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Master’s Thesis

The Impact of Exogenous Shocks on Hub Ports’ International Competition - The Great Hanshin Earthquake as a Case Study-

(ハブ港湾間の国際競争に外生的ショックが与える影響
－ 阪神淡路大震災を事例にして－)

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The Impact of Exogenous Shocks on Hub Ports' International Competition

— The Great Hanshin Earthquake as a Case Study —

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1 Introduction

Since the early 1970s international logistics have been containerized and ship size has become substantially larger. Along with that, ports all over the world are now divided into hub ports and others, and ports of call are reorganized: large vessels between hub ports and feeder ships between hub ports and other ports (Lee & Flynn, 2011). Consider the route from Hokkaido to Kuala Lumpur, for example. Goods may be transported in the following way: from Hokkaido to Kobe by a feeder ship, from Kobe to Singapore by a huge ship, and finally from Singapore to Kuala-Lumpur by feeder ship. This way of transporting is called hub-spoke system. As cargoes became containerized and ships became larger and larger, the efficiency of the hub-spoke transportation system became higher than that of the direct one. This trend gave rise to some huge ports in one region, such as Busan and Kobe in East Asia and Singapore in South-East Asia.

Table 1 shows the transition of the world's top 12 ports' handling volume. It provides the following facts: Fact1) Top ports are not necessarily located in countries with large hinterlands as Singapore and Hong Kong are ranked among the top 12 ports on the table. Fact2) Until the 1980s, Kobe was one of the largest ports in East Asia. Fact3) In the 1990s, Kobe and Busan competed severely in East Asia. Fact4) While Kobe ranked out of the list, Busan has maintained its position since 1994. Fact 1 shows that large ports do not necessarily have hinterland with large consumption or production power, and they deal with a large amount of transship cargo. Facts 2 to 4 show that after the Great Hanshin Earthquake, which occurred in 1995, Kobe lost international competitiveness continuously.

I can consider some intuitive reasons why this difference between the two ports has occurred. The most immediate explanation I may think of is the low economic growth in Japan. From the 1990s to today, the Japanese economy has been sluggish, and thus the demand for cargo has not improved steadily, which may have contributed to the lack of recovery of Kobe.

However, not only the sum of cargo volume but also the transship cargo volume has been declining (Figure 1). The volume of transship cargo is not solely reflective of the economic condition and amount of consumption and production in the host country of the port. Otherwise, ports such as Singapore would not be so large. Fact 1 supports this inference. Moreover, as the economic growth theory predicts, after a disaster or war, economic growth is accelerated to a steady state (Solow, 1956). While the theory applies to the level of countries in general, I can assume a similar effect of disasters at more micro level, such as this one. In summary, contrary to the prediction of growth theory and inference from Facts 1 to 4, Busan has improved, and Kobe failed to catch up on the other hand. Therefore, this phenomenon seems to be a puzzle. Given this background, my research question in this thesis is why Kobe has not seen a recovery since the Great Hanshin Earthquake even though Kobe and Busan competed in the early 1990s and Busan is still growing. The question is important as the findings directly relate to policies to support recovery of ports after disasters and can be generalized to other settings in other countries.

Several potential reasons answer the above question. First one is as follows. In the 1990s, since ships became larger and larger, deep-water ports became more favored internationally. However, investment in the Port of Kobe was delayed while the Port of Busan expanded the

Table 1: World's Top 12 ports (million TEU)

	1985		1994		2003		2007	
	Port	Handling Volume	Port	Handling Volume	Port	Handling Volume	Port	Handling Volume
1	Rotterdam	2.65	Hong Kong	11.27	Hong Kong	20.10	Singapore	27.90
2	NY/NJ	2.40	Singapore	10.60	Singapore	18.10	Shanghai	26.15
3	Hong Kong	2.29	Kaohsiung	5.20	Shanghai	11.28	Hong Kong	23.88
4	Kaohsiung	1.90	Rotterdam	4.48	Shenzhen	10.61	Shenzhen	21.10
5	**Kobe**	1.85	**Busan**	3.70	**Busan**	10.37	**Busan**	13.27
6	Singapore	1.70	**Kobe**	2.70	Kaohsiung	8.84	Rotterdam	10.79
7	Long Beach	1.44	Hamburg	2.70	Los Angeles	7.18	Dubai	10.65
8	Antwerp	1.35	Los Angeles	2.58	Rotterdam	7.10	Kaohsiung	10.26
9	Yokohama	1.32	Long Beach	2.55	Hamburg	6.14	Hamburg	9.90
10	Hamburg	1.16	Yokohama	2.39	Antwerp	5.45	Qingdao	9.46
11	Keelung	1.16	Antwerp	2.25	Dubai	5.15	Ningbo-Zhoushan	9.36
12	**Busan**	1.15	NY/NJ	2.17	Port Klang	4.80	Guangzhou	9.20

Source: Tsumori (2009)

Note: Original source is Containerization International each year.

scale and deepened the depth of the harbor. These contrastive policies have yielded a difference in international competitiveness. Second reason is that the Japanese government took a policy of strengthening the geographical diversification of ports to make the country more resilient to disasters. Therefore, the relative position of the Port of Kobe has declined. Here, both reasons suggest that the root cause of Kobe's loss is due to low investment.

However, my concern is that these reasons partly neglect how investment decisions are made. As the amount of investment is determined endogenously taking into account the demand from shipping companies and competition with other ports, it is possible that the current capital stock in Port of Kobe is in fact optimal. It is important to understand the mechanism of these decisions. One factor that seems crucial but has been overlooked in the existing studies is the switching costs for shipping companies to change ports. Therefore, my hypothesis focuses on that point, that is, after an exogenous great shock causes temporal port change by shipping companies, due to the switching costs incurred to them, it becomes difficult to come back to the original port again. Considering this decision-making by shipping companies, two ports determine investment levels and prices. Hence, Kobe was not able to catch up with Busan as a result of optimal investment and pricing by these ports.

Though switching costs are not observable, I justify them for the following reasons: Firstly, most container cargoes are shipped by liners, regularly scheduled ships, not by trampers, irregular ships which meet shippers' demand. Liners have a fixed timetable and ports of call. Thus, a smooth change of port of call is difficult. Secondly, the shipping company may have a long-term contract with ports and shippers. Thirdly, many shipping companies operate terminals in ports, so it is costly for them to switch back once they build new ones at the new ports.

To examine the ports' behavior, I first construct an economic model of port competition based on game theory and calibrate parameters. In the model, I introduce marginal cost which depends on capital stock and switching costs mentioned above, both of which are crucial to conclude my research. Based on this model, I analyze counterfactuals to examine the effects of potential policy interventions.

The remainder of the thesis proceeds as follows. Section 2 gives the literature review, Section

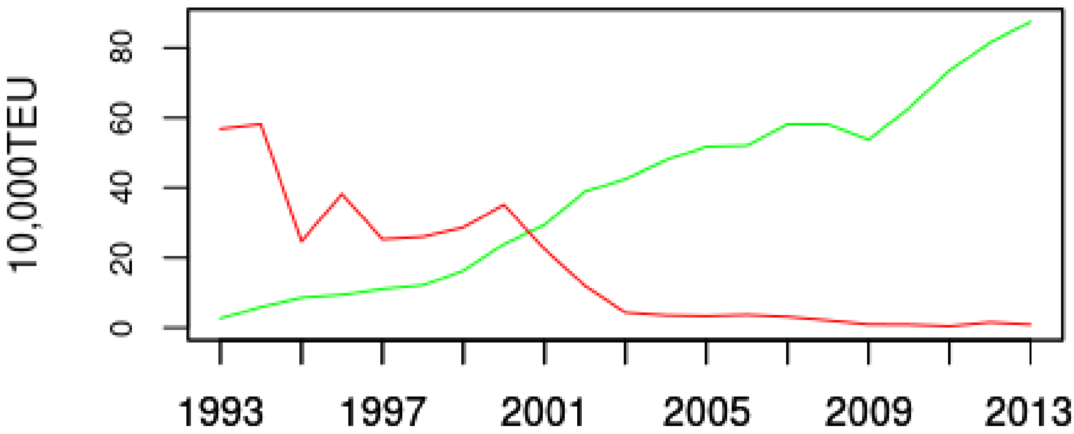


Figure 1: Transship Cargo Volume of Kobe and Busan from 1993 to 2013
Source: ICSEAD (2014) and City of Kobe (2020)
Note: Red line indicates Kobe and green line indicates Busan.

3 explains the structure of the model, Section 4 exhibits results, Section 5 indicates the case study of Port of Kobe and Busan, and Section 6 concludes the paper.

2 Literature Review

In this section, I would like to introduce papers based on two perspectives, the game theoretical modeling about the port competition and shipping companies' port selection, which is related to the main part of this paper, and recovery from disaster.

I explain the literature on the game theoretical analysis at first. Anderson et al. (2008) propose an investment game between two ports. They estimate the payoff from data and conduct scenario analysis by applying the framework to the competition between Shanghai and Busan. They conclude that the amount of both ports' revenue is small while much effort has been invested in capturing and defending the transshipment market share in contrast to the large number of studies justifying additional investment.

Ishii et al. (2013) also investigate the port competition using a game theoretical model. They model the port expansion process and pricing dynamically and apply predictions to the competition between Kobe and Busan. They conclude that Kobe has imposed higher port charges than the equilibrium prices, and thus it lost international competitiveness. Though this paper overcomes the lack of dynamics of Anderson et al. (2008), the conclusion is not very convincing because price should converge to equilibrium in the long run. A model with price difference between the two ports in equilibrium is more natural and it is necessary to examine how the price difference arises.

Secondly, I introduce the papers about economic recovery from disasters, not just about the port. Although the economic growth model predicts catching up from the state after a disaster to a steady state, this process has not been examined with real data sufficiently. duPont & Noy (2015) indicate that the Great Hanshin Earthquake imposed a negative impact on per capita GDP, in the long run, using the Synthesized Control Method. However, Fujiki & Hsiao (2013) indicate that this negative long-run effect is not observed when they also consider the change of industrial structure in Hyogo prefecture in the analyses. So, the impact of the disaster on the real economy is still controversial.

As mentioned above, several papers have investigated the competition between ports and the economic impact of a disaster. However, few papers analyze port competition after a disaster. Chang (2000) is one of the few prior studies on this topic. He investigates the impact of the Great Hanshin Earthquake and concludes that the earthquake accelerated the fall of the Port of Kobe. However, this study does not examine why it failed to catch up after the disaster. This is where my study contributes by introducing the switching cost in my model. It is the crucial parameter that leads to the impossibility of catch-up. In doing so, I can also overcome the limitations of previous research.

3 The model

I think of the port competition of Kobe and Busan as Bertrand price competition and investment competition. I focus only on the transshipment cargo from third countries to third countries excluding Japan and Korea. That is because import and export cargoes would be dependent on other reasons as I mentioned. After a disaster, capital stock must be damaged exogenously and demand for such ports of call from shipping companies is determined by this given capital stock. I regard this time when a disaster happened as the beginning of time 0 (Figure 2). At the end of time 0, both ports choose investment level simultaneously. At time 1, both ports determine prices with Bertrand competition after observing investment level and capital stock.

This model is justified as describing competitions between hub ports such as Kobe and Busan in the following reason. Some ports compete to capture transship cargo in one region, which can be regarded as an oligopolistic market. Ports make an effort to capture larger demand by lowering price and by expanding port facilities, so they have strategies of price and investment. There are switching costs for shipping companies as I mentioned, so current demand for ports is dependent of previous demand for those.

Thus, I assume the following dynamic and complete information game: players are port A and port B, strategies are investment level and price, and payoff functions are defined by profit functions of the two ports. All elements of the game are assumed to be common knowledge for the sake of simplicity in this model, though, for instance, cost functions are not to be common

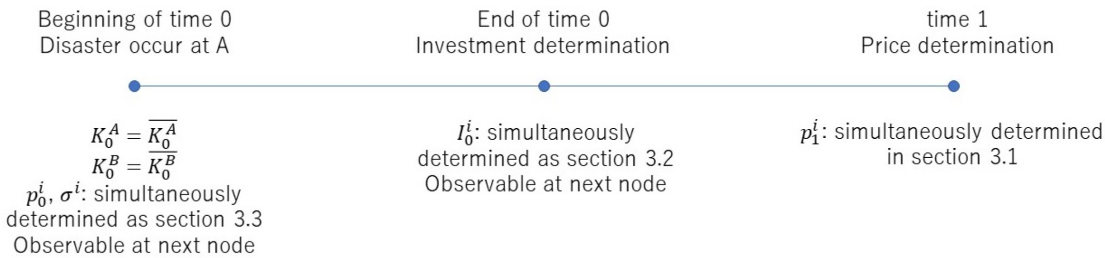


Figure 2: Timeline

knowledge practically. Then, I find the subgame perfect equilibria. Hence, I solve this game by backward induction.

3.1 Price competition: The 2nd stage game

I assume Bertrand competition in this game. Cournot competition is not appropriate because the capacity of port service must be predetermined. To model the heterogeneity of the two ports' services, I use the demand function originally derived by Hotelling (1929) based on a linear city model.

Consider an economy with two competing ports at both ends of a linear space and infinite shipping companies uniformly distributed in $[0, 1]$ which demand one unit of port service (Figure 3). The location of shipping companies is indexed by $h \in [0, 1]$. Assume shipping companies' maximum evaluation of port i's service are v^i $(i = A, B)$, and assume $v^A = v^B = v$. η (≥ 0) is a parameter which measures the degree of two goods' differentiation. Thus, consumer surplus of a shipping company buying from A and B is defined by $v - \eta h - p^A$ and $v - \eta(1 - h) - p^B$, respectively. Shipping companies from point 0 to the marginal point $\hat{h}$, where the shipping company is indifferent between using port A and port B and satisfies $v - \eta h - p^A = v - \eta(1 - h) - p^B$, can be defined as the port A's demand, and shipping companies from marginal point to point 1 can be defined as the port B's demand. With this, I can derive the demand for each port as equations (1) and (2):

$$x^A(\boldsymbol{p}) = \frac{p^B - p^A + \eta}{2\eta} \tag{1}$$

$$x^B(\boldsymbol{p}) = \frac{p^A - p^B + \eta}{2\eta} \tag{2}$$

where $\boldsymbol{p} = (p^A\ ,\ p^B)$. Note that sum of the demand is normalized to one.

Moreover, I add switching cost. Then, demand functions are transformed to

$$\begin{aligned} x^A(\boldsymbol{p}) &= \sigma^A \left(\frac{p^B - p^A + \eta + s^B}{2\eta} \right) + \sigma^B \left(\frac{p^B - p^A + \eta - s^A}{2\eta} \right) \\ &= \frac{p^B - p^A + \eta}{2\eta} + \frac{\phi}{2\eta} \end{aligned} \tag{3}$$

$$\begin{aligned} x^B(\boldsymbol{p}) &= \sigma^A \left(\frac{p^A - p^B + \eta - s^B}{2\eta} \right) + \sigma^B \left(\frac{p^A - p^B + \eta + s^A}{2\eta} \right) \\ &= \frac{p^A - p^B + \eta}{2\eta} - \frac{\phi}{2\eta} \end{aligned} \tag{4}$$

where σ^i is the time 0 demand share of port i, which is determined by the capital stock at time 0, K_0^A and K_0^B. Note that $0 \leq \sigma^i \leq 1$ and $\sigma^A + \sigma^B = 1$. s^A indicates the switching cost from B to A at time 1, and s^B indicates cost from A to B[1]. Equations (3) and (4) intuitively mean that shipping companies using port i at time 0 can easily use the same port at time 1 and vice versa. $\phi \equiv \sigma^A s^B - \sigma^B s^A$ means the difference of the total switching costs that need to be incurred from those moving from port A to port B and that need to be incurred from those moving from port B to port A.

[1] This model follows Klemperer (1987). See its equation (1). For simplicity, I omit the first term and the last term of it, and assume $\mu = 1$.

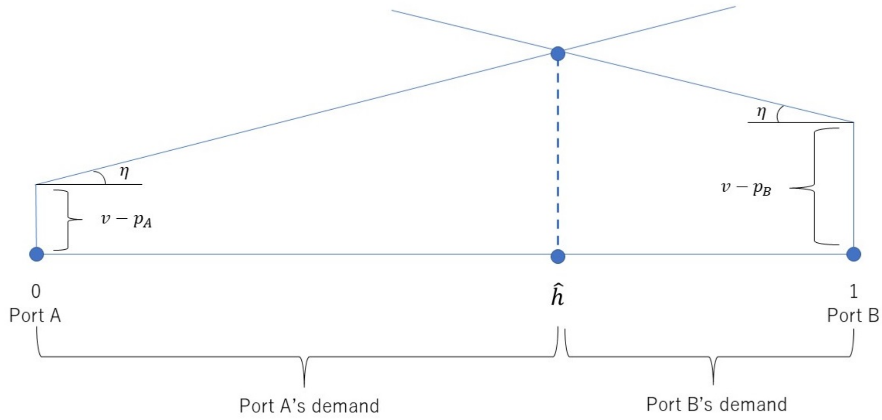


Figure 3: Hotelling Model

I point out that s^A and s^B are function of σ^A and σ^B, because there must be congestion effect or agglomeration effect. Moreover, I assume a linear function for s_i, which depends the difference of initial share, $\sigma^i - \sigma^j$. In summary, I define the switching costs as follows[2]:

$$s^i = a(\sigma^i - \sigma^j + 2) + b. \tag{5}$$

Note that $a > 0$ demonstrates agglomeration effect as only a share of the difference in initial demand translates into the switching cost, making ships easy to switch to benefit from agglomeration effect, and $a < 0$ demonstrates congestion effect as the higher initial demand share for port i translates into to the higher switching cost from port j to i, making ships difficult to switch. These are because of the following. I can show that $\phi = a(2\sigma^A - 1) + b(2\sigma^A - 1)$. When $a > 0$ and $\sigma^A > 0.5$, which means $\sigma^A > \sigma^B$, ϕ become larger. Larger ϕ means larger demand at port A. (See equation (3) and (4).) In summary, when $\sigma^A > \sigma^B$, x^A is larger and it means agglomeration effect. Similarly, I can show that $a < 0$ means congestion effect. Note also that $b\ (\geq 0)$ is constant which is independent of $\sigma^A - \sigma^B$.

Then, the ports solve following maximization problem. I abbreviate the time subscript t in this subgame for the sake of simplicity.

$$\begin{aligned} \max_{p^i} \quad & (p^i - c_v(K^i))x^i(\boldsymbol{p}) - c_f(K^i) \\ \text{s.t} \quad & x^i(\boldsymbol{p}) \leq \bar{x}(K^i) \end{aligned} \tag{6}$$

where $c_v(K^i)x^i$ indicates variable cost, $c_f(K^i)$ indicates fixed cost, and $\bar{x}$ is maximum amount of service a port can provide. Note that the cost function is common for both ports and marginal cost is constant given K. I assume marginal cost is decreasing in K and fixed cost is increasing in K. Note also that inequality constraint is the capacity constraint. $\bar{x}$ is function of K, which is also common for both and increasing in K. Without this constraint, ports would provide services infinitely, but it is not realistic. Hence, I add this kind of constraint.

The way to solve this problem with inequality constraint is given by Appendix. Then, first order conditions lead to the optimal pricing as follows:

[2] In order to prevent the situation where switching cost become lower than 0, I add 2 in the first term.

$$p^{A*} = \eta + \frac{\phi}{3} + \frac{2}{3}c_v(K^A) + \frac{1}{3}c_v(K^B) - \frac{2}{3}\chi^{A+} - \frac{1}{3}\chi^{B+} \tag{7}$$

$$p^{B*} = \eta - \frac{\phi}{3} + \frac{2}{3}c_v(K^B) + \frac{1}{3}c_v(K^A) - \frac{2}{3}\chi^{B+} - \frac{1}{3}\chi^{A+}. \tag{8}$$

Substituting (7) and (8) to (3) and (4) respectively, I have these demand functions given K:

$$x^{A*} = \frac{1}{2\eta}\left\{\frac{1}{3}c_v(K^B) - \frac{1}{3}c_v(K^A) + \frac{\phi}{3} + \eta - \frac{1}{3}\chi^{B+} + \frac{1}{3}\chi^{A+}\right\} \tag{9}$$

$$x^{B*} = \frac{1}{2\eta}\left\{\frac{1}{3}c_v(K^A) - \frac{1}{3}c_v(K^B) - \frac{\phi}{3} + \eta - \frac{1}{3}\chi^{A+} + \frac{1}{3}\chi^{B+}\right\}. \tag{10}$$

3.2 Investment competition: The 1st stage game

At the end of time 0, ports need to optimize the investment level. Then, maximization problem is defined by:

$$\begin{aligned} \max_{I_0^i} \quad & (p_1^{i*} - c_v(K_1^i))x^{i*} - c_f(K_1^i) \\ \text{s.t} \quad & K_1^i = (1-\delta)K_0^i + I_0^i \end{aligned} \tag{11}$$

where I_0^i is investment and δ is the capital depletion rate[3].

Optimal investment level is the I_0^i that satisfy following (12) and (13).

$$\begin{aligned} &\frac{1}{\eta}\left\{\eta + \frac{\phi}{3} - \frac{1}{3}c_v(K_1^A) + \frac{1}{3}c_v(K_1^B)\right\}\left\{-\frac{1}{3}c_v'(K_1^A)\right\} \\ &+\frac{1}{2\eta}\left(-\frac{1}{3}\chi^{A+} - \frac{2}{3}\chi^{B+}\right)\left\{-\frac{1}{3}c_v'(K_1^A)\right\} - c_f'(K_1^A) \\ &= 0 \end{aligned} \tag{12}$$

$$\begin{aligned} &\frac{1}{\eta}\left\{\eta - \frac{\phi}{3} - \frac{1}{3}c_v(K_1^B) + \frac{1}{3}c_v(K_1^A)\right\}\left\{-\frac{1}{3}c_v'(K_1^B)\right\} \\ &+\frac{1}{2\eta}\left(-\frac{1}{3}\chi^{B+} - \frac{2}{3}\chi^{A+}\right)\left\{-\frac{1}{3}c_v'(K_1^B)\right\} - c_f'(K_1^B) \\ &= 0 \end{aligned} \tag{13}$$

I point out that ϕ, which indicates the magnitude of the disaster indirectly, and $c_v(K^i)$ play the crucial role for this model. It is both that can show the probability that after the great disaster port cannot catch up with the other port.

I cannot show the solution by closed form unless I assume linearity of K in marginal cost. Because of this, I use numerical calculation, which is shown in the next section.

3.3 Initial share determination

Finally, I determine the initial share σ^i by solving following problem for given $\bar{K}_0^i$. I assume that ports maximize their profits without considering the effect on the market share in the next term:

$$\max_{p_0^i} (p_0^i - c_v(\bar{K}_0^i))x^i(\boldsymbol{p}) - c_f(\bar{K}_0^i). \tag{14}$$

[3]This objective function does not include time 0 profit. However, I can ignore dynamics because K_0^i is not the control variable, and therefore I can reduce dynamic problem to this static problem.

Then, I have these price and demand:

$$p_0^A = \eta + \frac{2}{3}c_v(\bar{K_0^A}) + \frac{1}{3}c_v(\bar{K_0^B}) \tag{15}$$

$$p_0^B = \eta + \frac{2}{3}c_v(\bar{K_0^B}) + \frac{1}{3}c_v(\bar{K_0^A}) \tag{16}$$

$$\sigma^A = \frac{1}{2\eta}\left\{\frac{1}{3}c_v(\bar{K_0^B}) - \frac{1}{3}c_v(\bar{K_0^A}) + \eta\right\} \tag{17}$$

$$\sigma^B = \frac{1}{2\eta}\left\{\frac{1}{3}c_v(\bar{K_0^A}) - \frac{1}{3}c_v(\bar{K_0^B}) + \eta\right\}. \tag{18}$$

Note that K_0^i is given since great disasters must not be fully expected and must be exogenous, and capacity constraint is not required in this game because K_0^i is given.

4 Calibration and Comparative Statics

4.1 Calibration

For numerical simulations, I am unable to determine functional forms of c_f, c_v, and $\bar{x}$, and exogenous parameters need to be specified. Because of the lack of data, I am unable to estimate functional form and parameters by using econometric method. Therefore, I assume functional form and extrapolate the parameters.

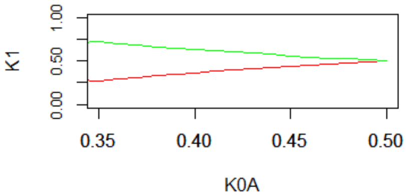
First, I assume concavity of marginal cost which depends on the capital stock because of the guarantee of the existence of solutions. Here, marginal cost is given by $c_v(K^i) = 10,000,000,000 - 10{K^i}^{\frac{1}{2}}$. Second, I assume linear fixed cost which also depends on capital stock. Here, fixed cost is given by $c_f(K^i) = 6K^i$. Third, I assume linear capacity function such that $\bar{x}(K) = K$.

In addition, I have to assume parameters. Because these are not observable, I need to extrapolate parameters and adopt the candidates which reasonably adjust reality. I conduct comparative statics of η later, but for now, I assume $\eta = 2$ because of the computation and theoretical characteristics[4].

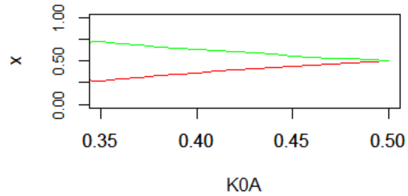
4.2 Comparative Statics

Figure 4 is the comparative statics of K_0^A and the outcome variable in (a) is optimal capital stock and that in (b) is demand share at time 1 when switching cost is set to 0.5, which means $a = 0$ and $b = 0.5$ in equation (5). This figure shows how much both ports invest when $K_0^B = 0.5$, which is fixed. When a disaster occurs near A, port A's capital stock is damaged, and I can regard it as low K_0^A. For example, when $K_0^A = 0.4$, optimal capital stock at A is about 0.4, which shows imperfect catch-up, and on the other hand, optimal capital stock at B is about 0.6. I can conclude that the greater a disaster is, the greater the divergence in the optimal capital stocks between the two ports.

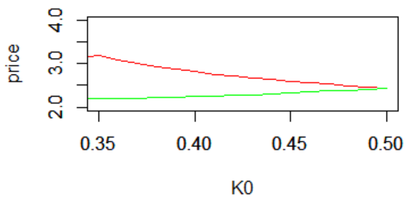
[4]When $\eta \geq 4$, two ports are completely heterogeneous goods in my calculation. This means perfect regional monopoly, so it is not appropriate in this circumstance.



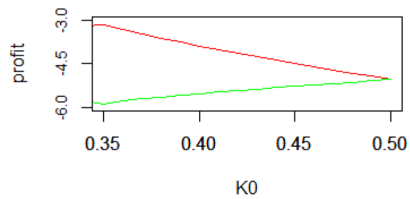
(a) Optimal capital stock K_1^i



(b) Demand share x_1^i



(c) Equilibrium prices p_1^i



(d) Profits

Figure 4: comparative statics of K_0^A

Note: The red line represents port A and the green line represents port B.

Outcome variables in (c) and (d) are equilibrium price given capital stock at time 1 and the total profit, respectively. All exogenous variables are the same as the above. Note that 9,999,999,990 is subtracted from each price to make it easier to see. The total profit is defined by the sum of discounted present value of profit. I assume interest rate is 5 because I assume an annual interest rate of 4.5 percent and years of port's durability is 40 years[5]. Note also that fixed cost make profits negative, but the value itself does not make sense in my model.

As expected, equilibrium price at port A is higher than that at port B, because optimal capital stock at port B is higher than that at port A and from equation (7) and (8). A's profit is higher than B's one. There exists huge fixed cost in my model, so the profit of port B, which has larger capital stock, is less than that of port A, even though this strategy is optimal. This kind of circumstance is not so unnatural. Sometimes it is more profitable to be small.

Figure 5 is comparative statics of a, the element of switching cost, which indicates the degree of congestion or agglomeration effect. I set $b = 0.2$. All other exogenous variables are the same as in Figure 4 except for a and b. This shows that the optimal capital stock of both ports diverges more if there exists agglomeration effect. On the other hand, if there exists congestion effect, the optimal capital stock of both ports converges.

Figure 6 is comparative statics of b, the element of switching cost, and the outcome variable is optimal capital stock when $a = 0$ in equation (5), and $K_0^A = 0.4$. Other exogenous variables are the same as Figure 4 setting. It shows that the bigger the switching cost is, the larger the difference in optimal capital stock between the two ports is.

Figure 7 is comparative statics of η, the degree of two goods' differentiation. I set $K_0^A =$

[5] One term is set at 40 years. $1.045^{40} - 1 \approx 5$.

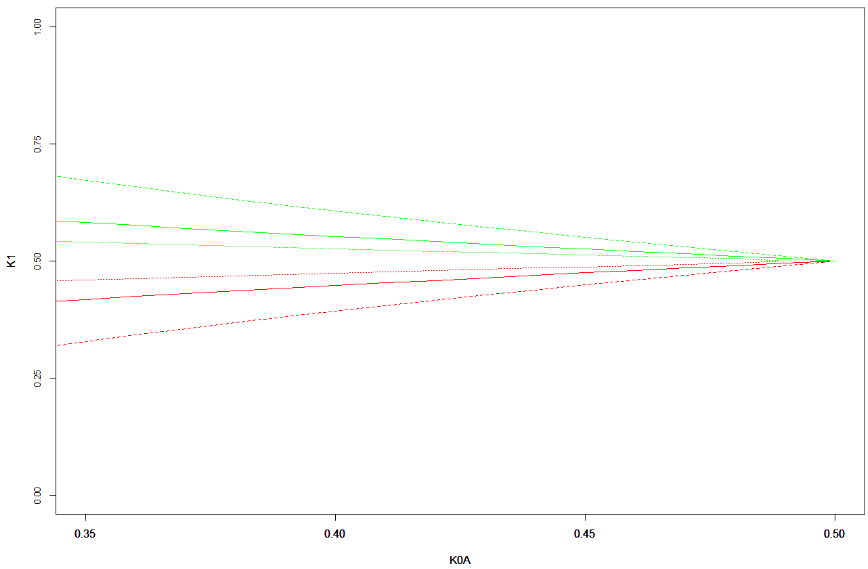


Figure 5: Optimal capital stock K_1^i; comparative statics of the element of switching cost a
Note: The red lines represent port A and the green lines represent port B. The dashed lines represent when $a = 0.2$, the dotted lines represent when $a = -0.1$, and solid lines represent when $a = 0$.

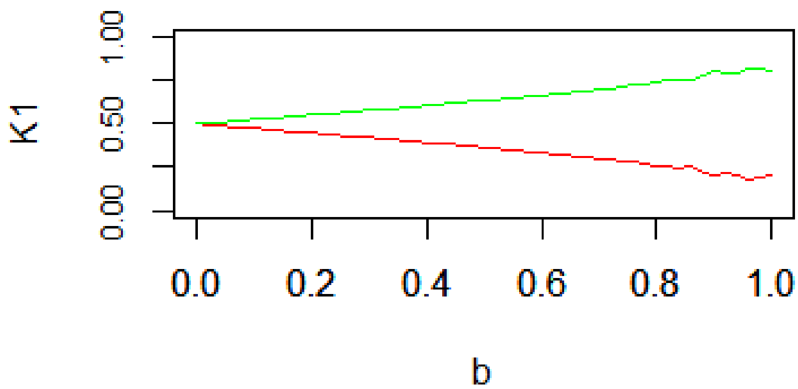


Figure 6: Optimal capital stock K_1^i; comparative statics of the element of switching cost b
Note: The red line represents port A and the green line represents port B.

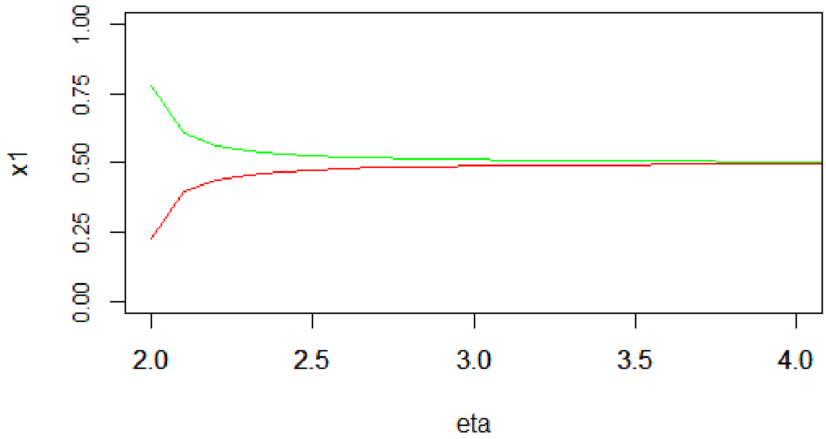


Figure 7: Demand share x_1^i; comparative statics of η

Note: The red line represents port A and the green line represents port B.

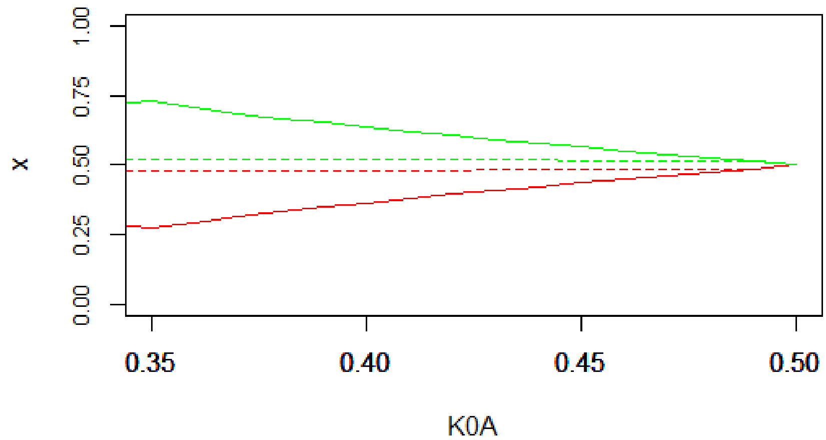


Figure 8: Demand share x_1^i; comparative statics of K_0^A

Note: The red lines represent port A and the green lines represent port B. The dashed lines represent when counterfactually government invests 0.5–K_0^A. The solid lines represent when investing optimally.

0.3. All other exogenous variables are the same as in Figure 4. Results show that the more heterogeneous the two ports' services are, the more the difference in demand share converges. This indicates the probability that a subordinated port can catch up to a reader port by providing characteristic services.

Next, I state the result of counterfactual analysis, which is the greatest benefit of a structural model. This is the major contribution of this paper. Figure 8 shows the situation when the government which hosts port A invests $0.5 - K_A^0$ with external funding no matter how large the disaster is. Note that all exogenous variables are the same as the Figure 4 setting. This indicates that the demand share cannot completely be recovered even when the government recovers the capital stock to the original level. Needless to say, the profit internalizing external funding over the optimal level is lower than when optimal.

5 Discussion

In this section, I apply the implication of my model to the case of Kobe and Busan. I first look at the overview of the history of the two ports from around 1990. Figure 9 shows the trend of the port capacity of the two ports. Before the Great Hanshin Earthquake, which occurred at time 80 in Figure 9, Kobe and Busan had almost the same capacity. After that Busan expanded its capacity more and more. Korean government planned to construct Busan new port in 1995 and a total of \$3.73 billion has been invested in the port so far. This project is still ongoing, and now the port has 23 berths and can handle around 9 million TEUs (Twenty-foot Equivalent Unit) (Ikegami ed., 2012). On the other hand, although the reconstruction of the Port of Kobe after the great disaster was very quick, and cargo handling resumed only two months after the great disaster, this restoration project was limited to recovering the facility to the pre-disaster situation. The Japanese government had been criticized for failing to invest intensively in critical ports including the Port of Kobe (Matsuo, 2010).

On the other hand, my model shows that optimal capital stock is low level, and the resulting demand share is also small if I consider switching costs. From this perspective, the small demand share in the Port of Kobe may have been caused not by the lack and delay of investment but by the result of rational decision-making which led to the low but optimal investment.

The implication of my model can be applied to the airport. A typical example may be newly constructed airports with large capital stock that cannot capture the demand. Mattala Rajapaksa International Airport in Sri Lanka is one of the examples. It had been expected to mitigate the congestion of Bandaranaike International Airport, which is the largest airport in Colombo, and capture the demand from it even more, but it is now called the world's most empty international airport (Enomoto, 2017). One of the major reasons is the distant location from Colombo. This causes high switching cost. Therefore, this example shows optimal capital stock is low level and the demand share is also low when the airport is newly constructed, that is, has zero initial share, and high switching cost. This situation is largely consistent with the implication of my model. Fleming & Hayuth (1994) show another similar example. During the Iran-Iraq war, shipping companies became hesitant to use inner Persian Gulf ports. Then, they diverted to other ports as transshipment points, and one of the largest ports which received these ships was the port of Rashid in the UAE. This trend continued even after the war ended.

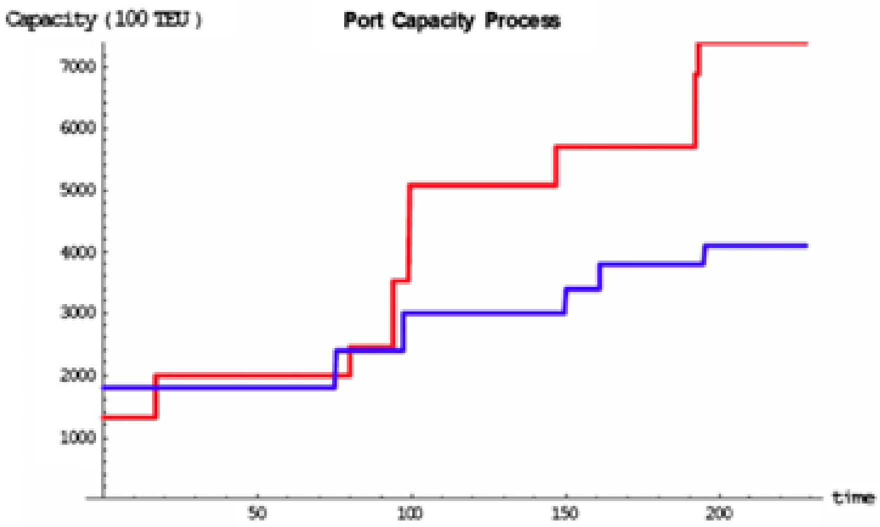


Figure 9: Port Capacity process of Kobe and Busan

Source: Ishii et al. (2013)

Note: The red line is the port capacity process of Busan, and the blue line is that of Kobe. Time 0 is equal to Jan. 1990, time 1 is Feb. 1990, time 2 is Mar. 1990, and so on. The last is time 228 and it indicates Dec. 2008.

These examples may justify the existence of path dependence of the equilibrium and difficulty of irreversibility once a port loses incoming ships.

To sum up, in this thesis, I demonstrated the possibility that the current difference in handling volume between Busan and Kobe is the result of optimal decision-making of these ports, and counterfactual analysis shows that a huge investment is needed to realize catch-up though this strategy is not optimal.

Next, I consider the way to catch up. My model shows the successful catch-up when two ports' services are heterogeneous, namely the high η, which also means that demand is not so elastic, or when the switching cost is low. Therefore, one solution is service differentiating from Busan, specifically ensuring punctuality, because there is virtually no difference in quality no matter which port is used except for that. Moreover, it is more effective to collaborate with ports with punctual services and provide attractive routes for shipping companies. This is because maritime transportation has many port calls, which can drag on delays. In addition to that, Kobe may be able to capture the long-distance ship markets since these kinds of ships are not considered too price-sensitive. However, long-distance ships demand thick feeder networks, which are not existent in Kobe now. Thus, it must be not so easy to capture these demands. Alternatively, when government subsidizes the amount of switching cost for shipping companies, Kobe may be able to capture half of the demand in parts of East Asia.

Finally, I explain the current port policy. In 2010, the Ministry of Land, Infrastructure, Transport, and Tourism designated the Port of Hanshin, the collective name for the ports of Osaka and Kobe, as an International Container Strategic Port along with the Port of Keihin. It invests intensively over 40 billion yen annually in these ports. One of the gigantic projects is deepening the water depth of 7 berths to 16m which accommodates the recent increase in the size of vessels. Handling cargo volume is increasing steadily now, but the situation is far from catch-up even now.

6 Concluding Remarks

I have examined the impacts of the disaster on the port competition. I construct the game theoretical model with switching cost and find that the subgame perfect equilibrium is consistent with the current situation of Kobe and Busan. In summary, I can show the possibility that great disasters make it impossible for ports to catch up when port services are substitutes. In addition, counterfactual analysis indicates that even if the government invests above the optimal capital stock, the port will capture less demand than it would have if the disaster had not occurred. In the context of Kobe and Busan, I point out that the two ports have invested optimally, and the difference in the handling volume share is the result of rational behavior.

This research contributes to policy-making of the ports. The Japanese port policy has been said to be a failure due to a delay in investment (Matsuo, 2010). However, I point out the possibility that the determination of investment in Kobe has been optimal, and switching costs caused the small share of the cargo volume. I also demonstrate the way to catch up to the leading port. One solution is service differentiation, especially providing punctual service. The other is government's subsidizing the amount of switching cost for shipping companies. Moreover, this model might be applied to broad industries that need huge capital stock because it cannot be recovered quickly. This model shows the possibility that the demand is limited when the initial capital stock is very small, for example, when those industries are newly established.

Several issues remain. First, this model assumes two periods and two ports, but an infinite horizontal model with three or more ports is the possible extension. Second, while I chose plausible parameters, it would provide more robust results if these could be estimated econometrically using cross-section data.

Appendix

In the 2nd stage game, I have inequality constraint when solving (6). To realize continuity and differentiability, Lagrange multiplier is replaced to the following:

$$\chi^{+} = (\max\{0, \chi\})^2 \tag{19}$$

$$\chi^{-} = (\max\{0, -\chi\})^2. \tag{20}$$

Then, by applying the result in Section 4.2 of Zangwill & Garcia (1981), I have (7),(8) and following:

$$-\chi^{i-} - x^i(\boldsymbol{p}) + \bar{x}(K^i) = 0. \tag{21}$$

In the 1st stage game, system of equations are (12), (13), and

$$-\chi^{i-} - x^{i*} + \bar{x}(K^i) = 0. \tag{22}$$

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