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Как экономически связаны «пояс» и «путь»: моделирование и политические последствия

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Аннотация. Мы предлагаем аналитическую модель, которая отражает взаимосвязь между «Поясом» и «Путём» в рамках программы Китая «Один пояс – один путь» (ИВГ). Мы показываем, что краткосрочные минимальные субсидии, получаемые компаниями-операторами терминалов (КОТ) новых железных дорог, зависят от рыночной конъюнктуры в существующем портовом секторе. В частности, на эти субсидии влияют спрос на внешнее судоходство, фрахт морских перевозок и количество КОТ в существующем порту. Уровень субсидирования и чувствительность грузоотправителей к времени и цене играют важную роль при определении социальных выгод от ИВГ. Кроме того, регион может получить дополнительные выгоды от строительства или модернизации железных дорог в тех случаях, когда железнодорожные КОТ могут конкурировать с существующими портовыми КОТ. Рост благосостояния населения обусловлен повышением качества обслуживания (снижением издержек, связанных с задержкой), сокращением расходов на автомобильные перевозки и снижением цен на морские перевозки в результате конкуренции. Авторы обсуждают политические и экономические последствия раздельного и совместного управления портами и железными дорогами.

Ключевые слова. «Один пояс – один путь», морской транспорт, железнодорожный транспорт, субсидии, конкуренция фирм, китайско-европейские грузовые поезда, порты.

“带”和“路”的经济联系：模型分析和政策启示

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摘要. 我们提出一个理论模型来分析中国的“一带一路”倡议中的“带”和“路”之间的经济联系。研究表明，铁路运营商所需要的短期最低补贴取决于现有海运行业的市场条件。具体来说，补贴受外部海运需求、海运费率和现有港口运营商数量的影响。补贴水平和托运人对时间和价格的敏感性在决定“一带一路”倡议的社会效益时起着重要作用。此外，当铁路运营商与现有港口运营商竞争时，该地区可以进一步受益于铁路的建设或改善。社会福利的提高来自于服务质量的提高（延误成本的降低）、道路运输成本的降低以及竞争导致的海运价格的降低。我们进一步讨论了港口和铁路分开和联合管理时的政策和经济意义。

关键词. “一带一路”倡议；海洋运输；铁路运输；补贴；公司竞争；中欧班列；港口。

How «Belt» and «Road» are Related Economically: Modelling and Policy Implications

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Abstract. We propose an analytical model to capture the relationship between the «Belt» and the «Road» in China's Belt and Road Initiative (BRI). We show that the short-term minimum subsidies received by the terminal operator companies (TOCs) of the new railways depend on the market conditions in the existing port sector. Specifically, the subsidies are affected by the external shipping demand, the shipping freight rate, and the number of TOCs at the existing port. The level of subsidy and the shippers' sensitivity to time and price play a significant role when determining the social benefit from the BRI. Furthermore, the region can further benefit from the construction or improvement of the railways when the rail TOC could compete with the existing port TOCs. The welfare gain arises from the improvement in service quality (decrease in delay costs), reduction in road transport costs, and decrease in shipping price resulting from competition. The policy and economic implications of separate and joint management of the port and rail are discussed.

Keywords. Belt and Road Initiative, Maritime transport, Rail transport, Subsidy, Firm Competition, China-Europe freight trains, Ports.

Introduction

Since 2013 the Chinese Government has instituted a major policy initiative, to build the «Silk Road Economic Belt and the 21st-Century Maritime Silk Road,» also known as the «Belt and Road Initiative» (BRI). The BRI focuses on promoting connectivity and creating new trading routes passing through over 71 countries across Asia, Europe, and Africa. It consists of two main components, namely, the Silk Road Economic Belt, and the 21st-Century Maritime Silk Road. The former («Belt») is a land route designed to build a transportation and logistics chain from China to Europe (via Central Asia and Russia), and to develop economic corridors that connect China with other Asian countries. The latter («Road») is a sea route that runs through west from the east coast of China to Europe through the South China Sea and the Indian Ocean, and east to the South Pacific Ocean, and it aims to build efficient transport routes among major seaports in various countries.

The BRI is important and timely, especially given the rising costs in China (labor, land/housing, electricity, RMB appreciation, increasing environmental awareness, etc.) and the associated industrial structure changes. It also gives some structure and connectivity support to consolidate several regional economic blocks that China has actively engaged, such as ASEAN, ASEAN+3, RCEP, IBSA, and BRICS. The initiative becomes increasingly feasible now with China's rich experiences with transportation infrastructure development, trade liberalization, and its high-speed rail development, which has released much rail capacity for freight transport. Chinese ports have also gone through rapid developments over the last 25 years: for example, eight of the ten largest container ports are now located in China (including Hong Kong).

Until 2018, the freight trains operated on the China-Europe railway service network had reached 12,937 trips (Figure 1) and had

Figure 1. Number of China-Europe Freight Trains

Source: <https://www.yidaiyilu.gov.cn>

transported in total more than 1.1 million TEU (twenty-foot equivalent units) of goods between China and Europe. By the end of 2018, the freight rail services had 65 routes that link 56 Chinese cities with 49 cities in 15 European countries (<https://www.yidaiyilu.gov.cn>).

The main objectives of this paper are to develop an analytical model that captures the relationship between the «Belt» and the «Road», and to discuss the policy implications. The existing discussions (and, sometimes, debates) about the BRI have focused on the «Belt» and the «Road» separately, as if the two are independent and run in parallel. We will argue that the two are closely related, and further show the nature of the relationship. To illustrate, we notice, for instance, that the subsidies provided by governments (central, local) to container trains to Europe via the «Belt» are much higher than expected. A major reason for this may have to do with the recession in the ocean shipping industry due in part to the global financial crisis in 2008–09 and the European government debt crisis in 2011–12, and in part to the industry's overcapacity problem. As elaborated in the text, our analysis is based on the observation that very low container freight

rates in the «Road» have negatively spilled over the market in the «Belt».

On the other hand, one aim of the BRI is, as mentioned above, to develop economic corridors including the China-Pakistan Economic Corridor, and the Bangladesh-China-India-Myanmar Economic Corridor. Through these two corridors, China plans to allow its inner cities to connect to the Indian Ocean, without using river/land transport to seaports on the east coast. As a consequence, they would impact the container and liquid cargo movements for the Middle East, Europe and Shanghai and Hong Kong transshipments through the Malacca Strait (Li, 2014; Ranjan, 2015). In other words, the «Belt» development can, in turn, affect the «Road» development. Yang et al. (2018) suggested the negative impact of the improvement of the Eurasian Rail on the profit of COSCO, the largest Chinese liner shipping company. These inter-dependencies are very important not only for the industries but also for policy coordination. For instance, the BRI involves massive infrastructure development and hence, investment financing. This is a major driver behind the Asian Infrastructure Investment Bank, which was launched in 2015 and currently has 87

member states from around the world. A thorough understanding of the interdependencies will help develop better infrastructure financing and government support programs.

So far, most of the studies and debates on the BRI involve discussions revolving around the definition, motivation, and objectives of the project or its two components, «Belt» and «Road», in a separate fashion. A thorough analysis of the economic impacts of the initiative, as well as the interaction of its components, is still lacking. For example, Huang (2016) discussed the domestic and international motivation for the BRI, its general framework including geographic coverage, priorities for cooperation and key policy mechanisms along with as an assessment of the opportunities and risks brought about by the initiative. Cheng (2016) reviewed the real objectives behind the initiative, its priority country targets in terms of economic cooperation, along with the main drivers of the investment and trade (i.e., if they are market-based transactions or a form of foreign aid that is not based on economic calculation of gains and losses), and argued that the success of the BRI crucially depends on mutually beneficial economic cooperation. For the implications, Sheu and Kundu (2018) adopted a multi-methodological approach to address the dynamic and stochastic challenges that underlie the problem of the international logistics network reconfiguration induced by the BRI, and forecasted the time-varying logistics distribution flows along the «Belt» and the «Road». Lee et al. (2015) empirically analyzed the effects of the New Silk Road policy on the inter-country relationships between the countries involved in the project, using bilateral-trade data from more than 70 countries. They found that China has a dominant position in the New Silk Road network, while Central Asian countries such as Kazakhstan and Uzbekistan show no potential as hubs. Moreover, the success of the new initiative seems to mainly depend on the ability of the Chinese government to incorporate India, Turkey, and Russia.

Our study is related to the literature on the interaction between transportation facilities and on the economic impacts of transport infrastructure projects. There are extensive

studies on competition between transportation facilities and capacity decisions. De Borger and Proost (2012) and Lee and Song (2017) provide a general comprehensive review of literature, whereas Wan et al. (2018) provide a literature review in the maritime industry. The applications in the context of BRI are relatively rare. In this study, we borrow the Hotelling framework to model the demand for services at the new rail and at the existing port. A game theory approach is used to analyze the nature of the relationship between the existing marine trade routes and the new rail options in the context of BRI. Specifically, we investigate: (i) the impacts of the market conditions in the (exogenous) port sector on the demand for transport services and prices at the new rail; and (ii) the implications for the demand for rail and social welfare when the rail and port TOCs compete with each other. Our study focuses on the implications for the demand, subsidies and welfare gain while abstracting away the capacity decisions of the local authorities.

This paper is also related to modal choice studies. A conventional way to model the consumer's choice between multiple available transportation modes is to use discrete choice model. The discrete choice models use the probability that a specific alternative is chosen over the other alternatives to derive the demand for a mode of transportation. Our study uses, instead, the industrial organization (IO) and game theory approach to derive the facility demands. Similar to Basso and Zhang (2007), we assume that shippers are uniformly distributed along the city, while the transportation services are differentiated horizontally. This approach allows us to capture the impact of product differentiation and service quality on the demand for the new rail and social welfare. Unlike the existing literature, we provide a unified framework that allows us to analyze the relationship between the Belt and the Road in both the short and long run. More specifically, we investigate how the conditions in the port market affect the minimum subsidy required for the new rail TOC under the BRI. Furthermore, we identify the benefits for the shippers and TOCs from the development of the new railways under the BRI. Most importantly,

we analyze the policy and economic implications of different types of management of the rail and port facilities including separate and joint management of these two facilities. To our knowledge, this paper is the first to apply this IO and game theory approach to analyze the interaction between multiple transportation modes in the context of the BRI.

Our results show that the subsidy from the local and regional governments to the new rail terminal operator (TOC) is influenced by the economic conditions in the Road market. Essentially, the minimum subsidy is affected by the external shipping demand for the existing port, the maritime shipping freight rate, the marginal costs (operating cost and cost per departure) and ground transportation costs, along with the shippers' gross benefit and their value-of-time. The shippers' sensitivity to time and price also plays a significant role in determining not only the social benefit from the BRI but also the policy and economic implications of the management of the port and rail facilities. If the new rail can compete with the existing port TOCs, this would generate positive benefits for the region, by reducing the ground transportation costs and the shipping prices. Most importantly, the welfare gain for having the rail relies on the improvement of the service quality offered at the rail (potential reduction of delay costs) and the proportion of time-sensitive shippers.

The remainder of the paper is organized as follows. In Section 2, we develop a baseline model with a single transportation mode in pre-BRI. Section 3 analyzes the situation within the BRI where two transportation modes (port and rail) are considered but the port sector is exogenous. Section 3 investigates competition between rail and maritime TOCs. Section 4 considers a long-run situation where the port sector is no longer exogenous and explores the benefits of BRI in terms of social welfare gain, i.e. the benefit of having rail. Section 5 concludes.

Baseline model: a single transportation mode in pre-BRI

Over the last 25 years, Chinese seaports have shown rapid growth in the maritime

sector (for example, eight out of the world's top-10 container ports are from China). All shippers transport cargo using the sea routes, commonly known as the «Road» (labeled «r»; r for «Road»). The ports in China are usually owned and managed by the governments, while the downstream terminal operator companies (TOCs) operating the facilities are profit-maximizer firms (e.g., Yuen et al., 2013). Shippers using the services at the ports would pay the «full price», which includes the price charged by the TOCs, ground transportation cost, maritime freight rate and potential delay costs. In the present setup, we assume that the shippers are affected by the shipping market conditions, which are captured by the maritime freight rate. For the port delays, they are associated with the shippers' schedule preferences. Specifically, a shipper incurs a schedule-delay cost when his/her preferred departure (or delivery) time differs from the actual departure (or delivery) time set by the terminal operator company. Alternatively, lack of yard space to store containers and queues of trucks loading and unloading containers as well as an increase in the number of vessels relative to terminal capacity can contribute to delays at the port. As is common in the literature on congestible facility pricing, and for analytical tractability, we assume that the delay function is linear in quantity (i.e., the number of shippers using the port), but is inversely proportional to the port capacity, K_r . That is,

$$DC(q_r, K_r) = \frac{\gamma Q_r}{K_r} \text{ where } \frac{\partial DC}{\partial Q_r} > 0, \frac{\partial DC}{\partial K_r} < 0 \quad (1)$$

where DC denotes delay cost, Q_r denotes quantity, γ is a positive parameter that captures the shippers' valuation of time. Eq. (1) suggests that, given capacity K_r , a higher traffic volume on the sea routes generates additional delays at the port terminal, which in turn increase the delay costs incurred by shippers. Conversely, when capacity K_r increases, the port can handle more traffic movements and higher frequencies, leading to less delays and better service quality.

For simplicity, we assume that shippers are uniformly distributed along an infinite city with a density of one, and the existing port is located

at point 1, as depicted in Figure 2. Shippers will ship cargo through the port if their net utility, U_r , is positive, i.e. if their gross benefits from the cargo shipment exceed the full price. That is,

$$U_r = V - p_r - DC(Q_r, K_r) - t_r x_r - \bar{p}_s \geq 0, \quad (2)$$

where V denotes the common level of the shippers' gross benefit, p_r is the service price charged by the downstream operator, t_r is the road toll, x_r denotes the distance between the shippers' location and port terminal, and $\bar{p}_s$ is the sea shipping freight rate. Throughout the paper, we assume that the road toll is positive. We also suppose that the freight rate is given to shippers, as the market conditions in the maritime sector are influenced by external factors such as the local and global economic and financial conditions. Figure 2 presents the geographic representation of shippers along the city.

Denote x_l and x_r the last shipper located on the left and right side of the port terminal, respectively. The catchment area of the port is defined by $[x_l, x_r]$, where $x_l = 1 - \frac{1}{t_r} [V - p_r - DC(Q_r, K_r) - \bar{p}_s]$ and $x_r = 1 + \frac{1}{t_r} [V - p_r - DC(Q_r, K_r) - \bar{p}_s]$. Assuming that shippers have no benefits if they do not ship cargos, the demand curve is defined by $Q_r = x_r - x_l$, which leads to:

$$Q_r = \frac{2}{t_r} [V - p_r - DC(Q_r, K_r) - \bar{p}_s]. \quad (3)$$

For the port to receive a positive demand, the gross benefit from cargo shipment V needs to be sufficiently large and satisfies $V \geq p_r + \gamma Q_r / K_r - t_r / 2 + \bar{p}_s$. The inverse demand function, which comes from solving Eq. (3) for p_r , is:

$$p(Q_r) = V - \bar{p}_s - \left(\frac{t_r}{2} + \frac{\gamma}{K_r} \right) Q_r. \quad (4)$$

Consider N symmetric firms that operate the sea routes. The operating costs of firm i consist of a fixed cost per departure θ and a fixed cost per cargo unit ϕ . Denoting $f_r^i(K_r)$ the frequency of shipment offered by firm i , the cost of all departures for firm i is $\theta f_r^i(K_r)$. The total cost of all departures at the port terminal is $\theta f_r(K_r)$, with $f_r(K_r) = \sum_{i=1}^N f_r^i(K_r)$. As noted, we assume a positive relationship between capacity and frequency of shipment, i.e., a capacity

expansion leads to an increase in frequency. Additionally, frequency is an increasing function of capacity. Therefore, the total frequency at the port terminal can be expressed directly as a function of port capacity. To simplify the notations, hereafter we use θK_r^i and θf_r^i instead of $\theta f_r^i(K_r)$ and $\theta f_r(K_r)$, respectively, to denote the costs related to departures at the port terminal. With these specifications, the profits for firm i , denoted by $\pi^i(q_r)$, are:

$$\pi^i(q_r^i, q_r^{-i}) = p(Q_r) q_r^i - (\phi + \tau_r) q_r^i - \theta K_r^i, \quad (5)$$

where q_r^i is the output of TOC i , q_r^{-i} denotes the outputs of the port TOCs other than i , and $Q_r = \sum_{i=1}^N q_r^i$, and τ_r is the port charges. Following Wan and Zhang (2013), we consider the quantity competition between the TOCs, i.e., the TOCs simultaneously choose output q_r^i so as to maximize profits $\pi^i(q_r^i, q_r^{-i})$, given port capacity K_r . The first order conditions are characterized by:

$$\frac{\partial \pi^i(q_r^i, q_r^{-i})}{\partial q_r^i} = V - \bar{p}_s - q_r^i \left(t_r + \frac{2\gamma}{K_r} \right) - \left(\frac{t_r}{2} + \frac{\gamma}{K_r} \right) Q_r^{-i} - \left(\frac{t_r}{2} + \frac{\gamma}{K_r} \right) Q_r^{-i} - (\phi + \tau_r) = 0, \quad \text{for } i = 1, \dots, N,$$

where $Q_r^{-i} = \sum_{j=1, j \neq i}^N q_r^j$ is the total output of TOCs except TOC i . Solving the FOC for q_r^i , we obtain:

$$q_r^i = \frac{1}{t_r + 2\gamma/K_r} (V - \bar{p}_s - \phi - \tau_r) - \frac{1}{2} Q_r^{-i}.$$

Considering all firms operating the maritime routes. we have:

$$q_r^1 + q_r^2 + \dots + q_r^N = \frac{N}{t_r + 2\gamma/K_r} (V - \bar{p}_s - \phi - \tau_r) - \frac{1}{2} (Q_r^{-1} + Q_r^{-2} + \dots + Q_r^{-N}).$$

If we assume that the port TOCs are identical and have the same cost functions, the best response functions are similar across the TOCs. Therefore, there exists a Nash equilibrium, denoted by q_r^* , in which the outputs of the firms are the same i.e. $q_r^1 = q_r^2 = \dots = q_r^N = q_r^*$. This implies:

$$N q_r^* = \frac{N}{t_r + 2\gamma/K_r} (V - \bar{p}_s - \phi - \tau_r) - \frac{1}{2} [(N-1) q_r^* + (N-1) q_r^* + \dots + (N-1) q_r^*],$$

yielding:

Figure 2. Representation of shippers with a single transportation mode (port)

$$q_r^* = \frac{1}{t_r + 2\gamma/K_r} (V - \bar{p}_s - \phi - \tau_r) - \frac{(N-1)}{2} q_r^*.$$

Solving the above equation for q_r^* , we obtain the output produced by each TOC in equilibrium, which

$$q_r^* = \frac{1}{(N+1)(t_r/2 + \gamma/K_r)} (V - \bar{p}_s - \phi - \tau_r). \quad (6)$$

Given quantity q_p^* , the total output provided by the N TOCs in equilibrium is $Q_r^* = \sum_{i=1}^N q_r^* = Nq_r^*$. Equivalently, the derived demand for the existing port is:

$$Q_r^* = \frac{N}{(N+1)} \frac{(V - \bar{p}_s - \phi - \tau_r)}{(t_r/2 + \gamma/K_r)}. \quad (7)$$

For $Q_r^* \geq 0$, demands for port increase with the shippers' gross benefit and port capacity, but decrease with the marginal costs and shipping freight rate. An increase in road toll or transportation cost also reduces the number of shippers transporting cargo through the port. Not surprisingly, the demand expands when the number of TOCs (N) increases. The (equilibrium) price, denoted by p_r^* , is obtained by replacing Q_r with Q_r^* in the inverse demand function in Eq. (1). It is given by:

$$p_r^* = \frac{1}{(N+1)} (V - \bar{p}_s + N\phi + N\tau_r). \quad (8)$$

Interestingly, the price charged by each operator decreases with the number of TOCs at the port. Indeed, when the number of TOCs increases, the total output increases, resulting in a price decline and a reduction of the market share of each TOC. The total (equilibrium) profit is the sum of all the TOC profits, i.e. $\Pi_r^* = \sum_{i=1}^N \pi^i(q_r^*)$, yielding:

$$\Pi_r^* = \frac{1}{N} \left(\frac{t_r}{2} + \frac{\gamma}{K_r} \right) Q_r^{*2} - \theta K_r, \quad (9)$$

where $\sum_{i=1}^N K_r^i = NK_r^i = K_r$. For the case of a single terminal operator ($N = 1$), the monopolist offers quantity $q_{r,M}^*$ equal to $[(V - \bar{p}_s - \phi - \tau_r) / (t_r + 2\gamma/K_r)]$ and charges the price $p_{r,M}^*$, where $p_{r,M}^* = \frac{1}{2}(V - \bar{p}_s + \phi + \tau_r)$. The profit of the monopolist becomes $\Pi_{r,M}^* = \left(\frac{t_r}{2} + \frac{\gamma}{K_r} \right) q_{r,M}^{*2} - \theta K_r$.

Having explored the market conditions for the existing port and its downstream TOCs before the introduction of the BRI, we turn to the analysis of the new transportation system with two transportation modes: land and sea routes.

Two transportation modes (port and rail) with an exogenous port sector

In this section, we investigate the short-run situation following the implementation of the BRI, which brings into force a new transportation system that combines the port and rail facilities. The railways serve three land routes referred to as the «Belt» (labeled «b») starting from China to several destinations, while the «Road» (labeled «r» as indicated above) refers to the existing sea routes departing from Chinese coastal ports. Both port and rail facilities are owned by the government and run by either a branch of the central government or the local authorities. The BRI thus gives the shippers two alternative transportation mode choices, including the existing marine routes and the new railways. We assume that the geographic location of the existing port remains the same (at point 1 as shown in Figure 2), while the new rail station is built on the other side of the city, at point 0. Figure 3 gives a representation of the shippers along the linear city after the introduction of the BRI.

Though the new rail station is assumed to be located apart from the port terminal, there may be cases where the shippers incur the same amount of road toll whichever of the two transportation modes (rail or marine routes) they choose. Conversely, the transportation cost may differ depending on the land routes they select. To capture this locational effect, we consider two different road tolls for the marine and rail routes, denoted by t_r and t_b , respectively. This specification allows us to capture all the possible scenarios under the BRI and express the difference between the two options in terms of the transportation cost.

Pricing decisions of the terminal operator companies

Consider that the incumbent downstream terminal operator companies (TOC) serve the sea routes, while one major firm provides the services at the rail terminal station. Following Wan and Zhang (2013), we assume that the TOCs are competing with each other in quantity. Since the existing port is a “mature market”, the new entrant needs to offer better services or charge lower prices to receive a positive demand. Otherwise, the governments have to subsidize the downstream firms, at least in the short term, to ensure the continuation of services at the new rail station. In practice, the service price charged to shippers by rail TOCs has indeed been subsidized by the Chinese governments. The subsidized firms include terminal operators and local transportation companies (e.g. trucks) which transport shippers and cargos from their location to the

terminal rail station. In the next section, we attempt to determine the minimum subsidy for downstream rail TOCs.

We suppose that the downstream port TOCs maintain quantity, i.e., $Q_r^* = \bar{Q}_r$, given capacity $\bar{K}_r$. Therefore, when the new rail terminal operator enters the market and offers new services to shippers, it can expand the output, thereby lowering the service price. Similar to the previous case, the demand for rail services is determined by the net utility of shippers transporting cargo through the railways. This net utility, denoted by U_b , is given by:

$$U_b = V - p_b - DC(Q_b, K_b) - t_b x_b, \quad (10)$$

where p_b is the full price charged by the rail TOC including the line-haul cost, the shipping price per cargo unit, as well as the maritime shipping freight rate, $DC(Q_b, K_b)$ is the delay cost borne by shippers using the railways, x_b denotes the distance between the shippers' location and the rail station, and t_b is the unit transportation cost (or road toll). As previously stated, the road toll can be different across the two modes of transportation (hence, we add subscript b on t). The DC function depends on the total number of shippers using the rail facility and the rail capacity. A shipper will use the railways if his/her net utility is nonnegative, i.e., $V - p_b - DC(Q_b, K_b) - t_b x_b \geq 0$. Under the assumption of a uniform distribution of shippers along the infinite city, the (residual) demand that the new entrant is facing, denoted by Q_b , is:

$$Q_b = \frac{1}{t_b} [2V - 2p_b - 2DC(Q_b, K_b)]. \quad (11)$$

Figure 3: Representation of shippers with the “Belt” and the “Road”

Note: The figure is adapted from Basso and Zhang (2007) and Yang and Zhang (2012).

As expected, the quantity Q_b increases as the price p_b decreases. Moreover, the new entrant needs to provide a minimum frequency to guarantee a positive demand. This implies that the rail capacity should be able to handle all departures and container movements at the rail station. Hereafter, we maintain the assumption that the rail has enough capacity to fulfill the demand, i.e., capacity K_b satisfies $K_b \geq K_b^{min}$ where $K_b^{min} = \gamma Q_b / (V - p_b)$ is the minimum capacity level at which demand for rail services is null. Given that the rail TOC supplies quantity Q_b and the incumbent port TOC maintains $\bar{Q}_r$, the total market output becomes $Q_b + \bar{Q}_r$, and the associated inverse demand function facing the rail operator is $p(Q_b + \bar{Q}_r)$, where

$$p(Q_b + \bar{Q}_r) = V - \left(\frac{t_b}{2} + \frac{\gamma}{K_b} \right) (Q_b + \bar{Q}_r). \quad (12)$$

It is clear that as $\bar{Q}_r$ increases, the price $p(Q_b + \bar{Q}_r)$ drops for each shipped cargo. The price facing the new entrant also falls to zero when the number of port TOCs is sufficiently large, i.e., when the output $\bar{Q}_r$ exceeds $V / [(t_b/2 + \gamma/K_b) - Q_b]$, resulting in market exit for the latter. The profits of the rail TOCs, denoted by $\pi(Q_b)$, are:

$$\pi(Q_b) = p(Q_b + \bar{Q}_r) Q_b + s_b Q_b - \phi Q_b - \theta K_b, \quad (13)$$

where θ denotes the fixed cost per departure, ϕ corresponds to the operating cost per cargo unit, and s_b denotes the per cargo unit subsidy provided by the governments. In the short term, the new rail terminal operator does not pay a fee for using the rail ($\tau_b = 0$), but receives subsidy s_b . The maximization problem of the rail TOC with respect to the quantity Q_b leads to the following first order condition:

$$\frac{d\pi(Q_b)}{dQ_b} = V + s_b - \phi - \left(\frac{t_b}{2} + \frac{\gamma}{K_b} \right) (2Q_b + \bar{Q}_r) = 0.$$

The equilibrium quantity, denoted by Q_b^* , is the solution of the first order condition for Q_b and is given by:

$$Q_b^* = \frac{1}{t_b + 2\gamma/K_b} (V + s_b - \phi) - \frac{1}{2} \bar{Q}_r. \quad (14)$$

Assuming $t_b > 0$, the quantity produced by the rail TOC in equilibrium increases with

the shippers' gross benefit and rail capacity, but decreases with the fixed operating cost and exogenous demand for the port. A higher road toll would also penalize the users of the railways. Furthermore, the demand for rail services is hindered when the fixed demand for the port is large, and it even becomes null if $\bar{Q}_r$ reaches a certain level $\bar{Q}_{r,max}$, such that $\bar{Q}_{r,max} = (V + s_b - \phi) / (t_b/2 + \gamma/K_b)$. Nevertheless, the subsidies from the governments help the new rail TOC to maintain a positive demand and, much more, expand its output.

As the rail TOC uses quantities as a strategic variable, the price adjusts to clear the market. The price charged to shippers comes from replacing Q_b with Q_b^* in the inverse demand function in Eq. (12), yielding:

$$p_b^* = \frac{1}{2} \left[V - s_b + \phi - \bar{Q}_r \left(\frac{t_b}{2} + \frac{\gamma}{K_b} \right) \right]. \quad (15)$$

The rail TOC profits in equilibrium are:

$$\pi_b^* = \left(\frac{t_b}{2} + \frac{\gamma}{K_b} \right) Q_b^{*2} - \theta K_b = \frac{1}{2(t_b + 2\gamma/K_b)} \left[V + s_b - \phi - \bar{Q}_r \left(\frac{t_b}{2} + \frac{\gamma}{K_b} \right) \right]^2 - \theta K_b. \quad (16)$$

To prevent market exit, the TOC profits must be non-negative. To ensure $\pi_b^* > 0$, the quantity Q_b^* must be large enough (it should be higher than $\sqrt{\theta K_b / \left(\frac{t_b}{2} + \frac{\gamma}{K_b} \right)}$). Otherwise, the subsidies received by the rail TOC for each unit of cargo shipped through the railways should exceed $s_b \geq \phi - V + \bar{Q}_r \left(\frac{t_b}{2} + \frac{\gamma}{K_b} \right)$ for all $Q_b^* \geq 0$. The perspective of the public authorities, however, is slightly different in regard to setting the minimum subsidy for the new rail TOC. As the Chinese government owns the rail and the port facilities, they care about the profitability of both rail and marine businesses (rather than the rail only). In the next section, we discuss in detail the minimum subsidies required from the authorities to the rail TOCs.

Minimum subsidy for the new rail terminal operator company

Consider a local authority that chooses subsidy s_b to be allocated to the new TOC so as to ensure the starting and continuity of the rail services. Since both the port and the rail

facilities are owned and run by the Chinese governments, the authority considers the profits of both port and rail TOCs when setting the minimum subsidy. The total surplus, denoted by $\Pi_o(s_b)$, are:

$$\Pi_o(s_b) = \Pi_r^* + \pi_b^*(s_b),$$

where Π_r^* is the (equilibrium) profits of the incumbent firms operating the sea routes, and $\pi_b^*(s_b)$ denotes the rail TOC profits. The minimum subsidy, denoted by s_b^* , is the level at which the total TOC profits Π_o are non-negative. Equivalently, s_b^* is the solution of $\Pi_o(s_b^*) = 0$, which leads to:

$$s_b^* = \phi - V + \bar{Q}_r \left(\frac{t_b}{2} + \frac{\gamma}{K_b} \right) + \sqrt{2 \left(t_b + \frac{2\gamma}{K_b} \right) (\theta K_b - \Pi_r^*)}, \text{ with } \Pi_r^* = \frac{1}{N} \left(\frac{t_r}{2} + \frac{\gamma}{K_r} \right) \bar{Q}_r^2 - \theta \bar{K}_r. \quad (18)$$

First, it is required that the expression under the square root in Eq. (18), i.e. term $\left[2 \left(t_b + \frac{2\gamma}{K_b} \right) (\theta K_b - \Pi_r^*) \right]$, should be positive. This condition is satisfied when $\theta K_b \geq \Pi_r^*$. It states that the minimum subsidy accounts for the costs of all departures from the rail station, especially if they are very large, exceeding the profits of the port TOCs. The intuition behind this equation is that the local authority may use the net benefits from the existing port operations to cover the costs of all departures at the new rail facility. The part of costs not covered by the port TOC profits is incorporated into the minimum subsidy.

Second, the minimum subsidy s_b^* covers the fixed cost per cargo unit ϕ , but excludes the benefits arising from the exploitation of the shippers' valuation of services and their location preferences. It also compensates the loss of market share caused by the maturity of the port market and the exogenous demand for the port. In other words, the new entrant may fail to compete with the well-established firms serving the marine routes at least in the short term if it does not receive subsidies. Therefore, the minimum subsidy corrects this market failure and incorporates the costs associated with it, which mainly transportation and delay costs, in its expression. The last term on the RHS of s_b^* consists of a positive term under

the square root, which increases with the port capacity K_b and road toll t_b , but decreases with profits Π_r^* and with external shipping demand $\bar{Q}_r$. Nevertheless, this term captures only the partial effect of K_b , t_b and $\bar{Q}_r$ on the minimum subsidy.

The marginal impacts of each parameter of interest are given in the following equations:

$$\frac{\partial s_b^*}{\partial V} < 0; \frac{\partial s_b^*}{\partial \phi} > 0; \frac{\partial s_b^*}{\partial \theta} > 0; \frac{\partial s_b^*}{\partial t_b} > 0; \frac{\partial s_b^*}{\partial \gamma} > 0; \frac{\partial s_b^*}{\partial K_b} < 0; \quad (19)$$

$$\frac{\partial s_b^*}{\partial N} > 0; \frac{\partial s_b^*}{\partial \bar{Q}_r} > 0; \frac{\partial s_b^*}{\partial \bar{K}_r} > 0; \frac{\partial s_b^*}{\partial t_r} < 0; \frac{\partial s_b^*}{\partial \bar{p}_s} < 0. \quad (20)$$

Eq. (19) states that the minimum subsidy decreases with the shippers' benefits, but increases with the marginal costs per cargo unit and per departure. Not surprisingly, the rail operator would charge higher service price if the shipper's willingness to pay for the cargo shipment through the railways is large. This leads to higher profits, which therefore reduces the required minimum subsidy. Conversely, a large subsidy is needed if the marginal operational costs (per cargo unit and per departure) are large. Furthermore, the minimum subsidy is an increasing function of the value-of-time and road toll or transportation cost from the shippers' location to the rail station. When shippers have a higher value-of-time, it indicates that they will bear higher costs when delays happen at the rail station. The increase in the full costs leads to a decrease in demand for the rail, thus a loss of profits. As a consequence, a large subsidy is required to compensate for this loss. The same reasoning applies when transportation cost increases. As Wan and Zhang (2013) argued, a fall in road toll by an intermodal chain reduces the generalized cost paid by shippers and allows its downstream operator to charge a higher price, thus increasing the operator's marginal profit.

Regarding the influence of the market conditions on the marine market, clearly as the number of TOCs operating the sea routes increases, the residual demand for the new entrant decreases. The profits of the latter drop, resulting in higher minimum subsidy. The same situation happens when the external shipping demand ($\bar{Q}_r$) increases up to a threshold ($\bar{Q}_r^*$) or if there is a new investment in the port

capacity ($\bar{K}_r$) as it would stimulate the port demand. Interestingly, the impact of additional rail capacity depends on the level of external (exogenous) shipping demand for the existing port. When the port demand is very low, the potential market for the new entrant is large. Therefore, the rail operator can access this market, thereby expand its residual demand if there is an additional rail capacity. This leads to a reduction of the minimum subsidy. On the contrary, if the exogenous demand is large, the residual market for the new TOC is very limited, so an investment in additional capacity would not help increase the demand for the rail. The impact on the minimum subsidy therefore is reversed. Eq. (20) also shows that an increase in the ground access cost to the port reduces the minimum subsidy for the rail operator. The intuition behind this finding is that the market share for the existing TOCs is reduced if the transportation cost becomes more expensive. The new rail terminal operator can therefore benefit from this situation, especially if the cost incurred by the shippers to reach the rail station is cheaper. Interestingly, the effect of road toll is not as obvious when the road toll is similar across facilities (i.e., $t_b = t_r$). As a matter of fact, the effect depends on the level of different parameters, including external demand for the port, the actual road toll, the capacity levels and the number of firms operating the sea routes. Assuming that there is enough residual for the new rail operator, an increase in the road toll leads to an increase in the minimum subsidy. A higher road toll penalizes all the shippers transporting cargo through either mode. However, the demand for the new rail TOC is more affected considering that the port TOCs possess an exogenous shipping demand, hence the need for higher minimum subsidy. Finally, an increase in the maritime shipping freight rate reduces the minimum subsidy for the rail TOC. It is noted that the parameter $\bar{p}_s$ captures the state of the maritime market, i.e., lower values indicate bad economic times while higher values show good economic times. Our finding suggests that large subsidies are needed during very bad economic times. However, when the economic situation of the region improves, the new TOC needs fewer subsidies.

These results are summarized in Proposition 1:

Proposition 1.

Consider two transportation facilities with an existing port and a new rail. The maritime sector which is a mature market has access to an external shipping demand, while the new rail terminal operator receives a subsidy from the local authorities. The minimum level of subsidy is affected by the market conditions in both maritime and rail sectors. It decreases with the shippers' gross benefit and additional rail capacity but increases with the shippers' value-of-time, marginal shipping costs, and ground transportation cost to the rail station. Higher minimum subsidy is also required when (i) the number of TOCs on the sea routes increases, (ii) the external shipping demand is larger, and (iii) there is a new investment in port capacity. Finally, a larger minimum subsidy is required for the rail TOC if the shipping freight rate is low or if the transportation cost to the port is reduced.

Proposition 1 has several implications for the BRI. Essentially, new investments in rail capacity should increase the number of users of the railways because it allows the quality of services offered at the rail station to be improved by handling more frequencies of shipment and faster services while reducing the shippers' delay costs. This increase in demand would induce more profits for the new rail TOC and dwindle the required minimum subsidy from the governments. *Proposition 1.* also suggests that a low shipping freight rate combined with a small niche market for the rail TOC results in a large minimum subsidy. The positive spillover effects from the new investment in rail capacity can thus be offset if the well-established port TOCs dominate a large part of the shipping market (i.e. when $\bar{Q}_r$ or N is very large), or during bad economic times. This has been the case of the recession experienced by the ocean shipping industry resulting from the 2008–2009 global financial crisis that depressed the container rates along the maritime routes, which, in turn, negatively spilled-over to the rail market.

In 2017, sea transportation was still the predominant transportation mode for goods trading among countries under the BRI (66.1 %

of the total value of trading goods), while railway transportation was still not significant (2.0 % of the total) (SIC, 2018). In practice, the current sea shipping rate is quite low, i.e., approximately 3,000 USD per FEU (forty-foot equivalent units) from China to Europe. Given Proposition 1, the low shipping rate may imply that a large minimum subsidy is necessary for rail transportation. Thus, in order to support the development of the China-Europe freight trains, the Chinese governments provide generous subsidies for the rail services operated on the “Belt”, which can range from \$1,000 to \$5,000 for each FEU, accounting for up to one-half the total cost (Barrow, 2018; Mordor Intelligence, 2018). Table 1 presents information about some representative China-Europe freight trains, including the government subsidy, shipping rate, route distance, and time. The report by the Eurasian Development Bank (EDB) (2018) suggested that rapid growth of cargoes along China-Eurasian Economic Union (railway) routes in 2013 to 2016 was largely attributable to the subsidy of freight rates by the Chinese government. According to the EDB reports’ estimates, total subsidies on the freight trains provided by the Chinese government amounted to approximately \$88 million in 2016. China will start gradually reducing the subsidies it offers to China-Europe freight trains, in order to improve the efficiency and commercial viability of such services (Wang, 2018; Suokas, 2018).

In the next section, we investigate the long-run situation where the port sector is no longer exogenous, and the rail and port TOCs compete with each other in the shipping market.

Competition between the rail and maritime TOCs

In the long term, as the rail TOC develops its own market, strong competition between the TOCs in the downstream market is expected. The port and rail terminal TOCs are assumed to engage in quantity competition. We also allow for heterogeneity in the preferences of shippers in terms of service quality. Accordingly, the shippers are classified into two categories, including (i) those who are sensitive to time but less sensitive to price (labeled type «h=1») and (ii) those who are more sensitive to price but less sensitive to time (labeled «h=2»).

Let N_1 and N_2 be the number of type 1 and type 2 shippers, respectively, with $(N_1 + N_2)$ being the total number of shippers using the two facilities. The net utility of type h shippers transporting cargos from facility j is:

$$U_j^h = V - \beta_h p_j - \gamma_h \frac{Q_j}{K_j} - t_j x_j - \bar{p}_s, \quad (19)$$

$$j = \{b, r\}, \quad h = \{1, 2\},$$

where β_h and γ_h capture price and time sensitivity of type h shippers, respectively. We set $\beta_2 \geq \beta_1 > 0$ and $\gamma_1 \geq \gamma_2 > 0$. These conditions state that time-sensitive (price-sensitive) shippers are less (more) sensitive to price, but have higher (lower) value-of-time. This implies that time-sensitive shippers would normally favor the fastest services whereas the price-sensitive ones would choose the service offered at the lowest price. Under the above assumptions, the shipper who is indifferent between using either mode is located at $\tilde{x}^h$ (see

Table 1

Some representative China-Europe freight trains

Rail route	Distance (km)	Rate after subsidy (USD)	Days	Subsidy (USD)
Chongqing-Duisburg, Germany	11,179	6,200/FEU	14-16	3,500-4,000
Chengdu-Lodz, Poland	9,965	6,800/FEU	12-14	3,000-3,500
Zhengzhou-Hamburg, Germany	10,245	6,500/FEU	14-16	3,000-5,000
Wuhan-Czech, Poland	10,700	7,000/FEU	14-16	4,000-5,000
Suzhou-Warsaw, Poland	11,200	5,500/FEU	13-15	1,000
Yingkou-Moscow, Russia	8,232	2,650/FEU	10-11	0

Source: Compiled by the authors.

Figure 3), where $\tilde{x}^h$ comes from equalizing U_r^h with U_b^h . It is given by:

$$\tilde{x}^h = \frac{1}{(t_b + t_r)} \left[t_r + \beta_h(p_r - p_b) + \gamma_h \left(\frac{Q_r}{K_r} - \frac{Q_b}{K_b} \right) \right],$$

$$h = \{1, 2\}. \quad (20)$$

The last shipper (type h) located on the left side of the rail station and on the right side of the port terminal (see Figure 3), denoted by x_l^h and x_R^h , respectively, are given by:

$$x_l^h = - \frac{V - \beta_h p_b - \gamma_h Q_b / K_b - \bar{p}_s}{t_b} \quad \text{and}$$

$$x_R^h = 1 + \frac{V - \beta_h p_r - \gamma_h Q_r / K_r - \bar{p}_s}{t_r}. \quad (21)$$

By keeping the assumption of a uniform distribution of shippers along the city and further assuming that the shippers' location preferences are independent of their sensitivity to price and time, we derive the facility demands at any location $x \in [x_l^h, x_R^h]$, denoted by $\mathbf{Q} = (Q_b, Q_r)$, as follows:

$$Q_b = \rho (\tilde{x}^1 - x_l^1) N_1 + (1 - \rho) (\tilde{x}^2 - x_l^2) N_2, \quad (22)$$

$$Q_r = \rho (x_R^1 - \tilde{x}^1) N_1 + (1 - \rho) (x_R^2 - \tilde{x}^2) N_2, \quad (23)$$

where ρ denotes the probability that a shipper belongs to type 1, and N_1 and N_2 are the respective numbers of type 1 and type 2 shippers. Using the full expressions of the facility demands as a function of all parameters, it is easy to show that the demand for each facility is decreasing in own shipping price, but increasing in rival's price. The impacts of the price and time sensitivity depend on the relative price of services offered through the rail. Specifically, an increase in price sensitivity leads to higher demands for the rail (i.e. $\partial Q_b / \partial \beta_h > 0$) only if the shipping price via rail relative to that via port is low enough, satisfying $\partial p_b / \partial p_r < 1/3$. Conversely, if the shippers' value-of-time (γ_h) increases, it lowers the demand for rail because of the increased expected delay costs at the rail station.

The inverse demand functions come from solving Eqs. (22) and (23) for p_b and p_r . To save space and for the sake of clarity, we only report the expressions for the rail in the rest of the paper. The expressions for the port are

analogous because of symmetry. Hence, the inverse demand function for rail is given by:

$$p_b(\mathbf{Q}) = \frac{1}{\bar{\beta}} \left\{ \left[\rho N_1 \left(V - \bar{p}_s + \frac{t_b t_r}{t_b + t_r} - \frac{\gamma_1 Q_b}{K_b} \right) + \right. \right.$$

$$\left. + (1 - \rho) N_2 \left(V + \frac{t_b t_r}{t_b + t_r} - \bar{p}_s - \frac{\gamma_2 Q_b}{K_b} \right) \right] - \frac{t_b t_r}{2(t_b + t_r)} Q_r -$$

$$\left. - \frac{t_b(t_b + 2t_r)}{2(t_b + t_r)} Q_b \right\}, \quad (24)$$

where $\bar{\beta} = \rho N_1 \beta_1 + (1 - \rho) N_2 \beta_2$ is the (weighted) average price sensitivity of all shippers and N_h is the total number of type h shippers and Q_j is the demand for facility j . Because of the heterogeneity in the shippers' preferences, the average shipping price in (24) is weighted with factors ρN_1 and $(1 - \rho) N_2$, which are the proportions of time and price sensitive shippers. The price function also incorporates the heterogeneity in the transportation costs to the facilities. When the road toll is the same across the facilities, i.e. $t_b = t_r = t$, Eq. (24) becomes:

$$p_b(\mathbf{Q}) = \frac{1}{\bar{\beta}} \left\{ \left[\rho N_1 \left(V - \bar{p}_s + \frac{t}{2} - \frac{\gamma_1 Q_b}{K_b} \right) + (1 - \rho) N_2 \right. \right.$$

$$\left. \left(V + \frac{t}{2} - \bar{p}_s - \frac{\gamma_2 Q_b}{K_b} \right) \right] - \frac{t}{4} Q_r - \frac{3t}{4} Q_b \right\}. \quad (25)$$

In such case, road toll t measures the horizontal differentiation between the services, and thus the level of competition between the facilities.

Following De Borger et al. (2008) and Wan and Zhang (2013), we consider one monopoly TOC at each facility terminal. Since a few private operators often control the port-handling operations, they can be aggregated into one private monopoly operator per port for analytical simplicity. Profits of the TOC at facility j are given by:

$$\pi_j = p_j(\mathbf{Q}) Q_j - (\phi + \tau_j) Q_j - \theta K_j, \quad j = \{b, r\}. \quad (26)$$

where τ_j is the fee charged by facility j . The solution of the first order conditions with respect to $\mathbf{Q}$ leads to quantity equilibrium $\mathbf{Q}^* = (Q_b^*, Q_r^*)$, which is a maximum. The (equilibrium) quantity for the rail is given by:

$$Q_b^* = \frac{8}{g(\bar{\gamma})} \left[\frac{t_r(3t_b + 2t_r)}{4(t_b + t_r)} + \frac{\bar{\gamma}}{K_r} \right] \left[\rho N_1 \left(V - \bar{p}_s + \frac{t_b t_r}{t_b + t_r} - \right. \right.$$

$$\left. - \beta_1 \phi - \beta_1 \tau_b \right) + (1 - \rho) N_2 \left(V - \bar{p}_s + \frac{t_b t_r}{t_b + t_r} - \beta_2 \phi - \right.$$

$$\left. - \beta_2 \phi - \beta_2 \tau_b \right) \right], \quad (27)$$

where

$$g(\bar{\gamma}) = \frac{16\bar{\gamma}^2}{K_b K_r} + \frac{8\bar{\gamma}}{(t_b + t_r)} \left[\frac{t_r(2t_b + t_r)}{K_b} + \frac{t_b(t_b + 2t_r)}{K_r} \right] + \frac{t_b t_r (8t_b^2 + 8t_r^2 + 19t_b t_r)}{(t_b + t_r)^2}, \quad (28)$$

and $\bar{\gamma} = \rho N_1 \gamma_1 + (1 - \rho) N_2 \gamma_2$ is the (weighted) average time sensitivity of all shippers. It is noted that in equilibrium the demand for rail is affected not only by the level of heterogeneity in shippers' price and time preferences, but also by the level of transportation costs at each facility. As we can see in Eq. (27), the aggregate demand considers the weighted average value-of-time of shippers and heterogeneous road toll across the facility. This suggests that the impacts of road toll at each facility on the demand for rail is different, depending on their current levels. This distinction is important in our setting because it allows us to capture the impacts on the demand for rail transportation of any change in the transportation cost for the belt. However, when the road toll is the same for the rail and the port, the demand for rail becomes:

$$Q_b^* = \frac{32}{q_t(\bar{\gamma})} \left[\frac{5t}{8} + \frac{\bar{\gamma}}{K_r} \right] \left[\rho N_1 \left(V - \bar{p}_s + \frac{t}{2} - \beta_1 \phi - \beta_1 \tau_b \right) + (1 - \rho) N_2 \left(V + \frac{t}{2} - \bar{p}_s - \beta_2 \phi - \beta_2 \tau_b \right) \right], \quad (29)$$

where $g_t(\bar{\gamma}) = \frac{64\bar{\gamma}^2}{K_b K_r} + 48\bar{\gamma} t \left(\frac{1}{K_b} + \frac{1}{K_r} \right) + 35t^2$. In the latter case, the road toll has a similar impact on the demand for each mode.

Not surprisingly, the demand for the rail in equilibrium depends on the marginal costs of production, the shippers' willingness to pay and the average sensitivity to price and time, the road toll at each facility, the delay costs, and the sea shipping freight rate. The impacts of each parameter can be analyzed using Eq. (27), and through the following comparative statics:

$$\frac{\partial Q_j^*}{\partial V} > 0, \quad \frac{\partial Q_j^*}{\partial \phi} < 0, \quad \frac{\partial Q_j^*}{\partial \tau_b} < 0, \quad \frac{\partial Q_j^*}{\partial \bar{p}_s} < 0, \\ \frac{\partial Q_j^*}{\partial K_j} > 0, \quad j = \{b, r\}. \quad (30)$$

It is easy to show that the equilibrium quantities increase with the shippers' reservation value for cargo shipping V , but decrease with the marginal operational cost ϕ , facility fee τ_b , and maritime shipping freight rate

$\bar{p}_s$. Since an increase in the shipping freight rate leads to more expensive full costs for shippers, there will be less transportation demand for either mode as a result. Alternatively, if the marginal operating costs increase, the TOCs will increase the shipping prices, reducing the facility demand. In contrast, improvements in rail capacity or new investment in rail infrastructure stimulate the demand for the rail as they allow for reducing the delay costs at the rail station. However, new investment in port capacity reduces the demand for rail, as the alternative option becomes more attractive, leading to intensified competition.

An important feature of our model setup is the consideration of the shippers' valuation of quality of services and shipping price, along with the heterogeneity in the transportation costs. These aspects have important implications for the Belt and Road initiative. Taking the first derivatives of Eq. (27) with respect to the sensitivity parameters allows us to explicitly derive the following results for the rail:

$$\frac{\partial Q_b^*}{\partial \beta_1} < 0, \quad \frac{\partial Q_b^*}{\partial \beta_2} < 0, \quad \frac{\partial Q_b^*}{\partial \gamma_1} < 0, \quad \frac{\partial Q_b^*}{\partial \gamma_2} < 0. \quad (31)$$

Eq. (31) states that the sensitivity parameters have negative effects on the demand for rail. These findings suggest that when the shippers become more sensitive to time or to price, a slight improvement in the service quality or an increase in the shipping price would directly reduce the demand for rail transport. The difference of the impacts in terms of magnitude depends on the proportion of time- and price-sensitive shippers among all shippers. Indeed, the rail receives lower demand if the proportion of time-sensitive shippers decreases or if the shippers are less likely to be the time-sensitive type, while the port experiences the reverse effects due to competition effects. These results are summarized in *Proposition 2*.

Proposition 2.

Consider two downstream TOCs operating the rail and the port (one at the facility) and two types of shippers: time-sensitive and price-sensitive. The TOCs compete with each other in quantities to attract the shippers. Given the rail and port capacities, in equilibrium, the demand for the rail services decreases with

both the shippers' time and price sensitivity. The magnitude of the impacts of the sensitivity parameters depends on the proportion of time-sensitive shippers or/and the probability of being a time-sensitive shipper.

Proposition 2 states that the facility demands are largely affected by the sensitivity of shippers with respect to price and time. The implication for the BRI is that shippers who are more sensitive to price would consider transporting their cargos using the sea routes if the maritime industry can keep the maritime shipping price low. Conversely, the demand for rail should increase if the shippers are more likely to be the time-sensitive type as it is expected to provide faster services. In 2017, approximately 300,000 TEU of goods were transported between China and Europe using the railway. This constituted less than 2 % of the total trade volume (in TEU) between those two economies. However, regarding the value, the importance of China-Europe freight train services is much more visible – it is estimated that up to 7 % of the China-Europe trade was transported by rail in 2017 (Jakobowski, 2018). This comparison shows that the China-Europe freight trains are carrying high-value products. Indeed, goods transported by the China-Europe trains are mostly high-value and time-sensitive products, e.g., laptops, mobile phones, auto parts, household electronic appliances, and some perishable products. These products, particularly those produced in China's inland cities such as Chongqing and Chengdu, are still the main candidates for rail transport because the higher cost for using rail can be offset by lower inventory and capital costs (Hillman, 2018). It is also observed that companies such as HP, Dell, and Foxconn, who produce time-sensitive tech-related products, began moving production to inland cities in China, which might be taking the advantage of those cities linking with European countries by railway.

Welfare gain from BRI

Surplus gain with exogenous port sector

The surplus gain for having rail under the assumption of exogenous port sector consists of the sum of the net benefits of shippers arising from the development of the new or improved

railways and the profits of the rail TOC that receive subsidies from governments.

Recall that in the short term, the governments provide subsidies to the rail TOC for operating the railways. Without loss of generality, we assume that there is a subsidy cost c_s for each unit of shipped cargo. The welfare function is defined as follows:

$$SW_1 = CS_1 + \pi_b - c_s s_b, \quad (32)$$

where SW_1 denotes social welfare without competition and CS_1 denotes consumer surplus, which is given by:

$$CS_1 = \int_0^{x_l} [V - p(Q_b + \bar{Q}_r) - DC(Q_b, K_b) - t_b x] dx + \int_0^{x_r} [V - p(Q_b + \bar{Q}_r) - DC(Q_b, K_b) - t_b x] dx \quad (33)$$

where $x_l = 1 - \frac{1}{t_b} [V - p(Q_b + \bar{Q}_r) - DC(Q_b, K_b)]$ is the last shipper located on the left side of the rail and $x_r = 1 + \frac{1}{t_b} [V - p(Q_b + \bar{Q}_r) - DC(Q_b, K_b)]$ is the one on the right side of the port (see Figure 3). Replacing $p(Q_b + \bar{Q}_r)$ with its expression in Eq. (12) and solving the integrands in Eq. (33) yields:

$$CS_1 = \frac{t_b}{4} Q_b^2 + \left(\frac{t_b}{4} + \frac{\gamma}{K_b} + \frac{\gamma^2}{t K_b^2} \right) \bar{Q}_r^2 + \left(\frac{t_b}{2} + \frac{\gamma}{K_b} \right) \bar{Q}_r Q_b, \quad (34)$$

where $\bar{Q}_r$ is the exogenous port demand and Q_b is the (equilibrium) demand for rail which is given in (14). It is easy to show that the consumer surplus function is an increasing function of the shippers' willingness-to-pay but decreases with the costs (road toll, delay cost, and marginal operating cost). Interestingly, the shippers will benefit more from a higher subsidy s_b because it keeps the price of services through the railways lower. The rail TOC profit is given by Eq. (16), where Q_b is replaced with Q_b^* .

The following comparative statistics identify how the change in variable affecting the exogenous port sector, namely the external shipping demand, number of port TOCs, shipping freight rate, port capacity, and the subsidy and its cost, affect the social benefit from the new or improved railways. Therefore, we have:

$$\begin{aligned} \frac{\partial SW_1}{\partial \bar{Q}_r} &> 0; \quad \frac{\partial SW_1}{\partial n} > 0; \quad \frac{\partial SW_1}{\partial \bar{p}_s} < 0; \quad \frac{\partial SW_1}{\partial K_r} > 0; \\ \frac{\partial SW_1}{\partial s_b} &> 0; \quad \frac{\partial SW_1}{\partial c_s} < 0. \end{aligned} \quad (34)$$

As stated in Eq. (34), the market conditions in the port sector affect the surplus gain for the rail users. While the external shipping demand for the port, the number of terminal companies operating the maritime routes and the shipping freight rate have a positive influence on the welfare gain, and large subsidy cost reduces those benefits. The intuition behind these results is that as a mature market, the port either has a large external demand or accommodates a large number of TOCs. This situation results in a great subsidy for the rail TOC, especially if the shipping freight rate is low. This increased subsidy, in turn, allows the rail TOC to sustain and develop its operations. From the shippers' perspective, not only does the shipment through the railways remain at a low price due to the large subsidy from the government, but also the quality of service is also higher (i.e. faster services). This reasoning remains valid when the port capacity is expanded. However, the welfare gain diminishes when the subsidy cost increases.

These findings are stated in Proposition 3.

Proposition 3.

Consider an existing exogenous port sector which is a mature market with large external shipping demand. The social benefit for having a new rail depends on the market conditions in the port sector and the subsidy provided by the governments to the rail TOC. The benefit increases with the subsidy but decreases with the subsidy cost and the freight shipping rate. An increase in subsidy occurs when (i) the port demand gets larger, (ii) the number of TOCs serving the port increases, (iii) new investment in port capacity is made, and (iv) freight rate is higher.

The implication of Proposition 3 for the BRI is that in the absence of short-term competition between the rail and port terminal operators, the benefits from having a new rail mainly depend on the subsidies from the governments. Nevertheless, the subsidy cost should not be too high to countervail the positive effects of having rail transport. Therefore, it is not unreasonable for the Chinese governments to provide subsidies to the China-Europe freight trains to support their normal operations at the initial stage when the market demand is

not enough. The rail service between China and Europe is very beneficial for the regional economy, especially for those inland cities such as Chongqing, Chengdu, and Zhengzhou. The China-Europe freight trains have become an important platform for these inland provinces to open up and expand their cross-border trade. Although the governments provided subsidies to the rail service in the short term, they will be paid off through other business activities. For example, since Chongqing and Chengdu operate the freight trains between China and Europe, together with their low labor and land costs, HP and Foxconn chose to build plants there, which, in turn, generated many job opportunities and massive exports and imports.

Surplus gain when the port and rail TOCs compete

In this subsection, we consider the welfare gain from the BRI when we assume that the rail and port TOCs compete with each other to attract shippers. The welfare gain consists of the difference of social surpluses between post-BRI and pre-BRI, i.e. the difference between the benefits from having two transportation modes (outlined in Section 4) and a single transportation mode (outlined in Section 2). These benefits would come from the reduction in transportation costs and competition effects that lead to a decrease in shipping prices. Denote SW_0 as the social welfare pre-BRI, where:

$$SW_0 = CS_0 + \Pi_r + P_0. \quad (35)$$

CS_0 denotes consumer surplus, Π_r is the profit of the port TOC and P_0 denotes the revenue from the port charges during the pre-BRI period. Without loss of generality, the marginal operating costs of the facilities are null. Recall the net utility of a shipper in pre-BRI, U_r . For comparison purpose, we rewrite Eq. (2) as follows:

$$U_r^h = V - \beta_h p_r - \gamma_h \frac{\bar{Q}_r}{K_r} - t_r x_r - \bar{p}_s, \quad (36)$$

where $h = \{1, 2\}$.

In Eq. (36), we introduce terms β_h and γ_h to capture the price and time sensitivity of shippers. Hence, shippers are classified into two categories, i.e., time and price sensitive

shippers, as in Section 4. The use of terms ρ , N_1 and N_2 , which are, respectively, the probability of being a time-sensitive shipper, the number of time and price sensitive shippers, follows automatically. The equilibrium quantities, prices and profits obtained in (7)-(9) can also be easily adjusted. Furthermore, we assume that the services at the port in the pre-BRI period are offered by a monopoly TOC. Therefore, we set $N = 1$. These adjustments allow us directly to compare the outcomes from the two systems. Under the above assumptions, the consumer surplus function, CS_0 , is given by:

$$CS_0 = \rho N_1 \left\{ \int_0^{x_l^1} \left[V - \beta_1 p(\bar{Q}_r) - \gamma_1 \frac{\bar{Q}_r}{K_r} - \bar{p}_s - t_r x \right] dx + \int_0^{x_r^1} \left[V - \beta_1 p(\bar{Q}_r) - \gamma_1 \frac{\bar{Q}_r}{K_r} - \bar{p}_s - t_r x \right] dx \right\} + (1 - \rho) N_2 \left\{ \int_0^{x_l^2} \left[V - \beta_2 p(\bar{Q}_r) - \gamma_2 \frac{\bar{Q}_r}{K_r} - \bar{p}_s - t_r x \right] dx + \int_0^{x_r^2} \left[V - \beta_2 p(\bar{Q}_r) - \gamma_2 \frac{\bar{Q}_r}{K_r} - \bar{p}_s - t_r x \right] dx \right\}, \quad (37)$$

where $x_l^h = 1 - \frac{1}{t_r} \left[V - \beta_h p(\bar{Q}_r) - \gamma_h \frac{\bar{Q}_r}{K_r} - \bar{p}_s \right]$ and $x_r^h = 1 + \frac{1}{t_r} \left[V - \beta_h p(\bar{Q}_r) - \gamma_h \frac{\bar{Q}_r}{K_r} - \bar{p}_s \right]$ are the last type h shipper located on the left and right side of the port, respectively. The profits of the port TOC, denoted by Π_r , are given by Eq. (9) with $N = 1$. Without loss of generality, the marginal operating costs of the facilities are null. Therefore, the revenue collected from the port charges is $\tau_r \bar{Q}_r$.

Separate management of the rail and port facilities

We first consider the case where the local authorities manage the facility separately and set the facility fees $\tau = (\tau_b, \tau_r)$ so as to maximize its own welfare SW_j under the BRI. The maximization problem of each facility is given by:

$$\begin{aligned} \max_{\tau_b} SW_b &= CS_b + \pi_b + P_b; \\ \max_{\tau_r} SW_r &= CS_r + \pi_r + P_r \end{aligned} \quad (38)$$

where CS_j denotes consumer surplus post- BRI at facility j , π_j is the profit of the TOC of facility j , and P_b and P_r is the revenue from the facility charges. The optimal facility fees, denoted by $\tau^* = (\tau_b^*, \tau_r^*)$ is the solution of the following FOCs and SOC:

$$\frac{\partial SW_b}{\partial \tau_b} = 0; \quad \frac{\partial SW_r}{\partial \tau_r} = 0, \quad \frac{\partial^2 SW_b}{\partial \tau_b^2} \leq 0, \quad \frac{\partial^2 SW_r}{\partial \tau_r^2} \leq 0. \quad (39)$$

The surplus of the shippers who use the rail and port, respectively, are given by:

$$CS_b = \rho N_1 \left\{ \int_0^{x_l^1} \left[V - \beta_1 p_b(Q) - \gamma_1 \frac{Q_b}{K_b} - \bar{p}_s - t_b x \right] dx + \int_0^{x_r^1} \left[V - \beta_1 p_b(Q) - \gamma_1 \frac{Q_b}{K_b} - \bar{p}_s - t_b x \right] dx \right\} + (1 - \rho) N_2 \left\{ \int_0^{x_l^2} \left[V - \beta_2 p_b(Q) - \gamma_2 \frac{Q_b}{K_b} - \bar{p}_s - t_b x \right] dx + \int_0^{x_r^2} \left[V - \beta_2 p_b(Q) - \gamma_2 \frac{Q_b}{K_b} - \bar{p}_s - t_b x \right] dx \right\}. \quad (40)$$

$$CS_r = \rho N_1 \left\{ \int_0^{x_l^1} \left[V - \beta_1 p_r(Q) - \gamma_1 \frac{Q_r}{K_r} - \bar{p}_s - t_r x \right] dx + \int_0^{x_r^1} \left[V - \beta_1 p_r(Q) - \gamma_1 \frac{Q_r}{K_r} - \bar{p}_s - t_r x \right] dx \right\} + (1 - \rho) N_2 \left\{ \int_0^{x_l^2} \left[V - \beta_2 p_r(Q) - \gamma_2 \frac{Q_r}{K_r} - \bar{p}_s - t_r x \right] dx + \int_0^{x_r^2} \left[V - \beta_2 p_r(Q) - \gamma_2 \frac{Q_r}{K_r} - \bar{p}_s - t_r x \right] dx \right\}, \quad (41)$$

where $Q = (Q_b, Q_r) \geq 0$ are the (equilibrium) outputs obtained in Eq. (27); $\tilde{x}^h$, x_l^h and x_r^h are given by Eqs. (20) and (21). The profit function of each TOC in equilibrium is π_b and π_r , which can be obtained by replacing the quantity and price functions in Eq. (26) with their expressions in equilibrium. The revenues of the port and rail from facility charges, are, respectively:

$$P_b = \tau_b Q_b; \quad P_r = \tau_r Q_r. \quad (42)$$

The welfare function of each facility can be expressed as a function of the model parameters by substituting $\bar{Q}_r$, Q_b and Q_r in Eqs. (39) and (40) and in the profit functions with their expressions in equilibrium. Therefore, the surplus gain is defined as the difference between the social welfare when facility fees are chosen individually under BRI and the welfare pre-BRI. The social benefit under this scenario, denoted by ΔSW , is given by:

$$\Delta SW = SW_r(\tau_r^*) + SW_b(\tau_b^*) - SW_0(\tau_r), \quad (43)$$

where $\tau^* = (\tau_b^*, \tau_r^*)$ denotes the solution of Eq. (38). The expression for (42) is very long and tedious, thus we do not report the results to save space. Nevertheless, we discuss

the impacts of our parameters of interest in subsection 5.2.3.

Joint management of the rail and port facilities

This situation occurs when the local authorities choose facility fee $\tau = (\tau_b, \tau_r)$ so as to maximize the joint welfare. This is equivalent to assume that the rail and port are complementary. Denoted SW_1 , the joint-welfare of the facilities under the BRI. The maximization problem reads:

$$\max_{\tau_b, \tau_r} SW_1 = (CS_b + CS_r) + (\pi_b + \pi_r) + (P_b + P_r). \quad (44)$$

The optimal facility fees, denoted by $\tau^{**} = (\tau_b^{**}, \tau_r^{**})$, are the solutions of the following FOCs and SOC:

$$\begin{aligned} \frac{\partial SW_1}{\partial \tau_b} &= 0; \quad \frac{\partial SW_1}{\partial \tau_r} = 0, \\ \frac{\partial^2 SW_1}{\partial \tau_b^2} &\leq 0, \quad \frac{\partial^2 SW_1}{\partial \tau_r^2} \leq 0. \end{aligned} \quad (45)$$

The total consumer surplus is given by:

$$\begin{aligned} CS_b + CS_r &= \rho N_1 \left\{ \int_0^{|\bar{x}^1|} \left[V - \beta_1 p_b(Q) - \gamma_1 \frac{Q_b}{K_b} - \bar{p}_s - t_b x \right] dx + \int_0^{\bar{x}^1} \left[V - \beta_1 p_b(Q) - \gamma_1 \frac{Q_b}{K_b} - \bar{p}_s - t_b x \right] dx + \int_0^{1-\bar{x}^1} \left[V - \beta_1 p_r(Q) - \gamma_1 \frac{Q_r}{K_r} - \bar{p}_s - t_r x \right] dx + \int_0^{\bar{x}^1-1} \left[V - \beta_1 p_r(Q) - \gamma_1 \frac{Q_r}{K_r} - \bar{p}_s - t_r x \right] dx + (1-\rho) N_2 \left\{ \int_0^{|\bar{x}^2|} \left[V - \beta_2 p_b(Q) - \gamma_2 \frac{Q_b}{K_b} - \bar{p}_s - t_b x \right] dx + \int_0^{\bar{x}^2} \left[V - \beta_2 p_b(Q) - \gamma_2 \frac{Q_b}{K_b} - \bar{p}_s - t_b x \right] dx + \int_0^{1-\bar{x}^2} \left[V - \beta_2 p_r(Q) - \gamma_2 \frac{Q_r}{K_r} - \bar{p}_s - t_r x \right] dx + \int_0^{\bar{x}^2-1} \left[V - \beta_2 p_r(Q) - \gamma_2 \frac{Q_r}{K_r} - \bar{p}_s - t_r x \right] dx \right\} \right\}, \quad (46) \end{aligned}$$

where $Q = (Q_b, Q_r) \geq 0$ are the (equilibrium) outputs obtained in Eq. (27). The total profit functions in equilibrium is the sum of π_b and π_r , which are obtained by replacing the quantity and price functions in Eq. (26) with their expressions in equilibrium. Denoting $\tau^{**} = (\tau_b^{**}, \tau_r^{**})$ the solution of (38), the surplus gain for having rail when the rail and port are assumed to be complimentary are given by:

$$\Delta SW_1 = SW_1(\tau_r^{**}, \tau_b^{**}) - SW_0(\tau_r). \quad (47)$$

The analytical solutions of Eqs. (43) and (47) are very long and cumbersome, thus we do not report the results to save space.

Surplus gain for having rail

This section discusses the surplus gain for having rail obtained in Eqs. (43) and (47). The welfare gains can be expressed as a function of the model parameters by substituting $\bar{Q}_r$, Q_b and Q_r in the consumer surplus and profit functions with their expressions in equilibrium. The solutions of Eqs. (43) and (47) are very long and tedious, thus we do not report the results to save space. Nevertheless, the impacts of the model parameters in both competition and cooperation cases present similar features and can be analyzed through the following comparative statics:

$$\frac{\partial \Delta SW}{\partial V} > 0, \quad \frac{\partial \Delta SW}{\partial t_b} < 0, \quad \frac{\partial \Delta SW}{\partial t_r} > 0, \quad (48)$$

$$\frac{\partial \Delta SW}{\partial \theta} < 0, \quad \frac{\partial \Delta SW}{\partial \phi} < 0, \quad \frac{\partial \Delta SW}{\partial \bar{p}_s} < 0 \quad (49)$$

$$\frac{\partial \Delta SW}{\partial K_b} > 0, \quad \frac{\partial \Delta SW}{\partial K_r} < 0, \quad \frac{\partial \Delta SW}{\partial N_1} > 0, \quad (50)$$

$$\frac{\partial \Delta SW}{\partial \beta_h} < 0, \quad \frac{\partial \Delta SW}{\partial \beta_h} < 0, \quad h = 1, 2.$$

The results obtained in the first line of the results in Eq. (48) are as expected. The welfare gain is higher when the shippers show higher willingness to ship cargo through either transportation mode. Furthermore, improvements or new investments in railways induce positive benefits if the cost of transporting cargo to the rail station is cheaper but the transportation cost to the port is more expensive. If the latter cost remains very low, there may not be a shift in demand from the port to the rail. Therefore, the benefits of using the railways mainly rely on the improvement in service quality and reduction in delay costs. When the transportation cost is similar across facilities (i.e. $t_b = t_r$), road toll becomes an indicator of the competition between the TOCs. Hence, an increase in the road toll leads to a decrease in the surplus gain, as it increases the full costs of the shippers, regardless of the transportation mode chosen. The same situation occurs when the marginal costs (per cargo unit or per departure) increase. An increase in the maritime shipping freight rate also reduces the benefit from having

two transportation modes, as it penalizes the shippers that use the railways, by increasing their full costs.

The findings stated in Eq. (49) suggest that new investment in rail capacity improves the welfare gain while additional port capacity dampens it. An expansion of the rail capacity would reduce the potential delay costs at the rail. However, with new investment or improvement in the port facilities, the maritime routes become more attractive. As a result, there may be only a slight gain for having rail, unless the proportion of shippers who prefer better service quality over lower shipping price is very large. In the latter case, a small improvement in the service quality at the rail can lead to a significant modal shift from the maritime to the rail routes.

Finally, Eq. (50) shows the effects of time and price sensitivity on the surplus gain. Proposition 2. suggests that the demand for rail decreases with time and price sensitivity. It is clear that time-sensitive shippers are more penalized when the value-of-time increases (large value of γ_h) as they incur large delay costs ($\gamma_h Q_j / K_j$). The implication for the social welfare is that the net benefits of these shippers will be reduced significantly as a result of an increase in the value-of-time (γ_1). Though the welfare gain remains reduced when the value of time increases, the shippers who are less sensitive to time are less affected. Reversely, the demand from the price-sensitive shippers declines when price sensitivity parameter β_2 becomes higher, and this in turn reduces the welfare gain for having rail. It is noted that the magnitude of the shift in demand mainly depends on the relative importance of the time- and price-sensitive shippers. The more the number of the time-sensitive shippers increases, the more the benefit for having rail is evident.

Proposition 4 summarizes the findings.

Proposition 4.

The BRI leads to a positive social benefit when the port and rail TOCs compete in the downstream market. This benefit comes from the reduction in road transportation costs and in delay costs. But the benefit of having rail also depends on the investment in rail and

port capacity, the proportion of time-sensitive shippers and the probability that a shipper is a time-sensitive type. Indeed, a higher proportion of time-sensitive shippers and/or higher probability induces larger social benefits.

Proposition 4 implies that the BRI generates a positive surplus gain for both the shippers and TOCs in the long run if it induces reductions in the transportation costs and in shipping prices while providing better service quality. With the new rail facility (at point O), the transportation costs of the shippers located on the left side of the city are reduced because they are closer to a new transportation mode. Moreover, competition further leads to a decrease in the shipping price, reducing the full price paid by the shippers, then increasing the facility demands and the TOC profits. Nevertheless, the characteristics and preferences of shippers play an important role in determining this positive benefit. More specifically, there should be a considerable proportion of shippers who are time-sensitive, thus willing to use the railways and associated services for the surplus gain to be positive. Otherwise, the shippers will continue to use the maritime routes and the services offered by the rail TOC will not be sustainable in the long run without permanent subsidies from the Chinese governments.

Admittedly, subsidies are necessary for the China-Europe freight trains in the short term. However, it is not sustainable in the long term. The long-term benefits must come from a decrease in transportation and trade costs and better connectivity between China and Europe. A recent study by the World Bank shows that through a reduction in delivery times, the BRI could substantially reduce transportation and trade costs for participating countries, with positive spillover effects on the rest of the world (De Soyres et al., 2018).

Conclusion

In 2013, the Chinese governments launched the Belt and Road Initiative (BRI) to promote connectivity and create new trading routes passing through 71 countries across Asia, Europe, and Africa. This paper attempts to analyze the relationship between the belt and the road and discuss the policy implications

for the local and regional governments. Using the Hotelling framework and a game theory approach, we attempt to capture the interaction between the two transportation modes within the BRI, i.e., marine and rail. First, we study the complementarity between the existing port sector and the new railways. To do this, we investigate how the market conditions in the exogenous port sector affect the minimum subsidy provided by the Chinese governments to the terminal operator company of the new railways. Then, we explore the implications for the regional economy if the rail and port TOCs compete in quantity. The benefits of having rail transport are discussed in the two scenarios.

We find that the subsidy required for the new rail TOC to operate the new railways depends on the market conditions in the existing port market. Specifically, the minimum subsidy depends on the external shipping demand for the port and on the shipping freight rate. For example, the subsidy to the Zhengzhou-Hamburg freight trains equals the gap between the train shipping cost and the seaborne shipping cost (Jiang et al. 2018). The marginal operational costs, road tolls, shippers' gross benefits, and value-of-time also influence the subsidy. The benefits of shippers for having rail are perceived when the rail and port TOC can compete in quantities, as the reduction in shipping prices in conjunction with the decrease in ground transportation costs contribute significantly to improving the shippers' welfare gain. Accounting for the time and price sensitivity of shippers and the proportion of time-sensitive shippers is also very important in regard to the development of the belt. For example, the representative of a supply chain management company located at Chongqing indicated that in the past they would never import any fresh food from South East Asia, as it required 35 days to travel from South

East Asia, via Shanghai seaport, to Chongqing. After the New International Land-Sea Trade Corridor between Singapore and Chongqing, the logistics cycle is significantly reduced by 50%. Therefore, the company to launch the fresh food shipping service from South East Asia to the western part of China. It is also reported that the transportation cost for fresh fruits from South East Asia to Chongqing has been reduced by approximately 30%. High-value and time-sensitive products, such as IT products/components and auto accessories are the main cargos of the China-Europe freight trains (Hillman, 2018; Jiang et al., 2018). This study has important policy implications for the Chinese governments and for infrastructure financing and government support programs.

This paper uses an economic model that combines industrial organization and game theory to capture the relationship between the rail and the port, while focusing on the welfare gain for the regional economy, mainly the Chinese economy. However, the BRI is very complex as it involves many countries and several route alternatives. Though our modeling choice allows us to derive insights into the welfare gain for having rail, the modeling part can be enriched. First, discrete choice models can be incorporated into the modeling framework, as they analyze the decision-making of the shippers when choosing between several transportation modes. This approach allows deriving the probability that a specific mode is chosen over the other available alternatives. Second, for analytical tractability purpose, the model assumes that the shippers are uniformly distributed along the city. In practice, the hinterland partition among ports or modal splitting between the belt and the road are much more complicated. The analysis can be extended by considering Huff's Model of the trade area.

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