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Estimation of Economic Benefit of Major Chokepoint on Global Trade and Economy
Is the benefit of the Malacca Strait larger than that of the Suez/Panama Canal?

Abstract

The highly frequent, stable, and inexpensive maritime transport is the cornerstone of global trade and economy, with global shipping operations being concentrated at major straits and canals, which are called chokepoints. For example, in 2017, the total cargo value passing through the Malacca Strait was estimated at $3 trillion, accounting for 18% of world trade, an increase from 13% in 2007. Although assessment of economic benefits is crucially important for ensuring the sustainability of transport at these points, most previous studies were limited to a particular strait or ship type. Therefore, this study estimates the economic benefits of major chokepoints: the Malacca Strait, the Suez Canal, and the Panama Canal. In 2017, the annual direct economic benefits were estimated at $46 billion for the Suez Canal and $21 billion for the Malacca Strait and the Panama Canal. Although the cargo value passing through the Malacca Strait was larger than that of the Suez Canal, the shortcut distance of the Suez Canal was much longer. Additionally, the total economic values were estimated to be approximately twice as large as the direct benefits. Moreover, beneficiaries' contributions toward strengthening the navigational capacity, efficiency, safety, and disaster resilience of these chokepoints is discussed.

Keywords: *global supply chain, maritime trade, chokepoint, economic benefit.*

1. Introduction

The highly frequent, stable, and inexpensive maritime transport is the cornerstone of global trade and economy, with global shipping operations being concentrated at major straits and canals, which are called chokepoints or maritime global critical infrastructures. For example, in 2017, the total cargo value passing through the Malacca Strait was estimated as $3 trillion, accounting for 18% of world trade, an increase from 13% in 2007 (Akakura and Ono, 2019). Although the assessment of economic benefits is crucially important for ensuring the sustainability of transport at these points, most previous studies were limited to a particular strait or ship type. This study estimates the economic benefits of major chokepoints: the Malacca Strait, the Suez Canal, and the Panama Canal.

The British Admiral John Fisher is thought to be the first to use the word "chokepoint" to indicate the geopolitical importance of these points in the Royal Navy's strategy (Welchi, 2005, Daly, 2009). The word "chokepoint" originally meant a point where enemies suffer by being choked off. In military strategy, it is a geographical feature, including points on land, such as valleys and bridges, where an armed force is forced to pass through, thus reducing combat power at narrow passage. Nowadays, chokepoints refer to the intercontinental sea routes such as the Malacca, Hormuz, Gibraltar, Bab el Mandeb, Dover, and Bosporus Straits; the Suez and Panama Canals; the Cape Horn, Cape of Good Hope Routes, among others, where the navigational tracks are concentrated, as shown in Figure 1, indicated by red circles.

Figure 1 – Example of Chokepoints

Source: The Navigation Route Map is from Wu *et al* (2017)

Since the international division of labor has highly materialized in the current world economy, it can be said that trade is its keystone. The importance of chokepoints is obvious considering the economic slowdown caused by the dysfunction of such critical unit. The significance of chokepoints has further increased because of the highly advanced international division of labor and the recent development of sophisticated global supply chains. Additionally, there have been many instances of disasters or incidents in recent years, prompting the closure of chokepoints (Table 1). For instance, many ships collided with two grounded ships at the Suez Canal in July 2018, and two sailing oil tankers were attacked at the Hormuz Strait in June 2019, which increased the risk of strait blockade. However, it has not been clearly presented in terms of how important each chokepoint is, that is, how chokepoints benefit the world economy. Moreover, although the Suez and Panama Canals carried out projects to increase their capacities in recent years, some chokepoints may not be able to cover the project costs and undertake the necessary actions to secure the navigational capacity, efficiency, and safety. Furthermore, since a closure of any one of these points will possibly result in a devastating impact on world trade and economy, countermeasures are needed for preventing or reducing the impact caused by large-scale disasters. Therefore, it is very important to assess not only the profitability but also beneficiaries. This study estimates the overall economic benefits of major three chokepoints, including analysis of benefit incident areas.

Table 1 – Disaster/Incident at Chokepoint

Year	Chokepoint	Disaster/Incident	Impact on Chokepoint
1956	Suez Canal	Suez Crisis	Canal was closed for 10 months
1967	Suez Canal	Arab-Israeli War	Canal was closed for 8 years
1989	Panama Canal	Invasion of Panama	Canal was closed for 1 day
1997	Malacca Strait	Ship (Oil Tanker) Collision	Oil recovery efforts spanned 1 month
2012	Panama Canal	Heavy Rain and Flood	Canal was impassable for 17 hours
2018	Suez Canal	Multi-Ships Grounding and Collision	Canal was impassable for 2 days
2019	Hormuz Strait	Political Conflict	Attack against Tanker/Risk of Blockade

2. Literature Review

The importance of chokepoints has been recognized widely in the literature. Akimoto (2001) listed chokepoints in Southeast and Southwest Asia, and discussed the risks and detour routes of these points. Hirst (2014) emphasized the importance of the Malacca Strait for seaborne trade. The U.S. Energy Information Administration (2017) has continuously estimated the volume of oil transiting through world chokepoints. Bailey and Wellesley (2017) discussed the importance and risks of chokepoints in global food trade. Ducruet (2016) estimated the geographic coverage and canal-dependent flows of the Panama and Suez Canals.

From the economic viewpoint, Morisugi *et al* (1992) defined the economic value of chokepoints as the transport cost savings due to the availability of points, and estimated the economic value of the Malacca Strait. Additionally, Rimmer and Lee (2007), Qu and Meng (2012), and Kajitani *et al* (2013) estimated the economic impact of the Malacca Strait's closure, while Feyer (2009), Hugot and Dajud (2016) investigated the effects of the Suez Canal closure between 1967 and 1975. With respect to the Panama Canal, Maurer and Yu (2008) calculated the economic impact between 1921 and 1937, and Autoridad del Canal de Panamá (2006) and Panano *et al* (2012) estimated the economic impact of the expansion project, which was finished in 2016.

Many previous studies analyzed the impact of expansion of the Panama Canal on maritime networks (Fan, 2009, Akakura and Matsuda, 2014, Liu *et al*, 2016, Martinez *et al*, 2016, Herrera *et al*, 2017, Pham *et al*, 2018, Fan and Gu, 2019). Ungo and Sabonge (2012) assessed the competitiveness of the Panama Canal route in comparison with the intermodal route and the other all-water routes, while Notteboom (2012) analyzed the relation between the Suez Canal route and the Cape Horn route.

Furthermore, many studies analyzed the impact of new navigation routes such as the Northern Sea Route, which has recently gained a momentum for maritime trade as the Arctic sea-ice retreats due to global warming (Liu and Kronbak, 2010, Schøyen and Bråthen, 2011, Furuichi and Otsuka, 2013, Abudul Rahman *et al*, 2014, Zhang *et al*, 2016, Zhu *et al*, 2018, Shibasaki *et al*, 2018). Similarly, Somanathan *et al* (2009) and Fan *et al* (2012) analyzed the potential of the Northwest passage in northern Canada. Jeevan *et al* (2018) and Yuan *et al* (2019) investigated the feasibility of the project to construct the new Kra Canal in Thailand. Yip and Wong (2015) and Chen *et al* (2016, 2019) assessed the feasibility and economic effects of the Nicaragua Canal, for which commencement of the construction works was reported in 2016, including the technical and financial difficulties of the project.

As for the research concerning more than two chokepoints, Zheng *et al* (2019) analyzed the effect of the Panama and Suez Canals on the locations of liner hub ports. Wu *et al* (2019) calculated the changes in container shipping networks based on the disruptions of the Malacca Strait, Panama Canal, and Suez Canal. Gao and Lu (2019) estimated the impact of the blockades of nine chokepoints on transportation cost of the Chinese fleet.

As described above, although there have been many studies on the chokepoints of the maritime transportation system, most of them were limited to a particular chokepoint or ship type.

The contribution of this study to the literature is two-fold. First, this study proposes a method for estimating the economic benefits of chokepoints in terms of all maritime cargos to assess their impact on world trade and economy. Second, the estimation result of the economic benefit generated by a particular chokepoint, including benefit incident areas, enables us to discuss a beneficiary’s contribution toward maintaining and improving the navigational capacity, efficiency, safety, and the disaster resiliency of the chokepoint.

The remainder of this paper is structured as follows. Section 3 estimates the direct economic benefit, describes the methodology and data, and provides calculation examples. The overall benefit, including the ripple effects, is presented in Section 4. Section 5 discusses and identifies the stakeholders of the chokepoints that are requested jointly to participate in the cost/burden sharing scheme to operate and manage the chokepoint traffic in a sound manner. Section 6 summarizes the conclusions.

3. Direct Benefit

3.1. Estimation Flow

This study estimates the economic benefit generated by major maritime global critical infrastructures: the Malacca Strait, the Suez Canal, and the Panama Canal. The direct economic benefit is defined as the transport and inventory cost savings due to the availability of the chokepoint. Figure 2 shows the estimation flow for each chokepoint and each sector, with sectors indicating the ship type and corresponding cargo commodities. First, a shortcut distance table is created, considering the ship size constraint of the chokepoints. Then, the waterborne transportation cost savings between regions are calculated based on ship travel distance reductions, ship navigation speeds, operation costs, and the numbers of ship sailing. In addition, savings in the inventory carrying costs are calculated using the trade values and ship travel day reductions between regions. The total direct benefits are the sum of the savings in waterborne transportation costs and inventory costs.

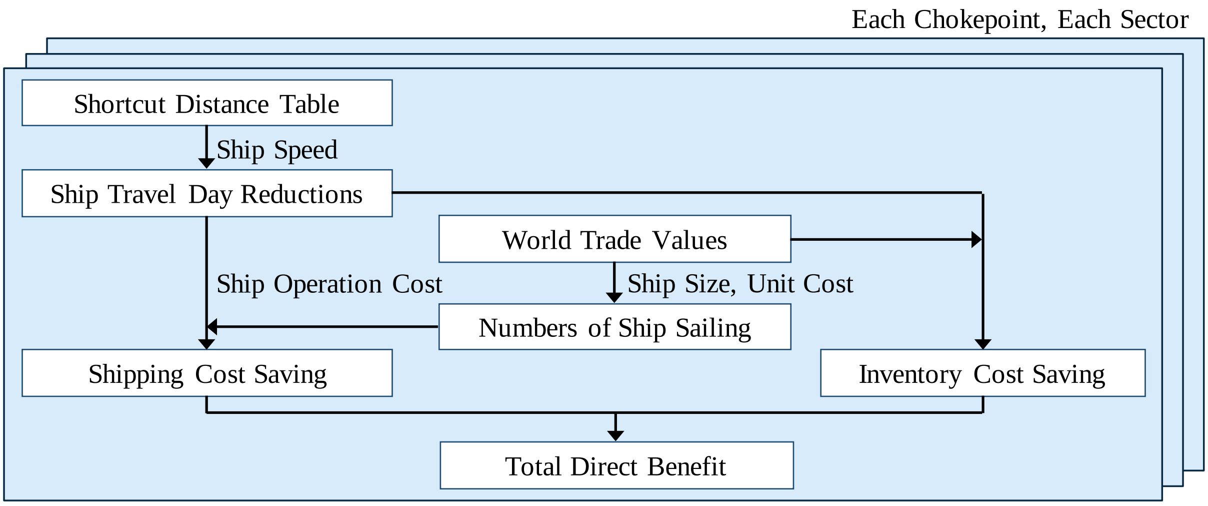


Figure 2 – Estimation Flow

3.2. Regional Division and Representing Ports

The shortcut distance table shows the ship travel distance reductions between areas/countries. In this study, the world was divided into 14 regions (i.e., 10 areas and 4 countries, which were located at three target chokepoints), as shown in Figure 3. The ship travel distances between the representing ports of these regions were calculated based on the Voyage Planner of Maritime Traffic (2019). We chose only one representing port for each region. However, two representing ports were selected for North America, South America, Panama, and Egypt as shown in Table 2, since we needed to identify whether ships pass through the Panama and Suez Canals. Regarding the Panama Canal, the ports of Colon and Balboa can be used alternatively for containers and general cargoes because of the existence of a railway connecting the Pacific and Atlantic sides of Panama.

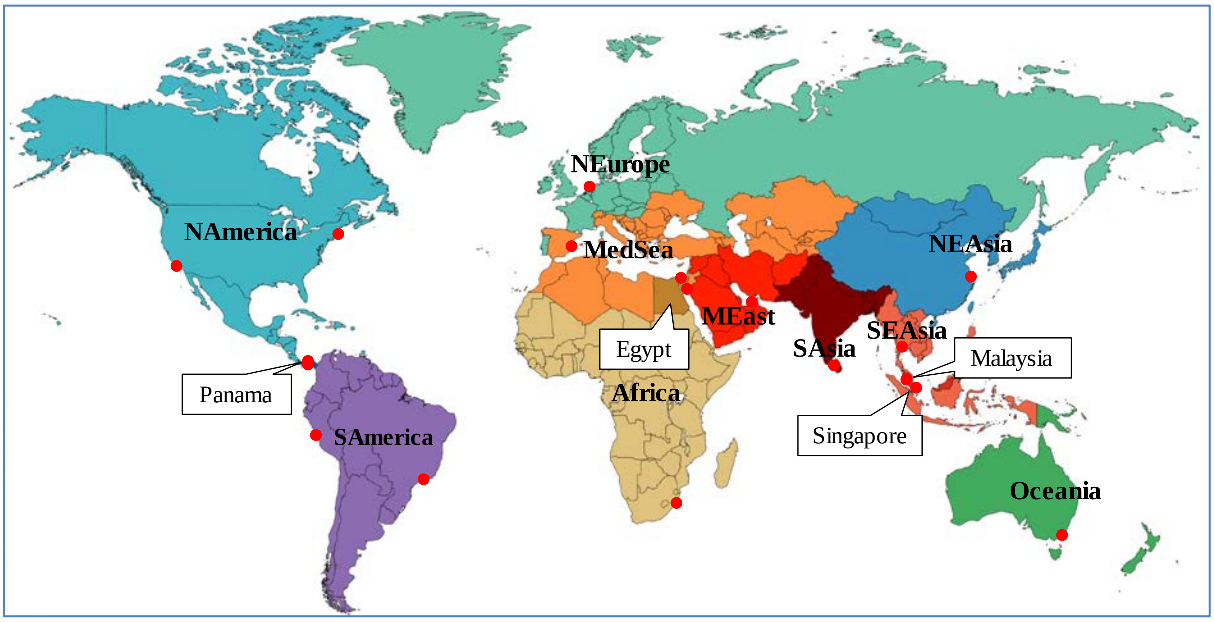


Figure 3 – The Regions

Source: Made by mapchart.net (https://mapchart.net/world.html)

Table 2 – Representing Ports

Region	Reperesent Port
NAmerica	Los Angeles
	New York
Panama	Colon
	Balboa
SAmerica	Callao
	Santos
NEurope	Rotterdam
MedSea	Valencia
Egypt	Port Said
	Suez
Africa	Durban

Region	Reperesent Port
NE Asia	Shanghai
SE Asia	Laem Chabang
Singapore	Singapore
Malaysia	Port Klang
SAsia	Colombo
MEast	Dubai
Oceania	Melbourne

3.3. Shortcut Distance

The shortcut distances are the differences in distance between routes via chokepoints and detour routes. All ships are assumed to navigate the shortest route. Figure 4 and Table 3 shows the possible routes and their distances between Shanghai (Northeast Asian port) and Rotterdam (North European port). These routes were set according to the ship sizes. Under Suezmax, the standard route is the blue line (10,600 miles) via the Malacca Strait and the Suez Canal. When the Malacca Strait is impassable, the detour route is passing through the Lombok strait (11,813 miles): route [1] and [3]. The Sunda Strait can be another detour route; however, it contains many navigational hazards including strong tidal flows, sandbank formations along the waterway, a live volcano, poor visibility during squalls; and the existence of numerous oil drilling platforms and small islands and reefs that may disrupt safe navigation (Mohd Rusli, 2012). If the Suez Canal is not a viable option (e.g., very large crude carriers (VLCCs), and very large ore carriers (VLOCs) cannot pass through the Suez Canal), the navigation route is via the Cape of Good Hope (13,602 miles): route [4] and [5]. When the Malacca Strait is impassable, the detour route distance is 14,529 miles.

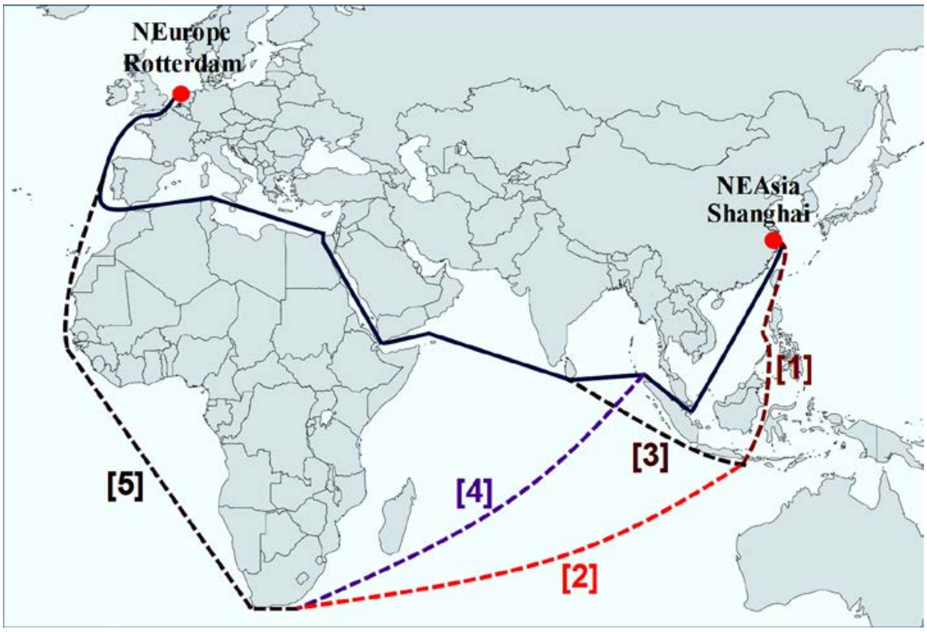


Figure 4 – Examples of Ship Travel Routes

Source: The map is from mapchart.net (https://mapchart.net/world.html)

Table 3 – Examples of Ship Travel Distances

Ship Size	State	Route	Distance (nm)	Difference (nm)
Under Suezmax (~200,000DWT)	Actual	Standard	10,600	–
	Malacca Impassable	[1], [3]	11,813	+1,213
	Suez Impassable	[4], [5]	13,602	+3,002
VLCC, VLOC	Actual	[4], [5]	13,602	–
	Malacca Impassable	[1], [2], [5]	14,529	+927
	Suez Impassable	[4], [5]	13,602	±0

Source: Calculated by Voyage Planner of Maritime Traffic (2019)

3.4. Data

The basic data for estimating direct economic benefits were the trade values between regions. The numbers of ship sailings were calculated based on the trade values considering the ship sizes and unit costs, as shown in Figure 2. The data source was the Global Trade Analysis Project (GTAP) Database Ver.9, with the data year being 2011. Its trade data were obtained from the United Nations International Trade Statistics Database (UN COMTRADE) and were selected to be consistent based on the statistical reliability of reporting countries (Gehlhar, 1996). The trade values were divided into categories according to the ship type to analyze the transport cost savings. Table 4 shows the sectors and their trade values. All GTAP sectors were categorized according to the ship type except for the service trade.

3.5. The Estimation Method

First, the transport cost savings were estimated based on the trade values. The sea trade volume (weight) of *i* sector from *r* region to *s* region (V_{rs}^i) is expressed as follows:

$$V_{rs}^i = \frac{T_{rs}^i}{\alpha^i}\beta^i \tag{1}$$

where T_{rs}^i is the trade value of *i* sector from *r* region to *s* region, α^i is the unit cost of cargos of *i* sector, and β^i is the rate of sea transport among all transport modes of cargo for *i* sector, as shown in Table 5. To estimate the maritime trade volume, the unit costs corresponding to all transport modes were used to convert from value to volume first, then the volume of maritime cargoes were calculated using the weight/twenty-foot equivalent unit (TEU) base. The figures in Table 5 were calculated based on the data of USA Trade Online and (Port Import/Export Reporting Service) PIERS by mapping the 6-digit (Harmonized System) HS codes to GTAP sectors (Angel, 2016). The rate of maritime cargo to the whole inter-regional trade was assumed to be constant for each sector regardless of the export/import region.

Table 4 – Sectors and Their Trade Values

Sector	GTAP Ver.9 Code	Ship Type	Trade Value (bn$)	
1Container	4, 7, 8, 10, 12, 14, 19, 20, 22, 23, 25~31, 34, 36, 37, 39~42	Container Ship	8,467	52.8%
2Grain	2, 3, 5	Bulk Carrier	169	1.1%
3Coal	15	Bulk Carrier	129	0.8%
4Ore	18	Ore Carrier	360	2.2%
5CrudeOil	16	Oil Tanker	1,505	9.4%
6OilProd	32, 33	Product Tanker	3,179	19.8%
7Gas	17	Gas Carrier	268	1.7%
8Car	38	Vehicle Carrier	1,276	8.0%
9GeneralC	1, 9, 13, 21, 24, 35	General Cargo Ship	675	4.2%
10Services	43~57	-	-	-

Source: Trade Value (2011) is from the GTAP Database Ver.9

Table 5 – Unit Costs and the Rates of Sea Transport for Sectors

Sector	Unit Cost	Rate of Sea
1Container	29,195 $/TEU	97.59%
2Grain	280 $/MT	99.99%
3Coal	116 $/MT	100.00%
4Ore	146 $/MT	99.97%
5CrudeOil	359 $/MT	100.00%

Sector	Unit Cost	Rate of Sea
6OilProd	1,222 $/MT	99.71%
7Gas	242 $/MT	100.00%
8Car	11,068 $/MT	98.44%
9GeneralC	645 $/MT	99.82%

*Rates of Sea were based on MT (Metric Ton)

Source: Calculated based on the data of USA Trade Online and PIERS

The number of ship sailings for *i* sector from *r* region to *s* region (N_{rs}^{i}) is described as follows:

$$N_{rs}^{i} = \frac{V_{rs}^{i}}{C_{rs}^{i} L^{i}} \tag{2}$$

where C_{rs}^{i} is the cargo carrying capacity of the ships of *i* sector from *r* region to *s* region. Table 6 shows examples of a container ship. Regarding the other ship types, the cargo carrying capacities were assumed to be 90% of deadweight tonnage (the U.S. Energy Information Administration, 2017). L^{i} is the load factor of the ships of *i* sector, with 60% for the container ships and vehicle carriers based on the data of Drewry (2019) and Panama Canal Authority (2019) and 100% for the other ship types. The Transport cost savings (SC_{rs}^{i}) estimated as follows:

$$SC_{rs}^{i} = \frac{\Delta D_{rs}}{Ss^{i}} So^{i} \tag{3}$$

where ΔD_{rs} is the shortcut distance between *r* region and *s* region, Ss^{i} is the speed of ships of *i* sector, and So^i is the operating cost of the ships of *i* sector. Table 7 shows examples of Ss^i and So^i. The operating cost of a ship is derived from the cost benefit analysis manual for port projects (Ports and Harbours Bureau, 2017), and includes costs for shipbuilding, bunker fuel, manning, repair, managing, and so on.

Table 6 – Examples of Ship Size by region (Container Ship, TEU)

O D	1NEA	2SEA	3Sin	4Mal	5SA	6ME	7Oce	8NE	9Med	10Egy	11Af	12NA	13Pan	14SA
1 NEAsia	-	2,000	2,000	2,000	6,000	6,000	4,000	14,000	14,000	14,000	4,000	8,000	8,000	8,000
2 SEAsia	2,000	-	2,000	2,000	6,000	6,000	4,000	14,000	14,000	14,000	4,000	8,000	8,000	8,000
3 Singapore	2,000	2,000	-	2,000	6,000	6,000	4,000	14,000	14,000	14,000	4,000	8,000	8,000	8,000
4 Malaysia	2,000	2,000	2,000	-	6,000	6,000	4,000	14,000	14,000	14,000	4,000	8,000	8,000	8,000
5 SAsia	6,000	6,000	6,000	6,000	-	2,000	1,000	6,000	6,000	2,000	2,000	8,000	8,000	4,000
6 MEast	6,000	6,000	6,000	6,000	2,000	-	1,000	6,000	6,000	2,000	2,000	8,000	8,000	4,000
7 Oceania	4,000	4,000	4,000	4,000	1,000	1,000	-	4,000	4,000	1,000	1,000	4,000	4,000	1,000
8 NEurope	14,000	14,000	14,000	14,000	6,000	6,000	4,000	-	2,000	2,000	6,000	4,000	4,000	6,000
9 MedSea	14,000	14,000	14,000	14,000	6,000	6,000	4,000	2,000	-	500	6,000	4,000	4,000	6,000
10 Egypt	14,000	14,000	14,000	14,000	2,000	2,000	1,000	2,000	500	-	2,000	4,000	4,000	6,000
11 Africa	4,000	4,000	4,000	4,000	2,000	2,000	1,000	6,000	6,000	2,000	-	2,000	2,000	4,000
12 NAmerica	8,000	8,000	8,000	8,000	8,000	8,000	4,000	4,000	4,000	4,000	2,000	-	2,000	4,000
13 Panama	8,000	8,000	8,000	8,000	8,000	8,000	4,000	4,000	4,000	4,000	2,000	2,000	-	2,000
14 SAmerica	8,000	8,000	8,000	8,000	4,000	4,000	1,000	6,000	6,000	6,000	4,000	4,000	2,000	-

Source: Calculated based on the Data from Containership Databank of the MSD Transmodal

Table 7 – Ship Speeds and Operating Costs

TEU Capa.	Speed (kt)	Operating Cost (d/$)
500	11.4	23,313
1,000	13.0	37,014
2,000	14.6	59,321
4,000	16.2	101,572
6,000	17.2	141,489

TEU Capa.	Speed (kt)	Operating Cost (d/$)
8,000	17.9	181,046
10,000	17.9	216,630
12,000	17.9	252,428
14,000	17.9	289,223

Source: The Cost Benefit Analysis Manual for Port Projects (Ports and Harbours Bureau, 2017)

Second, the inventory savings were estimated based on the capital cost. Since the holding inventories induce a carrying cost, such as the storage cost, insurance, etc., Richardson (1995) estimated the rate of annual inventory carrying cost to the inventory value as shown in the "Min./Max." column of Table 8. However, estimating the rate is difficult, since it may vary cargo to cargo. In this study, the average values of the limited contents were applied to estimate the savings of the inventory carrying costs due to the availability of the chokepoint, as shown in Table 8. Since long-term storages are usual for coal, ore, and crude oil, obsolescence was excluded. The inventory cost savings (SI^i_{rs}) are calculated as follows:

$$SI_{rs}^{i} = \frac{\Delta D_{rs}}{Ss^{i}} \gamma^{i} \qquad (4)$$

where γ^{i} is the inventory carrying cost rate of *i* sector to the inventory value.

Finally, the total direct benefit (DB) was calculated as follows:

$$DB = \sum_{i} \sum_{r} \sum_{s} \left(SC_{rs}^{i} + SI_{rs}^{i} \right) \qquad (5)$$

Table 8 – Rate of Annual Inventory Carrying Cost to the Inventory Value

Description	Min./Max.	Coal, Ore, Crude Oil	The Others
Cost of money	6% ~ 12%	✓	✓
Taxes	2% ~ 6%	✓	✓
Insurance	1% ~ 3%	✓	✓
Warehouse expense	2% ~ 5%		
Physical handling costs	2% ~ 5%		
Clerical & inventory control	3% ~ 6%		
Obsolescence	6% ~ 12%		✓
Deterioration & pilferage	3% ~ 6%		
Total	25% ~ 55%	15%	24%

Source: The “Min./Max.” rates are obtained from Richardson (1995)

3.6. The Estimation Results

The annual direct benefits were estimated at $46 billion for the Suez Canal, $21 billion for the Malacca Strait and the Panama Canal in 2017, as illustrated in Figure 5. The cargo values passing through the Malacca Strait were larger than those of the Suez Canal; however, the ship travel distance reductions using the Suez Canal were much longer. Morisugi *et al* (1992) considering the shipping cost savings only, estimated figures of $4 billion/year from 1966 to 1985, and anticipated a figure of $13 billion/year for the next 20 years. Qu and Meng (2012) estimated the impact of blockade of the Malacca Strait, showing that the losses of shipping would be two to five times larger than that of inventory depending on the blockade duration. Nevertheless, it is difficult to compare the results of this study with other previous studies, since the estimation methods and time points are different. Figure 6, shows the share of benefits by the ship type, with the shares of containers being larger than those of bulk and tanker cargos in all chokepoints, especially in the Panama Canal.

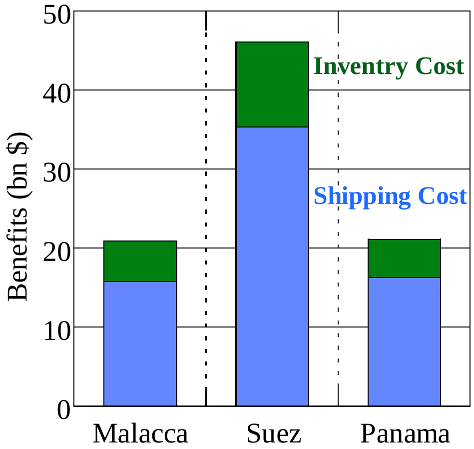


Figure 5 – Direct Benefits

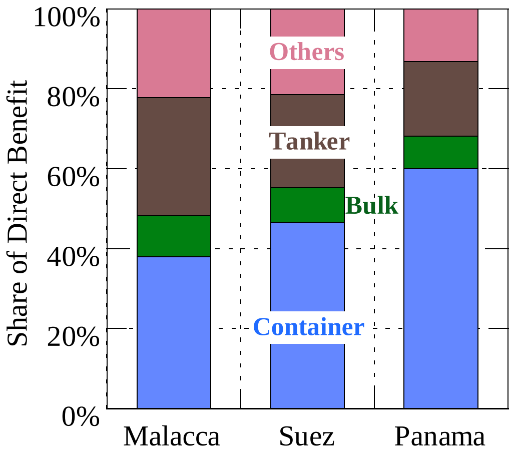


Figure 6 – Share by Ship Type

4. Overall Benefit

4.1. Estimation Method

The direct economic benefit, estimated in the previous section, induce a ripple effect, which generates new demand, and consequently, boost the economy. This overall economic benefit was evaluated by employing the GTAP model. The GTAP model and Database was constructed by the Purdue University using a global network of researchers and policy makers. This model is one of the representative models of Spatial Computable General Equilibrium (SCGE) and is widely used to evaluate the economic impact of international trade policies such as the change of import tariffs. In this model, an optimizing behavior of economic agents are assumed: utility maximization for households and profit maximization for producers. The production function of producers in the GTAP model is shown in Figure 7. The intermediate input comprises a double layered structure, and the elasticities of substitution for the intermediate input were set at the domestic and international levels. One transport sector is set in the whole world, provides transport services, and receives an amount of money that subtracts import tariff from the difference between import cost, insurance, and freight (CIF) prices and export free on board (FOB) prices of each sector.

In the estimation, it was assumed that each chokepoint could not be passed through, and all direct economic benefits were reflected by the tariff rates. Regarding the transport costs, the income of transport sector was reduced directly by adding import tariffs (AT_{rs}^{i}), as shown in equation (6)

$$AT_{rs}^{i} = \frac{SC_{rs}^{i}}{T_{rs}^{i}} \tag{6}$$

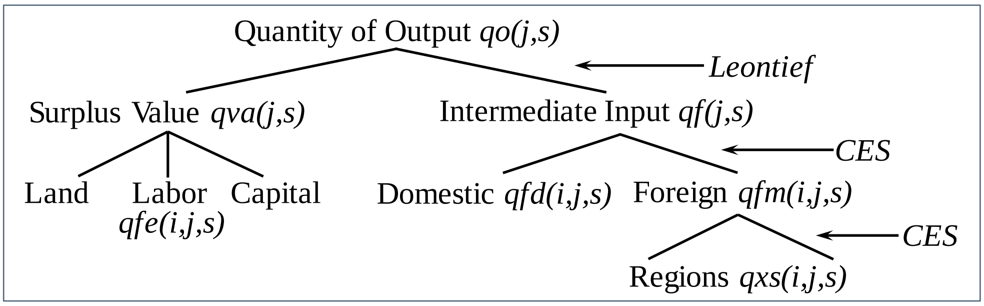


Figure 7 – Production Function of the GTAP Model

Source: Hertel and Tsigas (1997)

Although the inventory costs are not imposed on the transport sector directly, additional travel days are the trade barrier for cargo owners. Minor (2013) calculated the ad valorem trade time costs for GTAP. The increase in the inventory cost with respect to the converted additional tariffs (AI_{rs}^{i}) was calculated as follows:

$$AI_{rs}^{i} = \frac{\Delta D_{rs}}{Ss^{i}}\delta^{i} \tag{7}$$

where δ^{i} is the conversion factor of the ad valorem trade time cost of *i* sector as shown in Table 9. The sum of AT_{rs}^{i} and AI_{rs}^{i} were used as input into the GTAP model to estimate the impact on each sector.

Table 9 – The Ad Valorem Trade Time Cost (% points per day)

Sector	Conversion Factor
1Container	0.77
2Grain	0.17
3Coal	0.00
4Ore	0.45
5CrudeOil	0.00

Sector	Conversion Factor
6OilProd	1.44
7Gas	0.00
8Car	1.65
9GeneralC	1.01

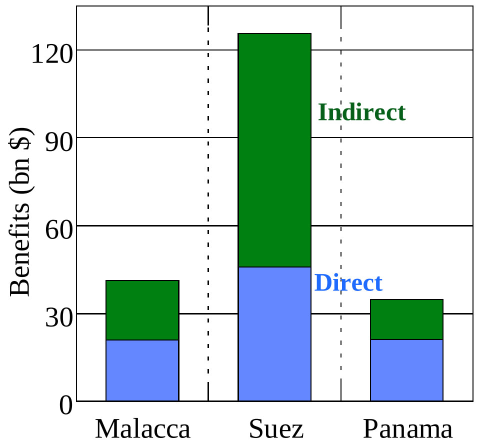
Source: Calculated based on the data in Minor (2013)

Although there is a discussion that additional tariff rates in the SCGE model leads to an increase in government revenues, the proportion of tariff revenues to government revenues were only 1.8% in the United States and Japan (Ministry of Finance (Japan), 2017).

4.2. The Estimation Results

In 2017, the annual overall benefits were estimated at \$126, \$41, \$35 billion for the Suez Canal, the Malacca Strait, and the Panama Canal, respectively, as illustrated in Figure 8. The overall benefits were equivalent to approximately 1.7 to 2.7 times of direct benefits. Using the original SCGE model, Kajitani *et al* (2013) estimated the impact of the Malacca Strait's closure as \$15 billion in 2004. Figure 9 shows the change rate of gross domestic product (GDP) of each region.

The change rates greatly differed among regions. For the Malacca Strait, the economic benefits for Southeast Asia was the largest; for the Suez Canal, benefits for South Asia and the Middle East was the largest; while for the Panama Canal, benefits for South America was the largest. Additionally, there were some regions with negative economic benefits, as the chokepoints have a negative impact on these economies. Since chokepoints boost the economies of neighboring regions, distant regions might slightly decline.



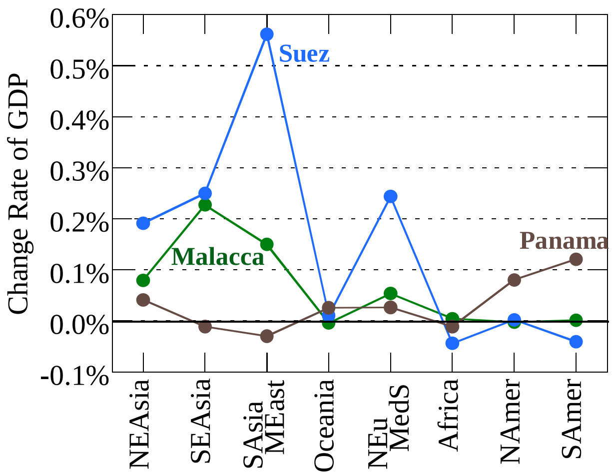


Figure 8 – Estimate Result of Overall Benefit **Figure 9 – Change Rate of Real GDP**

5. Discussion

5.1. The possible economic impact of chokepoint closing

The large benefits brought by the chokepoints indicate that a closure of any one of these points will possibly result in a devastating impact on global trade and economy. Some previous studies estimated the economic impact of the closure of the Malacca Strait (Rimmer and Lee, 2007, Qu and Meng, 2012, Kajitani *et al*, 2013). The basic concepts of these estimations were the same as those used in this study: detour routes induce additional cost. However, there are many differences between the route choice at ordinary time and the sudden route change.

First, at the outbreak of a chokepoint closure, many ships will be forced to wait at the entrance of the closed chokepoint as assumed by Qu and Meng (2012). This situation may cause serious troubles for the Suez and Panama Canals in particular, as their detour routes are very long. Therefore, the arriving days of these waiting ships to their destinations are far beyond estimation. Second, air transportation will be largely utilized to complement the cargos that will not arrive. During the U.S. West Coast ports disruption in 2014/15, considerable amounts of automotive and machinery parts, fresh foods, and other time-sensitive products were carried by many aircrafts (Akakura *et al*, 2018). Third, the function of container hub ports, located at the entrance of the chokepoints, will be seriously affected, resulting in, lowered traffic services and business opportunities in the ports of Singapore, Tanjung Pelepas, and Klang along the Malacca Strait; the port of Port Said of the Suez Canal; and the ports of Balboa, Colon, and Manzanillo of the Panama Canal. Once the traffic through a chokepoint is stopped, the containers that are scheduled to load to waiting ships at the other side of the closed chokepoint will be piled up at the ports in the entrance of the chokepoint. Simultaneously, many ships will be forced to wait at these ports to load the containers that have not arrived. After the elapse of a certain period, many ships may navigate around the chokepoint and cancel their calling to the ports. Kajitani *et al* (2013) estimated a negative impact of $4.7 billion on the global economy by one-year closing of Singapore Port resulted by the Malacca Strait navigation closure. Fourth, traffic congestion at another chokepoint located on the detour route could occur. An example may be congestion at the Panama Canal in the case of a Suez Canal blockade. Thus, some ships may be forced to use other longer detour routes.

Based on the results of this study and considering the aforementioned points, we can assess the economic impact of the closure of the maritime global critical infrastructures. An expected result is that the economic impact of a sudden closure will be larger than the economic benefits of the chokepoints estimated in this study because of the additional costs induced by the aforementioned issues. However, the degree of this negative impact will rely on the risk treatment measures to be undertaken mainly by the littoral states. Therefore, burden sharing schemes and risk management strategies should be formulated to minimize the impact of chokepoint closures in the case of natural and man-made disasters, including serious maritime accidents.

5.2. Management of Chokepoints

Notably, the maritime global critical infrastructures have brought enormous benefits to the world trade and economy, thus indicating importance of maintaining and further developing ship navigation safety in chokepoints in a sustainable manner. Additionally, since the growing global economy will increase its dependence on navigation through these chokepoints, the capacities of these navigation channels have to be expanded to accommodate the increasing traffic volumes and vessel sizes.

The Suez and Panama Canals are directly operated and managed by canal authorities, while the Malacca Strait is mainly controlled and maintained by the littoral countries under the Co-operative Mechanism. This fact can be seen in the differences in the driving forces for undertaking necessary actions to ensure the navigational capacity, efficiency, and safety. The Suez Canal was expanded in 2015 to increase the canal capacity by expanding the two-way track section, and also to allow the passage of larger ships: increasing the navigable container ships in size from around 18,000 to 24,000 TEU. The third set of locks project of the Panama

Canal from 2007 to 2016 provided additional larger traffic lanes and allowed for a larger number of ships to pass through the canal, while simultaneously increasing the maximum size of the ships that could pass through the Canal; for example, the container ship size increased from 5,000 to up to 14,000 TEU.

VLCCs can only pass through the Malacca Strait at high tide because of the International Maritime Organization (IMO) recommendation that VLCCs shall always maintain an under-keel clearance of at least 3.5 meter during the entire passage through the strait. This is because the water depth is about 23 meter in a few shallow sections of the strait, while the average of maximum drafts of 300,000-ton class tankers exceeds 21 meters. IMO conducted a real-time basis monitoring study in terms of the under-keel clearance from 2013 to 2016. Then, the reliable tidal and wind monitoring systems including the automatic identification system (AIS) data transmission capability were installed at six locations by Singapore and Malaysia. In addition, the joint hydrographic survey of the strait for updating navigational charts with the nautical information to improve navigational safety was initiated by the littoral countries in 2017, under the support of the Malacca Strait Council of Japan. However, no physical improvement projects were carried out to allow larger ships to pass through the strait, such as those completed in the Suez and Panama Canals in recent years. There is a possibility that a channel navigation management system, such as slot allocation and compulsory pilotage, will be urgently needed to secure the navigational safety, as the number of VLCCs passing through the Malacca Strait increases continuously. In this situation, it may be an option to increase the beneficiaries' contributions, although many user countries already participate in the present Co-operative Mechanism. Figure 10 shows the estimated results of GDP increase and equivalent variation (EV) for each region based on the impact of the Malacca Strait. The EVs of Northeast Asian countries (e.g., China, Japan, Taiwan, and South Korea) were much larger than those of Southeast Asian ones, including three littoral countries (i.e., Singapore, Malaysia, and Indonesia). Moreover, the EVs of regions such as South Asia, the Middle East, North Europe, and the Mediterranean Sea were also fairly large.

For reference, Turkish government collects the transit fees from vessels passing through the Bosporus Strait, which is one of the chokepoints in Figure 1, linking the Mediterranean Sea and the Black Sea, to maintain and manage the navigational conditions of the strait. Although there is no lock and slot reservation system in the Bosporus Strait, the fees are gathered through the ships' agents. Interestingly, there is a discussion regarding raising the fees for constructing a new alternative route, “Istanbul Canal” (AP, 2011).

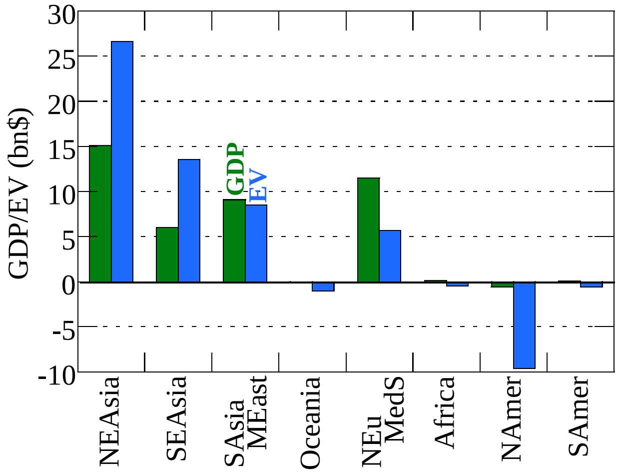


Figure 10 – Estimate Result of GDP Increase and EV of the Malacca Strait

6. Conclusion

This study estimates the economic benefits of major chokepoints: the Malacca Strait, the Suez Canal, and the Panama Canal. The direct economic benefit is defined as the transport and inventory cost savings due to the availability of chokepoint navigation. First, a shortcut distance table was created for each chokepoint and each sector, with sectors indicating the ship type and corresponding cargo commodities, considering the ship size constraints of the Suez and Panama Canals. Then, the waterborne transportation cost savings between regions were calculated based on the ship travel distance reductions, navigation speeds, operation costs, and number of ship sailings. In addition, the inventory carrying cost savings were calculated based on the trade values and ship travel day reductions between regions, with the total of direct benefits being the sum of the savings in waterborne transportation costs and inventory costs. In addition, the overall economic benefit, including the ripple effect, was evaluated employing the GTAP model.

The annual direct benefits were estimated at $46 billion for the Suez Canal and $21 billion for the Malacca Strait and the Panama Canal in 2017. The transportation cost savings were larger than the inventory cost savings, and the shares of containers were larger than those of bulk and tanker cargos in all chokepoints, especially in the Panama Canal. Additionally, the overall economic benefits were estimated at 1.7 to 2.7 times of the direct benefits. The change rates of regional GDPs greatly differed among regions; for example, the rate of Southeast Asia was the largest for the Malacca Strait.

The contribution of this study to the maritime economic literature is as follows. First, this study proposes a method for estimating the economic benefits of chokepoints in terms of all maritime cargos, and enables us to assess their impact on world trade and economy. Second, the estimated economic benefits imputed to the respective regions were used to discuss beneficiaries' contribution toward maintaining and further improving the navigational capacity, efficiency, safety, and disaster resilience of these chokepoints.

As mentioned in section 5, the impact caused by chokepoint blockade on the global economy was not fully addressed in this study. The authors would like to tackle this issue in a future work, and assess and research its negative impact as well as the countermeasures; this is because the impact of a blockade may be much larger than the estimated benefit. This study calculated the benefit based on the operating cost of the ship, which involves high volatility in the costs of shipbuilding, bunker oil, and so on. Although the relative position between each chokepoint does not change, sensitivity analysis may be required further to assess the effect of this cost volatility.

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