

**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—)

47-216760, Haruka Maeoka

Supervisor: Aya Suzuki

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**1. INTRODUCTION**

The spread of hub-spoke transportation system has given rise to large ports in certain regions, such as Busan and Kobe in East Asia. The port of Kobe has declined its international competitiveness since the 1990s and has not recovered since the 1995 Great Hanshin Earthquake, while the port of Busan continued to grow.

Potential reasons for this difference between the two ports include differences in investment policies, the Japanese government's policies on port diversification, and the impact of disasters on port infrastructure. However, my concern is that these reasons partly neglect how investment decisions are made. It is possible that the current capital stock in Port of Kobe is in fact optimal, as it is determined endogenously. So, my research question is why Kobe has not seen a recovery since the earthquake. The findings of the study may have potential implications for disaster recovery policies in other settings.

There are some literatures on game theoretical modeling of port competition and shipping companies' port selection, and also on economic recovery from disasters. Anderson et al. (2008) and Ishii et al. (2013) use game theoretical models to study the competition between ports, and duPont & Noy (2015) and Fujiki & Hsiao (2013) examine the economic impact of disasters. Chang (2000) is a rare study on the port of Kobe after the disaster but does not explain why one failed to recover. My study aims to contribute by introducing the concept of switching cost in the analysis and improving the limitations of previous research.

**2. The model**

After a disaster, capital stock must be damaged exogenously and demand for such ports of call is determined by this given capital stock. I regard this time when a disaster happened as the beginning of time 0. 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. Thus, I assume the following dynamic game: players are port A and port B, strategies are investment level and price, and payoff functions are defined by profit function.

I use the so-called Hotelling demand function with switching cost as follows:

$$x^A(\mathbf{p}) = \frac{p^B - p^A + \eta}{2\eta} + \frac{\phi}{2\eta} \quad (1)$$

$$x^B(\mathbf{p}) = \frac{p^A - p^B + \eta}{2\eta} - \frac{\phi}{2\eta} \quad (2)$$

where  $\phi \equiv \sigma^A s^B - \sigma^B s^A$ . Note that  $\sigma^i$  is the initial demand share and  $s^i$  is the switching cost.

Ports' profit maximization problem determining the prices at time 1 (2<sup>nd</sup> stage game) is derived as follows:

$$\max_{p^i} (p^i - c_v(K^i)) x^i(\mathbf{p}) - c_f(K^i) \quad (3)$$

$$s. t. \quad x^i(\mathbf{p}) \leq \bar{x}(K^i) \quad (4)$$

where  $\mathbf{p} = (p^A, p^B)$ ,  $c_v$  is marginal cost,  $c_f$  is fixed cost, and  $\bar{x}$  is a capacity constraint. Let  $p^{i*}$  be the solution for (3) and (4). Substituting  $p^{i*}$  to (1) and (2), I have  $x^{i*}$ .

Substituting the solution for this problem to the profit function, I derive following ports' maximization problem determining the investment at the end of time 0 (1<sup>st</sup> stage game).

$$\max_{p^i} (p^{i*} - c_v(K^i)) x^{i*} - c_f(K^i) \quad (5)$$

$$s. t. \quad K_1^i = (1 - \delta)K_0^i + I_0^i \quad (6)$$

First order conditions are following.

$$\begin{aligned} \frac{1}{\eta} \left\{ \eta + \frac{\phi}{3} - \frac{1}{3} c_v(K_1^A) + \frac{1}{3} c_v(K_1^B) \right\} \left\{ -\frac{1}{3} c'_v(K_1^A) \right\} \\ + \frac{1}{2\eta} \left( -\frac{1}{3} \chi^{A+} - \frac{2}{3} \chi^{B+} \right) \left\{ -\frac{1}{3} c'_v(K_1^A) \right\} \\ - c'_f(K_1^A) = 0 \end{aligned} \quad (7)$$

$$\begin{aligned} \frac{1}{\eta} \left\{ \eta - \frac{\phi}{3} - \frac{1}{3} c_v(K_1^B) + \frac{1}{3} c_v(K_1^A) \right\} \left\{ -\frac{1}{3} c'_v(K_1^B) \right\} \\ + \frac{1}{2\eta} \left( -\frac{1}{3} \chi^{B+} - \frac{2}{3} \chi^{A+} \right) \left\{ -\frac{1}{3} c'_v(K_1^B) \right\} \\ - c'_f(K_1^B) = 0 \end{aligned} \quad (8)$$

Initial demand share  $\sigma^i$  is derived by the following maximization problem,

$$\max_{p^i} (p_0^i - c_v(\bar{K}_0^i)) x^i(\mathbf{p}) - c_f(\bar{K}_0^i) \quad (9)$$

and I have

$$\sigma^i = \frac{1}{2\eta} \left( \frac{1}{3} c_v(\bar{K}_0^j) - \frac{1}{3} c_v(\bar{K}_0^i) + \eta \right). \quad (10)$$

**3. Calibration and Comparative Statics**

I do not have enough data to estimate parameters and functional form using econometric methods, so I have to make assumptions about the functional form and extrapolate the parameter values.

Solid lines in Figure 1 represent the optimal capital stock at time 1 for two ports. When a disaster occurs

near port A, the capital stock of port A is damaged and can be considered as a low value of  $K_0^A$ . This figure suggests that the greater the disaster, the greater the divergence in the optimal capital stocks between the two ports if

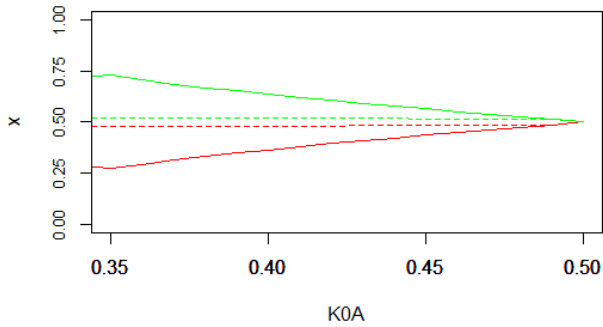


Figure 1: Comparative Statics of  $K_0^A$

Note: Lower two lines represent port A. Upper two lines represent port B.

switching cost exists. Dashed lines in Figure 1 show the situation when the government which host port A invests  $0.5 - K_0^A$  with external funding no matter how large the disaster is. This indicates that the demand share cannot completely be recovered even when the government recovers the capital stock to the original level.

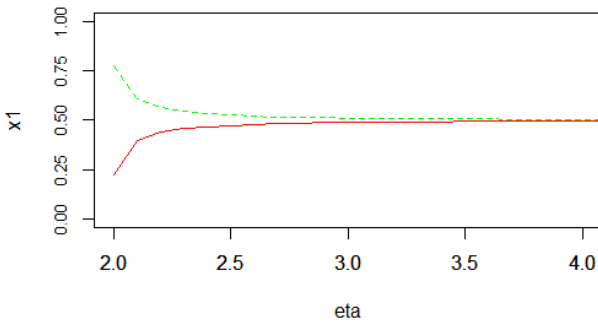


Figure 1: Comparative Statics of  $\eta$

Figure 2 shows that the higher  $\eta$  is, in other words, the more differentiated two ports' services are, the more the difference in demand share converges. This indicates the probability that a subordinated port can catch up with a leading port by providing characteristic services.

#### 4. Discussion

After the Great Hanshin Earthquake, Busan significantly expanded its capacity while Kobe's reconstruction was limited to returning to its pre-disaster state. My model suggests that the small investment for the Port of Kobe may have been the result of rational decision-making taking into account the small demand. The model also predicts that for a port to successfully catch up with another, its services must be significantly differentiated or the switching cost for shipping companies must be low. The Japanese government has invested heavily in the Port of Hanshin (comprised of the ports of Osaka and Kobe) in an effort to increase its handling volume. I suggest additional following solutions to catch up to other ports: subsidizing switching cost for shipping companies and increasing the port's specialization, such as providing punctual service.

#### 5. Concluding Remarks

This research examines the impact of disasters on port competition using a game theoretical model with switching costs. I find that when ports are substitutes and a disaster occurs, it can make it difficult for the port which experienced the disaster to catch up with the other. Counterfactual analysis shows that even with substantial government investment the port affected by the disaster may capture less demand than it would have without the disaster. I suggest that service differentiation and government subsidization of switching costs for shipping companies could be solutions for catching up with the leading port. The findings from the model have potential implications for application in other industries that require large initial capital stocks. Lastly, I note that the model has some limitations, such as that it only considers two ports and two periods and lacks econometric estimation based on real data. These can be considered as the future extensions of the model.

#### References

- Anderson, C. M., et al. 2008. A game-theoretic analysis of competition among container port hubs: The case of Busan and Shanghai. DOI: 10.1080/03088830701848680
- Chang, S. E. 2000. Disasters and transport systems: loss, recovery and competition at the Port of Kobe after the 1995 earthquake. DOI: 10.1016/S0966-6923(99)00023-X
- Dupont, et al. 2015. What Happened to Kobe? A Reassessment of the Impact of the 1995 Earthquake in Japan. DOI: 10.1086/681129
- 榎本俊一 2017. 中国の「一帯一路」構想は『相互繁栄』をもたらす新世界秩序か?. 経済産業研究所 RIETI Policy Discussion Paper Series 17.
- Fleming, D. K., et al. 1994. Spatial characteristics of transportation hubs: centrality and intermediacy. DOI: 10.1016/0966-6923(94)90030-2
- Fujiki, H., et al. 2015. Disentangling the effects of multiple treatments - Measuring the net economic impact of the 1995 great Hanshin-Awaji earthquake. DOI: 10.1016/j.jeconom.2014.10.010
- Hotelling, H. 1929. Stability in Competition. DOI: 10.2307/2224214
- 池上寛編 2012. アジアにおける海上輸送と主要港湾の現状.
- Ishii, M., et al. 2013. A game theoretical analysis of port competition. DOI: 10.1016/j.tre.2012.07.007
- Klemperer, P. 1987. The Competitiveness of Markets with Switching Costs. DOI: 10.2307/2555540
- 公益財団法人国際東アジア研究センター 2014. 釜山港 T/S 日本発着貨物の現状分析とモデル化.
- 神戸市 2020. 2020 年神戸港大観(年報).
- Lee, P. T. W., et al. 2011. Charting a New Paradigm of Container Hub Port Development Policy: The Asian Doctrine. DOI: 10.1080/01441647.2011.597005
- 松尾俊彦. 2010. 日本の港湾政策に関する一考察. 海事交通研究第 59 集.
- Solow, R. M. 1956. A Contribution to the Theory of Economic Growth. DOI: 10.2307/1884513
- 津守貴之 2009. 東アジア港湾間関係の再編成と日本港湾. 日本国際経済学会 2008 年度関西支部研究会第 4 回.
- Zangwill, W.I., et al. 1981. Pathways to Solutions, Fixed Points, and Equilibria. Englewood Cliffs: Prentice-Hall