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Should ports expand their facilities under congestion and uncertainty?

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ABSTRACT

This paper investigates simultaneous facility investments of risk-averse ports under congestion and uncertain market demand. We set up a two-period game, allowing two ports first choose their facility investment levels, and then decide their cargo-handling amounts and service prices. When investment costs of the two ports are large, the unique equilibrium is no investment. If investment costs of at least one port are small, then one or two ports will invest at equilibria. If both ports invest at equilibrium, they may become worse off than at non-equilibrium of no investment. This means that the ports may face a tradeoff between stability and efficiency. Moreover, we compare the behaviors of risk-averse and risk-neutral ports, as well as risk-averse ports' behaviors under uncertainty and no-uncertainty. It is found that ports' risk-averse degrees are the major factor determining their behaviors in different scenarios.

1. Introduction

With rising globalization and economic recovery around the world, international commercial activities through container shipping increase dramatically. According to the international trade statistics published by the World Trade Organization (2014), the average annual growth rate from 2005 to 2013 for export (import) of world merchandise in Asia is 6.5% (5.5%), which exceeds the corresponding numbers 2% (1%) in Europe as well as the numbers 3.5% (1.5%) in North America. Among the countries in Asia, China has the largest average annual growth rates of export and import between 2005 and 2013, 11% and 10% respectively.[1] Therefore, the Shanghai City government began developing its free-trade zone in 2013, and asked China's central government for permission to concurrently build a multi-billion-yuan container port facility to enhance the momentum of the free-trade zone. At the same time, Singapore planned to double its container port capacity after the Shanghai port overtook its port to become the world's busiest harbor. On the other hand, the Malaysian government launched an expansion plan for the Kuantan port, which aims to become a world-class port to serve regional trades in ASEAN (the Association of Southeast Asian Nations), the Far East, and other Asian-Pacific countries.[2] Many famous companies, such as Samsung Electronics Co. and Honda Motor Co., are constructing new factories in Vietnam and Thailand.

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[1] Source: https://www.wto.org/english/res_e/statis_e/its2014_e/its2014_e.pdf.

[2] Source: https://www.ijm.com/infrastructure.

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Accordingly, the Vietnam government plans to build a US$3.6 billon port to ship more cargoes, and the Thai government plans to construct a US$8.6 billion deep-sea port in Dawei.[3]

If a port is equipped with abundant facilities, its service and congestion costs decrease. However, ports' facility investment decisions are pretty risky since creating the facilities usually takes a long time and the future market demand is uncertain. In addition, if ports in many neighboring countries expand their capacity concurrently, then competition among these ports would become very severe and may not be good for them. Thus, whether ports should expand their capacity and how many facilities they should invest in are research-worthy issues. This paper thus explores these topics under real-world situations, which include uncertain market demands and risk-averse ports.

We construct a two-stage game to characterize interactions between two ports. As in previous works, both ports execute facility investments as their long-term strategy and cargo-handling amounts as their short-term strategy. Thus, in the first stage of the game, both ports simultaneously select their facility investment levels under uncertain future demand. In the second stage, new facilities are completed and the actual market demand is realized and observed. The two ports choose their cargo-handling amounts and service prices simultaneously.

This model differs from previous ones in two respects. First, instead of assuming risk-neutral ports, we allow ports to be risk-averse when facing uncertainty. Second, uncertain market demand is considered to reflect rapidly changing economies. The equilibria of this model are as follows. When ports' investment costs are large, the unique equilibrium is no investment. When investment costs of at least one port are not large, then there exist two equilibrium types: only one port invests, and both ports invest. At the second-type equilibrium, the ports may become worse off than at the non-equilibrium of no investment.[4] This is a tradeoff between stability and efficiency. It implies that when both ports invest, it is stable because no port deviates, but they will own lower payoffs than at the non-equilibrium of no investment. We further investigate whether a less or a more risk-averse port will face this tradeoff. In addition, we discover the conditions for a risk-averse port to invest more or less than a risk-neutral port, and the conditions for a risk-averse port to invest more or less under uncertainty compared to under no uncertainty. It is found that ports' risk-averse degrees play a major role in these conditions. If we replace ports by welfare-maximizing governments in the first stage of our game, our simulations reveal that governments' equilibrium facility investment levels may be greater or smaller than the first-best levels; that is, governments may over- or under-invest. Finally, we demonstrate how ports' service prices change with the model's parameters, such as market states, facility levels, and marginal service and congestion costs of the ports.

2. Literature review

This section compares our set-up with those in the literature. De Borger et al. (2007) investigate how two governments decide their tolls and capacity investments on a congested transport corridor they have jurisdiction over, and find that under some conditions governments' tolling policy may decrease the countries' welfare. Anderson et al. (2008) use a simple game to examine two competing ports' investments in new facilities and discover that the investments depend on their costs. De Borger et al. (2008) inspect the optimal pricing of two ports that have downstream congested transport networks to a common hinterland, as well as optimal investments of corresponding governments in ports' facilities. They find that the ports will internalize the hinterland congestion costs and charge their customers accordingly, and their capacity levels are negatively correlated with the charges. Following De Borger et al. (2008), Zhang (2008) analyzes how hinterland access conditions affect uncongested ports' competition in both price and quantity. While expanding inland road capacity may not increase ports' services and profits under quantity competition, Zhang concludes that enlarging a region's corridor capacity will raise a port's service prices and reduce its rival's under price competition. Under a Hotelling set-up, Takahashi (2004) examines how two competing governments decide the investments of their public facilities, and finds that the problem of coordination failure could exist- that is, both governments may choose to invest at equilibrium, but the outcome is Pareto-inferior to the result of no investment.

Dunkerley et al. (2009) analyze which policy among capacity expansion, congestion pricing, and a direct subsidy to the un-congested facilities can solve city congestion, and find that congestion pricing is the most effective one. Adopting Cournot and Stackelberg games, Gkonis and Psaraftis (2009) explore optimal transportation capacity of two liquefied natural gas companies. They find that under two companies continuous interaction the non-cooperative collusion can be sustained. Luo et al. (2012) study pricing and capacity expanding decisions of ports using a two-stage game and derive the conditions for ports to profit from a rising capacity level. They also find the conditions under which the preemptive prices set by the dominant port are ineffective. Van den Berg and Verhoef (2012) explore how private firms decide their road capacity sequentially and choose tolls. They demonstrate that the first-mover firm will set a travel time shorter than the social optimum. However, unlike this research, all the above works assume that governments or ports are risk-neutral and consider no uncertainty.

Ishii et al. (2013) probe the impact of stochastic demands on ports' equilibrium service prices assuming the ports have fixed facility levels. In contrast, this paper endogenizes ports' facility levels. Xiao et al. (2013) consider how duopoly airports

[3] Source: https://english.vov.vn/Economy/US36-billion-to-build-Van-Phong-transhipment-port/108867.vov and https://en.wikipedia.org/wiki/Dawei_Port_Project.

[4] If no ports expanding is not an equilibrium, it means that the best response of a port is to expand, instead of not expanding, its facilities if its rival does not expand.