIC LOSSES

5.1 Estimation Method

During the disruption at the West Coast ports, shippers could choose among three options. The first was to stop shipping operations. The second was to switch to air transport or use the East Coast route. The last option was to use the West Coast route, even though this significantly extended the transportation lead time. The second option of using an alternative route for transporting auto parts has already been discussed in a previous chapter. The direct economic loss resulting from the port disruption was calculated by multiplying the volume of the container that was halted, switched to another route, or kept waiting by the cargo value/cargo time value/freight change.

 $L_{\rm s}$, which denotes the loss resulting from stoppage of shipping was calculated using formula (1).

$$L_{\rm s} = C_{\rm s} \times V_{\rm s} \times 0.5 \tag{1}$$

where C_s denotes the corresponding container volume in twenty-foot equivalent units (TEU) and V_s denotes the corresponding cargo value (in US\$/TEU). The multiplication by 0.5 in the formula is based on the assumption that the corresponding cargo value was reduced by half. Some cargoes may have been exported to another country using land transport or they may have been transported through the East Coast ports, some may have been sold in the United States at discounted rates, and some may have incurred a complete loss. At the time of the 2002 lockout, the cargoes for which shipping was stopped became the business targets of 99-cent stores (Development Bank of Japan 2002). One case of spoilage of edible fresh fruit that could only be used as a juice ingredient was reported (Hall 2004). As the actual rate of loss of cargo value could not be captured by any statistic, it was assumed, for the sake of practical convenience, that the cargo value was reduced to half of its original value.

The second step entailed the calculation of L_c , which denotes the loss resulting from switching

to air transport or the East Coast route, using formula (2).

$$L_c = C_c \times VT_c \times T_c + C_c \times F_c \tag{2}$$

where C_c denotes corresponding container volume (TEU); VT_c denotes the corresponding cargo time value (US\$/TEU/h); T_c (h) denotes the difference in transportation lead time between the alternative route and the usual route; and F_c denotes the difference in freight charge (in US\$) between the alternative route and the ordinary route. The first part of formula (2) shows the loss induced by the increase in lead time. In the case of switching to air transport, the value of this loss was below 0, indicating a benefit. The second part of formula (2) shows the loss induced by the increase in the freight charge, which was very high for air transport and also increased for eastbound transport via the East Coast ports.

In the third step, L_W , which denotes the loss incurred from the waiting at the West Coast ports, was calculated using formula (3).

$$L_{W} = C_{W} \times VT_{W} \times T_{W} (Except \text{ for perishable food at peak time}) + C_{WP} \times V_{WP} (Perishable \text{ food at peak time})$$
(3)

where C_w denotes the corresponding container volume (TEU), with the exception of perishable food at peak time; VT_w denotes the corresponding cargo time value (US\$/TEU/h); T_w (h) denotes the difference in the transportation lead time between the normal and disruption states; C_{wp} denotes the container volume (TEU) of perishable food at peak time; and V_{wp} denotes the cargo value (US\$/TEU) of perishable food at peak time. The second part of formula (3) shows the total loss of perishable cargo at peak time, because gas and water vapor that fresh vegetables and fruits exhaust accelerates spoilage even under the temperature control. The quality of meat and fish also deteriorates over time, even in a reefer container. The peak time was set from January to March, 2015. Perishable food was defined using the HS Code (Harmonized Commodity Description Coding System) as follows; 02 (meat), 03 (fish), 04 (daily produce), 07 (vegetables), 08 (fruit and nuts), and 09 (drinking material).

Last, L_T , denoting the total amount of loss, was calculated using formula (4).

$$L_{\rm T} = L_{\rm S} + L_{\rm C} + L_{\rm W} \tag{4}$$

5.2 Stopped and Switched Container Volumes

 C_s , denoting the stopped container volume in formula (1) and C_c , representing the switched volume in formula (2) were estimated using trend analysis. X-13ARIMA, that is the seasonal adjustment program by U.S. Census Bureau, was used to calculate the assumed trend values in the absence of the West Coast port disruption. In this trend analysis, the observation period was set from 2009 to 2015, excluding the port disruption period. This is because of the obvious data discontinuity of container port traffic before and after 2008 on account of the worldwide economic recession in 2008. During the observation period, the reproducibility of the estimated data was very good, for example, in the second half of 2015, the coefficient of determination between the actual and the estimated volumes by country/month was 0.9999.

The stopped and switched volumes were obtained from the difference between actual and trend values. **Figure 7** shows an example of the actual and trend container volumes transported from the

United States to Japan. The trend volumes were greater than the actual volumes from October 2014 to January 2015, whereas the trend volume in March 2015 was less than the actual volume because of the delayed arrival of cargoes. The stopped volume was calculated as the total difference between these two volumes during this period.



Figure 7. Actual and trend container volumes transported from the United States to Japan

Table 3 shows the estimation result for the stopped and switched volumes. Concerning eastbound cargo coming from Japan, the switch to air transport was mainly used, whereas a switch to the East Coast route was mainly used by cargoes coming from other countries. A large number of westbound cargoes stopped shipping, with the exception of cargoes en route to Taiwan.

Eastbound	Japan	Korea	China	Taiwan		
Lustoouna	To United States					
Stoppage of Shipping	5.0	0.0	18.8	4.9		
Switch to Air	9.8	1.1	8.5	0.9		
Switch to East Coast	0.9	17.2	179.2	4.9		
Westbound		From Uni	ted States			
Westbound	Japan	From Uni Korea	ted States China	Taiwan		
Westbound Stoppage of Shipping	Japan 22.5	From Uni Korea 12.0	ted States China 157.8	Taiwan 0.0		
Westbound Stoppage of Shipping Switch to Air	Japan 22.5 3.6	From Uni Korea 12.0 0.3	ted States China 157.8 2.2	Taiwan 0.0 0.5		

Table 3. Estimation Results for Stopping and Switching Container Volumes ('000 TEU)

5.3 Estimation Results

To estimate direct losses, the cargo values were calculated using U.S. trade statistics and PIERS data, and cargo time values were estimated using the opportunity cost method. As to the interest rates for this method, short-term prime rates of importing countries were used because, as described later, these importing countries were assumed to incur the losses. **Table 4** shows the calculation results. The value of cargo shipped from Japan to the United States, and the

corresponding cargo time value were the highest.

	Japan	Korea	China	Taiwan	
Cargo Value	To United States	99.4	36.7	31.3	37.8
('000US\$/TEU)	From United States	21.7	20.4	12.8	14.6
Cargo Time Value	To United States	0.369	0.136	0.116	0.140
(US\$/TEU/h)	From United States	0.027	0.047	0.082	0.047

Table 4. Calculation results for cargo value and cargo time value

The direct loss for each country was estimated using formulas (1) to (4) presented in section 5.1 (**Figure 8**). With the exception of stoppage of shipping, losses were added up to imported country, because a large number of trade contracts are that the owner of the cargoes move to imported side after the shipments have started among various Incoterms (International Commercial Terms) (Yoshida 2015). The whole direct loss was estimated to be US\$7.2 billion. From a country-based perspective, the loss suffered by the United States was clearly the greatest, with Japan incurring a slightly higher loss than China. Among the categories of loss, waiting at the West Coast ports incurred the highest loss for all countries with the exception of the United States, and those losses by waiting of the U.S., Japan, and China were the same level. Japan's loss resulting from the extended waiting time at the West Coast ports rose, because the proportion of its imported container volume of perishable food was high compared with those of the United States and China.



Figure 8. Estimation results for direct loss

6. OVERALL ECONOMIC LOSSES INCLUDING INDIRECT LOSSES

6.1 Findings on risk communication in the information discussion process

As discussed in the first chapter, stagnation of transport decreases production and reduces economic activity. The estimation methodology discussed in section 5 is that for direct losses that were imposed mainly on shippers, however, these losses had additional negative impact to the whole economy (indirect losses). A GTAP (Global Trade Analysis Project) model was used to

estimate the approximate size of the overall impact of stagnation on economic activity. This model is one kind of computable general equilibrium (CGE) model developed at Purdue University and is widely used for estimating economic impacts associated with custom tariff changes. For example, the U.S. and Japanese governments applied this model to assess the economic impacts of the Trans-Pacific Strategic Economic Partnership Agreement (TPP). **Figure 9** shows the production function of the GTAP model. The intermediate input comprises a double layered structure, and the elasticities of substitution of intermediate input were set, respectively, at domestic and international levels. The GTAP9 Database for 2011, comprising 140 countries/areas and 57 sectors, is the most up-to-date database applied for the model.



Figure 9. Production functions of the GTAP model

To perform the estimation using data of the appropriate size, aggregations of countries/areas were constituted as follows: the United States, Japan, Korea, China, Hong Kong, Taiwan and the rest of the world. **Table 5** shows the aggregation of sectors based on the relationship between the HS Code and GTAP sector classification (Hutcheson 2006) considering the cargo property and the containerized rate. The proportions of the firm prices of each sector of endowment commodities (labor and capital) in each country/area were locked, because it was assumed that layoffs and the reduction of production facilities were not implemented because of the disruption of the West Coast ports. A number of studies have discussed the elasticity of substitution parameters (e.g., Arndt et al. 2001; Hertel et al. 2003; Annabi et al. 2006; Okagawa and Ban 2008; Hillberry and Hummels 2013) and the parameter of the GTAP model (Hertel and Mensbruqphe 2016) is one of the latest. If the purpose of conducting an estimation is to calculate the geographical spread of impact, the detailed estimation of elasticity of substitution parameters is indispensable. However, the aim in this study was to present an estimation of an approximate scale of overall economic loss. Consequently, the GTAP9 parameters were not modified.

No	A garageted Sectors	GTAP Sector Codes	Average Rate
No Aggregated Sectors		GTAT Sector Codes	of Container
1	FreshFoods	4, 8, 11, 14, 19, 20, 22, 25	72.3%
2	Primary Pro-Lo	1, 2, 3, 5, 6, 9, 21, 23	15.4%
3	Primary Pro-Hi	10, 13	83.3%
4	Extraction	15, 16, 17, 18, 32	27.1%
5	LightMnfc	7, 12, 24, 26, 27, 28, 29, 30, 31, 33, 34, 42	79.0%
6	HeavyMnfc-Lo	35, 40, 41	28.1%
7	HeavyMnfc-Hi	36, 37, 38, 39	71.1%
8	Services	43, 44	-

 Table 5. Aggregated sectors featuring in the calculation

* Average rate of container cargo was calculated based on the data by HS Code.

All direct losses in section 5 were reflected to the increase in the tariff rates. The increases of costs by switching to air transport or the East Coast route was converted into additional rates by using the average cargo values. As to the increase in transportation lead time, the parameters for converting into tariffs were calculated in previous studies (Freund and Rocha 2010; Hummels and Schaur 2012; Minor 2013) based on the differences in freight charge between various modes of transportation. In this estimation, the *ad valorem* trade time cost for each country/area was calculated from the data provided by (Minor 2013). Accordingly, as shown in **Table 6**, transport disruption was considered as the increase in tariff rates. For example, an additional one day lead time was equivalent to a 0.84 to 1.16 % point increase in the tariff rate for eastbound cargo transported from Japan to the United States. This range of *ad valorem* trade time cost was treated as a minimum loss case and a maximum loss case, respectively.

Country/Area	Eastbound	Westbound
Country/Area	To United States	From United States
Japan	0.840 -1.160	0.585 -0.950
Korea	0.760 -1.075	0.585 -1.075
China	0.670 _0.935	0.635 _0.930
Hong Kong	0.670 -0.935	0.680 -0.895
Taiwan	0.635 _0.860	0.450 _1.060
Rest of the World	0.700 -1.080	0.720 -0.980

Table 6. Ad valorem trade time cost (% points per day)

The additional tariff rate by the stoppage of shipping was calculated as the half value of corresponding cargoes as already assumed in section 5.1. In the same way, for perishable food, which was considered to incur a total loss at peak time during the waiting at the West Coast ports, the additional tariff rate for a minimum loss case was calculated from the recorded cargo value at peak time. The additional tariff for a maximum loss case was set at a value that was 20% higher than that of the minimum loss case considering disposal fee of wasted cargo.

In the trade between the United States and East Asia, cargoes are shipped not only in container ships, but also in conventional ships such as tankers and bulk carriers as well as in jets. The increase in the tariff rate was set for each sector considering the proportion of container transport along the

West Coast route. The calculation period was set at one half year commencing from November 2014, as the increase in lead time during that period was significant.

6.2 Opinions of participants in the information discussion process

Figure 10 shows the estimation results for overall economic losses. The total loss, worldwide, was estimated to be in the range of US\$10.3 to 12.4 billion, including the direct loss. This means that the indirect losses correspond to around 43 to 73% of the direct loss, although the simple comparison is difficult because the estimation methods are partially different. The United States incurred the highest loss, followed by China. The trade volume for the rest of the world ("ROW" in **Figure 10**) with the United States increased to compensate for loss of trade with East Asia, simultaneously, the economy was affected by the decrease in the GDP of the United States and East Asia. Consequently, there was a slight gain in the GDP for the rest of the world.



Figure 10. Estimation results for overall economic loss

7. THE SUBSEQUENT CONTINIOUS PRACTICE

Previous studies have provided estimates of the economic impacts of ports/water ways blockage. In some of the studies, as described in section 2, it was assumed that transportation through the targeted port came to a complete halt, and the production materials did not reach local manufacturers which could not continue production and shipping of goods. Such assumption makes it easy to estimate the economic losses but may lead to overestimation, because, as (Hall 2004) pointed out, shippers look for alternative routes. Estimating the alternative routes and calculating the additional costs and lead times are essentially indispensable to estimate the economic losses caused by port blockage. On the contrary, the losses caused by partially operational port can be also estimated by using the costs and times of alternative routes as shown in this study. In case that the complete halt of port function continues for longer period and all the values of cargoes are totally lost due to on ship waiting, the estimation method of this study for the spoilage of perishable foods is available.

The estimation of alternative routes is also one of the argument points. This study estimated

the routes after the disaster by using various data. However, these data cannot be available in advance. (Funase et al. 2011) and (Martin Associates 2014) deduced the alternative routes during port blockade. Theoretically, the estimation by a route choice model which is improved to apply it at the time of disasters is necessary. (Akakura et al. 2015) developed the alternative port/route choice model based on the travel time and cost for Japanese export and import container cargoes by considering the handling capacities of ports after the outbreak of disasters.

The economic impact of stagnation of international container traffic consists of the direct losses that are imposed mainly on shippers, and the indirect losses that reflect the economic ripple effect such as decrease in the demand of intermediate goods associated with the direct losses. (Funase et al. 2011) estimated the overall losses by adding the transport costs of alternative routes directly to the CGE model. In this study, the direct losses are estimated in section 5 and overall losses including indirect losses are discussed in section 6. Regarding the direct losses, the estimation does not depend on the cargo commodity classification, except for perishable foods waiting at the West Coast ports, because the scope of estimation is limited only in container transport. In terms of the estimation of overall losses, the proportion of maritime container traffic to all transport modes varied greatly by the cargo commodity as indicated in **Table 5**; therefore, the cargo commodity classification was essential. Among six regions included in the CGE model, the rest of the world was considered negligible in terms of the direct losses, whereas it is indispensable for calculation of CGE. The rate of cargo value loss due to the stoppage of shipping was assumed as 0.5 in section 5.1, was reflected to tariff rates in calculating the overall losses and was considered to need to improve in future studies. For this estimation method of overall losses, it should be pointed out that the additional tariff rate leads to an increase in government revenue (Funase et al. 2011). However, the proportion of tariff revenue in relation to government revenue was only 1.8% in the United States and Japan (Ministry of Finance 2017). Moreover, the trade volume was estimated to decrease in line with a tariff change. In this study, the impact of the disruption on domestic trade conducted through the West Coast ports was not considered. These factors contribute to reducing overall loss. Therefore, the actual loss may have been greater than the estimated loss.

Table 7 shows a comparison of the results of estimations of economic loss calculated in previous studies. The value of the overall loss incurred as a result of the U.S. West coast disruption, as calculated in this study, was somewhere between those incurred as a result of the one-year closure of the Nagoya port (Funase et al. 2011) and the one-year closure of the Malacca/Singapore Strait (IRGC 2011).

			Economic Loss	
Port/Water Way	Situation	Authors	(Billion US\$)	
			Direct	Overall
	11 days Lockout	CBO (2006)	0.715–1.65	
U.S. West Coast	9 month Stagnation	This study	7.2	
	5 month Stugnation	Tinb Study	10.3-12.4	
Los Angeles/Long Beach	1 year Closure	Haveman and Shatz (2006)	45	
Los i ingeles, Long Deach	1 year Closure	Winterfeldt and Rosoff (2007)	100	
Nagoya	1 year Closure	Funase et al. (2011)	7.1	
Malacca/Singapore Strait	1 year Closure	IRGC (2011)	1	8

Table 7. Estimation of economic loss associated with the disruption of various ports/water ways

8. RISK MANAGEMENT

As discussed in previous chapter, the disruption of the U.S. West Coast ports that was the outcome of labor contract negotiations in 2014/15 had a significant impact on the maritime container trade and resulted in extensive losses within the U.S. and East Asian economies. Transport disruptions may be identified as the Achilles' heel of global supply chains. Maritime transport and port operations can deteriorate or come to a halt as a result of various disasters. If the cargo that is en route does not arrive, and if the stock runs short because of the time taken to arrange an alternative route, then the concerned company will be compelled to decrease or stop producing the cargo items.

Insurance constitutes one countermeasure against various risks by transferring it to the other market. However, any delays are disclaimed by international freight insurance companies. Therefore, as in the case of the disruption of U.S. West Coast ports, if cargo arrives undamaged at the destination, it is not eligible for compensation by the insurance company, regardless of how long the cargo delays. In cases where the cargo shipment is canceled en route, the residual transport may be compensated through insurance. In the case of a strike, the insurance can be covered by waterborne agreement together with war risk, with the premium rate based on the countries/ports of origin and destination. However, even in this case, the insurance covers only the damage inflicted by strikers, while the loss caused by the walkout itself is discounted.

This raises the question of whether any methods exist for controlling risks during the transport of cargo. Multiplex transport routes constitute one of the most effective countermeasures for reducing the risk. As discussed in the chapter 4, during the disruption of the West Coast port, Japanese automakers that used only one route during normal circumstances were forced to choose air transport as an alternative route. By contrast, Korean automakers that used both the West and East Coast routes could shift to the other route without their car production suffering any adverse consequences. Shippers who ordinarily used both routes were able to switch easily to the other route in case one of the routes was in a stagnant state. However, this countermeasure is only effective under the condition that the transport efficiency does not decrease when multiple routes are retained. Generally, shippers cannot retain an uneconomical route solely for the purpose of risk management, although this depends on the frequency and impact of the targeted risk.

Another question concerns the existence of any countermeasures that relate to ports and shipping companies. In the United States, the Port Resilience Project has been promoted by the National Center for Secure & Resilient Maritime Commerce (CSR) and the Massachusetts Institute of Technology (MIT). In Japan, Port-Business Continuity Plans (BCPs) have been developed for almost all of the major ports in the country. In the U.K., University College London and the University of Nottingham are developing a tool known as the Methodology for Improving Resilience of Seaports (MARS), to strengthen the resilience of overall port system. Each of these approaches is aimed at increasing the durability and resilience of port functions. From this perspective, Area Port-BCPs, as the superordinate concept underlying each Port-BCP, have been developed in Japan to facilitate the substitution of other ports to compensate for the loss of functions of the disaster-stricken port during its restoration. In the area of shipping companies, THE Alliance, one of three groups operating in the East–West trade lane and comprising five major shipping companies, established an independent trust fund for handling the bankruptcy of a member company. Given that Hanjin Shipping declared bankruptcy in August 2016, shipments of

containers were subject to drastic delays, and many were terminated en route. These methods can be applied by organizations managing transport to reduce risk.

The most effective method of risk management will be that a shipping company/forwarder, which is commissioned to transport by shipper, provides an alternative route in consultation with the concerned organizations such as port authorities at the time of a disaster. At present, this approach is not within the scope of freight contracts, and it is not realistic to expect a shipping company to assist in the search to find its own replacement among other shipping companies, even in a state of emergency. However, this type of mutual cooperation system is already operating among Japanese railway companies. At the time of an accident, the concerned Japanese railway company provides the ticket-holding customer with an alternative route at no cost using another company's line. After an accident, the passenger fare required for availing of the alternative route is spent by the accident involved company. As in the case of international maritime freight, Japanese railway companies do not guarantee arrival times. However, because the risk of an accident applies to all companies, the provision of an alternative route is critical to provide customers with relief. Similarly, shipping companies can increase their reliability by providing their own temporary alternative route at the time of a disaster.

9. CONCLUSION

In this study, the economic impacts resulting from the stagnation of international container transport were assessed based on a review of the case of the 2014/15 U.S. West Coast port disruption. As discussed, the division of labor between production processes has been internationalized as a result of globalization, resulting in a dramatic expansion of trade between countries worldwide. In addition, a just-in-time production and delivery system has been established. However, this advanced and highly efficient global supply chain system is vulnerable in the face of various disasters, including port disruptions. Ports are also affected by man-made disasters such as strikes, explosions, and bankruptcy. Thus, disruptions in transport may constitute the Achilles' heel of global supply chains.

The U.S. West Coast disruption in 2014/15 reduced the efficiency of cargo handling to a low level and resulted extended offshore waiting times, leading to an additional two weeks of transportation lead time. During the disruption, Japanese automakers used air transport as an alternative mode of transport, whereas Korean car manufacturers mainly selected the East Coast route and were thereby able to avoid any impacts of the disruption on their production.

The findings of the review indicated that the switch in the case of cargoes from Japan was mainly to air transport, whereas the transport of cargoes from other East Asian countries was mainly diverted to the East Coast route. Stoppage of shipping was the main option selected for cargoes from the United States. Direct economic losses caused by the disruption were calculated at US\$7.2 billion. Based on the application of a GTAP model, overall losses, including indirect losses, were estimated to be within a range of US\$10.3 to 12.4 billion.

Any delays are disclaimed within international freight insurance agreements, including waterborne agreements. From the shipper's perspective, securing an alternative route, if feasible, constitutes an effective countermeasure against disasters. Mutual cooperation between ports/shipping companies may be another effective countermeasure.

The findings of this study confirmed that considerable economic losses result from the stagnation of a global supply chain, with ports being one of the most important components of the associated infrastructure. A major scientific contribution of this study that has not been explored in previous studies is its proposal of a method for estimating economic losses when port functions are not completely stopped, and its demonstration of this method using actual alternative routes. In the future, efforts will be made to extend this approach with the aim of developing a method for assessing differences in economic losses according to the degree of damage inflicted at a disaster-stricken port in relation to the evolving project for strengthening port resilience.

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