Density economies and transport geography: Evidence from the container shipping industry

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Abstract: By exploiting the 1995 Hanshin earthquake in Japan as an exogenous shock to the container shipping industry of Northeast Asia, this study provides empirical relevance on the role of transport density economies in shaping transport geography. The Hanshin earthquake caused severe damage to the Kobe port. Consequently, its container throughput was largely diverted to the nearby Busan port, which scaled up in this windfall. Focusing on the long-term growth of major port areas in Northeast Asia, we find that extensive diversions of container traffic occurred after the earthquake from the ports of Tokyo and Yokohama to Busan port, although container shipping operations in Tokyo and Yokohama were not directly affected by the earthquake. We interpret the economies of transport density benefitting Busan as an underlying mechanism: increased transport density allowed Busan port to further enlarge its hinterlands and reshape transport geography. We also find that the unintended diversions in container shipping led to a structural change in the manufacturing pattern of related regions.

Key words: hub port; density economies; transportation; Northeast Asia

JEL classifications: R40; L92; F19

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1. Introduction

Traditional New Economic Geography models consider the level of unit transportation costs as exogenously given and independent of the spatial structure of the economy (Fujita et al., 1999). However, this is implausible since the spatial distribution of economic activities directly affects trade flows and, therefore, unit shipping costs decrease in the presence of density economies of transportation (Behrens et al., 2006). For instance, in the context of the container shipping industry, density economies arise because the higher transport density of a route allows carriers to use larger vessels and operate this equipment more intensively. Additionally, higher transport densities allow for more intensive and efficient use of port facilities, and related services that serve the route, leading to lower time and costs per unit handled.

Based on the estimates of Mori and Nishikimi (2002), monetary transportation costs from Japan to Manila (non-hub port) are, on average, 22.6% higher than to Hong Kong (hub port), albeit the similar distance to Japan.[1] Increasing returns in transportation (i.e., density economies)[2] provide an incentive for collective cargo transport and, hence, stimulate the development of trunk routes, leading to the endogenous formation of trunk links and hub-spoke transportation structures. Thus, economies of transport density could be the primary source of industrial localization (Mori, 2012).

Nevertheless, given the solid empirical evidence that transport density is negatively associated with (both monetary and time) unit transportation costs, few empirical studies examine the role of transport density in shaping the transport geography, as predicted in theory. This study makes up the

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[1] Moreover, the port of Singapore is a large hub port linked to international trunk routes with a high frequency of ship calls, making travel time (including waiting time at port) to Japan only half of that from Jakarta, albeit the similar distances (Shipping Gazette, 1997). Similar evidence is found in Braeutigam et al. (1982), Caves et al. (1984), Brueckner et al. (1992), and Xu et al. (1994), for various transportation modes.

[2] Mori (2012) considers two types of increasing returns in transportation: distance economies and density economies. We focus only on density economies in this study (see Section 3 for details).

gap by employing a longitudinal container traffic dataset between Japan's prefectures (or shipper locations) and its domestic ports for exporting/importing cargo, and exploiting the exogenous shock of the 1995 Hanshin earthquake on Northeast Asia's container cargo flows.[3]

The Hanshin earthquake destroyed Kobe port, the largest container port of Northeast Asia at the time. Consequently, its container traffic was largely diverted to the closest major container port, Busan, reintegrating the container transportation market of Northeast Asia. Busan benefited from this exogenous windfall of container traffic and, thus, significantly expanded its scale of container transportation and increased transport density. Transportation costs from/to Busan were expected to decrease because of the existence of density economies. Therefore, Busan port enlarged its hinterlands by offering lower shipping charges and transportation time. Japan, whose territory is geographically close to Busan (pair-distances are 200–1,300 km, except for Okinawa prefecture), naturally becomes its potential new hinterland.

By establishing a toy model of port choice that links density economies in transportation, we test our hypotheses by examining the dynamics of shipper port choice behavior in Japan. Specifically, we choose northern Japan as study area (see Section 4.1 for the research design). We find that the container shipping market in northern Japan experienced a dramatic change after 1995, although this region was not directly affected by the earthquake. In the decade before the earthquake, more than 80% of its container cargoes were handled by Keihin port area (i.e., Tokyo and Yokohama, another major port area in Northeast Asia, except for the Hanshin port area and Busan port).[4] However, shortly after the earthquake, the situation within northern Japan changed significantly. Regions close to Keihin port area (*assumed to be its stable hinterland*) did not change port choice strategy. However,

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[3] As defined by the *Council on Foreign Relations*, Northeast Asia includes Japan, South Korea, and North Korea.

[4] Keihin port area refers to Tokyo and Yokohama ports (these two ports are geographically close to each other at around 30 km), Hanshin port area refers to Kobe and Osaka ports (these two ports are also around 30 km apart).

for regions remote to Keihin port area (*unstable hinterland of Keihin port area*), the market share of this port area declined significantly, to approximately 40%. The remaining shipping cargoes were largely diverted to Busan port via the regional ports in northern Japan for international transshipment. The diversion effect is quantitatively confirmed by a standard difference-in-difference (DID) estimation focusing on the port-specific cargoes in regions remote and close to Keihin port area, before and after the Hanshin earthquake.

We interpret these results as consequences of strengthened density economies in Busan port, caused by the windfall of container traffic diverted from the earthquake-affected Kobe port. Expanded shipping demands in Busan allowed it to develop a more efficient container transportation network,[5] thus successfully enlarging its hinterlands by gaining new markets that formed the hinterland of Keihin port area.

Furthermore, we provide a preliminary analysis on the impact of container traffic diversion on economic activity relocation. We find in northern Japan that regions diverting their container cargoes to Busan port expanded container trade tonnage volumes, while leaving trade values (taking the values of manufacturing input and output as proxies) largely unchanged, compared with the selected control regions. We interpret these results as more efficient shipping systems (through the expanded Busan port) shifting economic activity in related regions toward the production of heavy goods (high weight per value). This is consistent with Duranton et al. (2014), who find in the United States that cities with dense highways specialize in sectors producing heavy goods (high weight per value).

This study contributes to two bodies of literature. First, to the best of our knowledge, this is the first study to provide the empirical relevance of the role of transport density economies in the

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[5] For example, Busan port offers more international trunk routes, lower shipping rates for not only trunk route services but also feeder route services, and shorter transportation time (including waiting time at port).

transport geography, as theoretically confirmed by Mori and Nishikimi (2002), Behrens et al. (2006), and Mori (2012). Existing empirical studies find a negative relationship between transport density and unit transportation costs (e.g., Braeutigam et al., 1982 and Brueckner et al., 1992), but do not provide implications and evidence regarding the spatial scope of transportation activities. We find that the transport density may self-adjust transportation costs and thus reshape the transport geography.

Second, our analysis contributes to the literature on the empirical relevance of multiple equilibria (e.g., Davis and Weinstein, 2001, 2008; Bosker et al., 2007; Redding et al., 2011; Bleakley and Lin, 2012), which has hitherto been far from conclusive. Our work is most closely related to Redding et al.'s (2011), who examine the development of German airports before and after Germany's division following World War II, and identify the shift of the air hub from Berlin to Frankfurt as multiple equilibria in industrial locations. However, this study differs from Redding et al.'s (2011) in two respects. First, we use port-prefecture level container traffic data, while they rely on aggregate airport level traffic variation; one important advantage of our disaggregate data approach is that it allows identifying the source and heterogeneity of transport traffic change and exploit the underlying channel. Second, we examine related issues from a cross-country perspective, rather than a closed-economy one. Since the leading hubs for container shipping, as well as air traffic, are generally positioned globally, restricting the related analysis to a closed-economy perspective potentially leads to a one-sided analysis.[6]

The remainder of this paper is organized as follows. Section 2 presents the background information on the containerized shipping process, and port hierarchy in Northeast Asia. Sections 3,

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[6] It would be difficult to exploit the channel of post-1995 container cargo diversion in northern Japan if we consider only Japan's domestic ports and ignore the role of Busan port in South Korea.

4, and 5 present the theoretical framework, empirical strategies, and findings, respectively. Finally, Section 6 concludes the study.

2. Background

2.1. Typical container shipping process

Container cargo has become the major form of maritime shipping in Northeast Asia and globally since the 1970s. For example, containerization rates (i.e., proportion of container cargo in total maritime freight traffic, in ton base) in Japan were 94.6% for exports and 99.1% for imports in 2013 (74.7% and 81.5%, respectively, in 1985) (JALT, 1987, 2015). For South Korea, 90.3% of the throughput (in ton base) in Busan port (largest port of the country) was handled by containers in 2010 (Busan Port Authority, 2011).

Container shipping is operated by fixed time schedules (or, liner services) and ship calls serving for the interregional (intercontinental) carriage of freights. The typical process of container shipping consists of two parts: transportation in trunk and in feeder routes. Container ships navigating in a specific trunk route stop at designated major ports for container lift-on/off, but not stop at small-scale regional ports at the expense of longer transportation time, because the shipping demand in regional ports is limited. Then, feeder routes serve for the carriage of freights between a major port and its nearby small-scale regional ports, which use relatively smaller ships.[7] Therefore, in addition to port

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[7] For example, CMA-CGM/COSCO (CMA-CGM and COSCO are two worldwide leading container shipping companies) operates a trunk route between East Asia and North America, which starts from Shanghai port, stops at the ports of Ningbo and Busan, and then reaches the eastbound Los Angeles port. Subsequently, the ship returns to Shanghai directly, without any stops, because of limited transportation demands on westbound routes. The round trip is set for 35 days (Ocean Commerce Ltd., 2017). For a container cargo to be delivered by this route from a small-scale regional port in East Asia to Los Angeles, the cargo needs to be first transported from the regional port to a major port (gateway) where the trunk route stops (i.e., Shanghai, Ningbo, or Busan) through a feeder route. Moreover, when the trunk routes (or, frequency of ship calls) connecting two major ports are limited due to insufficient shipping demand, shippers need to transship cargoes to another major port as to reach the high frequent trunk route. A small-scale regional port usually has feeder routes with its nearby major ports only. For instance, a regional port in Japan may have short-haul liner services, or feeder routes, connecting it with Kobe and Tokyo ports (domestic), or Busan and Shanghai ports (foreign), rather than Singapore and Hong

infrastructure and facilities (e.g., berth length and water depth), the availability and capacity of container ships (e.g., ship size, number of trunk and feeder routes, and average frequency of ship calls on a shipping route) are also important for a port to efficiently absorb shipping demand and expand its capacity for container traffic.

Generally, there is no physical-operational difference between transshipment cargoes handled by domestic or foreign major ports in lifting on/off containers to/from trunk routes. A container ship can freely stop and make ship calls in a third country (i.e., in addition to the countries of origin and destination) based on the *"Principle of the Freedom of Shipping."*[8] Shippers' port choice for transshipment is thus mainly determined by the minimization of generalized transportation costs.[9]

2.2. The impact of Hanshin earthquake on port hierarchy in Northeast Asia

As a typical island country, the international trade activities of Japan are highly dependent on maritime transportation.[10] Among the dozens of sea ports in Japan, Kobe is historically the most important maritime hub of the country, its first container port with high standard container berths since 1967. During the late 1970s and the 1980s, with the generalization of scale economies on containerization and the development of hub-and-spokes networks, Kobe port became the main

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Kong port, because the latter are relatively far away from Japan, being inaccessible for most Japanese small-scale regional ports.

[8] Only except for the cases relate to the regulation of *Cabotage*, which is a protective policy for the domestic shipping market.

[9] For example, for Japanese container shippers to transship their cargoes in a major port before approaching their destination, they can freely transship in both domestic (e.g., Tokyo, Kobe) and foreign major ports (e.g., Busan, Shanghai) if related trunk routes are available in these ports. Japanese shippers are not subject to customs clearance if they just transship in Busan port (i.e., their destination is not South Korea), which is analogous to the air trip for passengers.

[10] In the case of international freight traffic, almost all cargoes are freighted by maritime transportation (99.2% for exports and 99.8% for imports, in ton base) in 2013 (99.6% and 100.0%, respectively, in 1985) (JALT, 1987, 2015). Domestic and international freight traffic are rather different in Japan. The former is dominated by overland transportation: 91.1% of domestic cargoes (in ton base) were freighted by truck in 2013 (90.2% in 1985), while the related share of maritime transportation is only 7.9% (8.1% in 1985) (JALT, 1987, 2015). [Railroads are mainly for the transportation of passengers but not cargoes in Japan. The related share of freight traffic was below 1% in both 1985 and 2013 (in ton base).] However, the related share of maritime transportation becomes considerable in terms of freight turnover (i.e., in ton-kilometer base). Maritime transportation accounts for 43.9% of domestic freight turnover in 2013 (47.4% in 1985) (JALT, 1987, 2015), which is much higher than that of freight traffic, implying the average shipping distance of maritime transportation is much longer than that of road transport.

gateway seaport in Asia and one of the leading container ports worldwide, reaching the top of the Japanese maritime hierarchy (Guerrero and Itoh, 2017). Although large container hubs emerged in neighboring countries (i.e., China and South Korea) from the late 1980s, diverting container cargoes from Japanese ports, Kobe port was still one of the leading container ports in Asia before 1995, having first-mover advantage.

However, Hanshin earthquake acted as a catalyst of the downgrade of Kobe port (Guerrero and Itoh, 2017). On January 17, 1995, southern Japan was struck by the Hanshin earthquake, which measured seven on the local seismic intensity scale. The port of Kobe, located 20 km from the epicenter, suffered destructive damage. The role of Kobe port in both Japanese and Northeast Asian port hierarchy underwent a significant change following the earthquake. Figure 1 (a) shows international container traffic for the major ports in Japan. Kobe ranked top in Japan's port hierarchy before 1995, while after the earthquake, Tokyo became the leading port, the container traffic of Kobe stagnating. By 2014, the container traffic of Kobe stabilized at roughly 80% of the pre-earthquake level (Figure 1 (a)). Regional ports (i.e., small-scale ports) in Japan developed during this period. Before the late 1980s, almost all international container cargoes in Japan were handled by the top five major ports (i.e., Kobe, Tokyo, Yokohama, Nagoya, and Osaka). From the early 1990s, particularly after the Hanshin earthquake, regional ports gained a greater market share (Figure 1 (a)).

Kobe performed as a major hub port for international container transshipment in Asia before 1995. In 1994, 31.6% of container cargoes in Kobe port were international transshipments. However, being the most vulnerable sector of port activities, the share of international transshipment cargo in Kobe significantly declined (below 1% in 2011; Figure 1 (b)).

The container traffic of Kobe port diverted to other major ports immediately after the Hanshin earthquake because port infrastructure and facilities were damaged. As shown in Figure 2, there are several major ports close to Kobe, either domestic ports (i.e., Osaka, Nagoya, Tokyo, and Yokohama), or foreign major ports (i.e., Busan, Shanghai, Keelung, and Kaohsiung),[11] which are candidates for diverting its international container traffic. Among these major ports, Busan port was selected to divert most container cargoes, especially transshipments, because of the following reasons.

First, Osaka and Nagoya ports were locally positioned, their scales being significantly smaller than the other three domestic major ports (Kobe, Tokyo, and Yokohama) in the 1990s. Therefore, their number of trunk routes and port facilities were not sufficient to absorb the container traffic of Kobe port. Second, the main hinterlands of Kobe port were the prefectures in southern Japan before the earthquake, which are relatively closer to Busan port than Keihin port area, especially the prefectures in Kyushu island or along the Sea of Japan (Figure 2). Third, the ports of Keelung and Kaohsiung are relatively further away from Kobe port.[12] Shanghai is relatively close to Kobe, however, its scale in the early 1990s was much smaller than that of Kobe port (as shown in Figure 1 (c)), that is, the capacity, especially water depth, was not sufficient to absorb the container traffic of Kobe port.[13] Then, the South Korean government provided policies and financial support for the development and expansion of Busan port.[14] Thus, shipping companies would prefer Busan port

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[11] All these four foreign major ports are located within 2,000 km of Kobe port. These four ports ranked top 25 (worldwide) in terms of container throughput in 1994: Kaohsiung, third; Busan, fifth; Keelung, 11th; Shanghai, 25th (Containerisation International Yearbook, 1996). China's Qingdao, Dalian, and Ningbo ports are also close to Japan and currently classified as major container ports. However, they were relatively smaller regarding container volume in the early 1990s, thus not being classified as major container ports.

[12] The spherical distances between the major ports (within 2,000 km of Kobe) and Kobe are as follows: Nagoya, 150 km; Keihin, 400 km; Busan, 550 km; Shanghai, 1,300 km; Keelung, 1,700 km; Kaohsiung, 1,950 km (precision of 50 km).

[13] The Yangshan deep-water port (terminal) at Shanghai started its operations in 2005, as a result, the port of Shanghai has been the world's top ranked container port since 2010.

[14] Along with offering discounted handling costs and expanded capacity at port terminals supported by the government, Busan has been developing more direct feeder services to regional ports in Japan since 1988 (Containerisation International, 1997) to enlarge its hinterlands, particularly after the Hanshin earthquake. Within the 29 Japanese regional ports with liner services to Busan port (by 2015), 12 regional ports established their first route to Busan during 1995–1998 (seven during 1999–2002), while during 1991–1994 (before the earthquake) only two did so (Source: Official homepages of Japanese regional ports).

when considering a new shipping route to replace Kobe port after the Hanshin earthquake (Harada, 1996).

Therefore, Busan port became the “winner” of the Hanshin earthquake. Immediately after the earthquake, during 1994–1995, the total container traffic of Kobe port decreased by 1.4 million TEUs (twenty-foot equivalent units), while that of Busan increased by 1.3 million TEUs (Figure 1 (c)). Given that the traffic of other major ports close to Kobe (i.e., Tokyo, Yokohama, Nagoya, Osaka, Kaohsiung, Keelung, and Shanghai) did not significantly fluctuate during 1994–1995, and the growth of Busan port in 1995 was significantly higher than in previous years (Figure 1 (a) and (c)), we may assume the container traffic in Kobe was mainly diverted to Busan. Regarding the hub function, Kobe port, as the gateway of Northeast Asia, was largely replaced by Busan port after the Hanshin earthquake (Guerrero and Itoh, 2017).[15] Busan’s international transshipment traffic received a major boost as a result of the diversion of several trunk routes from Kobe port (Fossey, 1997). As shown in Figure 1 (b), international transshipment cargoes in Busan port accounted for only 6% of its total container cargo in 1992, this figure increasing to 45% by 2011.

Table 1 shows the number of international liner services for major port areas in Northeast Asia in 1994 and 2012. We find the number of liner services to be significantly higher in Busan than in Hanshin and Keihin port areas, while in 1994 (before the earthquake), Hanshin and Keihin port areas had much more liner services than Busan.[16] Figure 1 (d) shows the relative scale of the three largest port areas in Northeast Asia (i.e., Keihin, Hanshin, and Busan). The sizes of the three port areas were comparable in 1994. Taking the total annual container traffic of the three port areas as 100%, Busan,

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[15] Although the damaged facilities of Kobe port were fully and quickly recovered, the container cargoes and trunk routes did not return back because the transportation network was reshaped (Guerrero and Itoh, 2017).

[16] When looking at the ranking changes of the world’s major container ports, Kobe ranked sixth in 1994, and fell in the top 20 by 1995 due to the Hanshin earthquake, while ranked fifth in 1994 and third position in 2000, becoming the top gateway port in Northeast Asia (Containerisation International Yearbook, various years).

Hanshin, and Keihin accounted for 29%, 33%, and 38%, respectively. However, in 2011, Busan accounted for 59%, while Hanshin and Keihin port areas accounted only for 16% and 25%, respectively.[17] Regarding container traffic, Hanshin port area showed an increase of 21% during 1994–2011, Keihin port area expanded by 68%, while Busan grew by 406% (Japan Port Statistics Yearbook, various years; Drewry Shipping Consultants Ltd., 2012).

3. Theoretical framework

This section shows how the density economies in container transportation affect the transport geography. Using a toy model on port choice, we assume that the economy is a two-dimensional space (expressed by rectangular coordinates) and firms (i.e., container shippers) are located on the X axis. Specifically, firms are continuously located at (x, 0), $x \in [0, F]$ $(F > 0)$, where (0, 0) and (F, 0) are the fringe locations on land, as shown in Figure 3 (a). Additionally, there are two hub ports located at (0, 0) and (0, c) ($c > 0$) of the Y axis, which are denoted as Hub 1 and Hub 2. Except for the one-dimensional space on the X axis, which holds the firms (and Hub 1), and location (0, c), which holds Hub 2, the other locations in this two-dimensional space are not available for economic activities, that is, they are assumed to be at sea. Each firm's location has a small-scale regional port, which is accessible to both hub ports, and feeder routes are available.

To freight container cargoes aboard (to an international destination beyond this two-dimensional space), these are loaded at firm locations (i.e., regional ports) and then transshipped in one of the hub ports, to be connected by an international trunk route. Direct delivery to the international destination

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[17] It is worth noting that the relative scale of Keihin port area also shrank, although it was not directly affected by the earthquake. The post-Hanshin earthquake decline of Keihin port area (relative scale) was first noticed by Chang (2000), who found the aggregate shares of regional ports increased after the earthquake and those of major ports decreased in Japan. However, Chang (2000) did not provide a detailed quantitative analysis due to data limitations.

without passing through a hub is assumed to incur significantly higher freight costs than that through a hub. The transportation costs of the feeder route (i.e., between the firm location and a hub) are proportional with the linear distance (without loss of generality, we assume the unit transportation cost on the feeder route to be 1). The transportation costs for shippers in location (x, 0) to Hub 1 are thus equal to x, and to Hub 2 are $\sqrt{c^2+x^2}$. We have $\sqrt{c^2+x^2}>x$ for all firm locations, since $c\neq 0$ (Figure 3 (a)).

We assume the transportation costs from hub port i to the international destination are negatively correlated with transport density ($d_i,\ i=1,\ 2$) on related trunk routes (each hub has its own trunk route to the international destination, and the trunk routes are independent), and the transportation distances from Hub 1 and 2 to the destination are assumed to be the same and constant. The transport density of trunk routes thus becomes the unique determinant of transportation costs on the trunk route between hub i and the destination (τ_i). If transport densities are same for both hubs (i.e., $d_1 = d_2$), then $\tau_1=\tau_2$.

The total transportation cost for container shipping (passing through hub i) is the sum of the freight costs on the feeder route (from the firm location to hub i) and the trunk route (from hub i to the destination), $TC_i(d_i,\ x),\ i=1,\ 2$, which is determined by d_i and x. Shippers make their hub port choice based on cost minimization. We set $TC(d_1,\ d_2,\ x)$ as the total transportation cost faced by a shipper located at (x, 0) after deciding on the transportation route to minimize costs, that is, $TC(d_1,\ d_2,\ x)=\min\{TC_1(d_1,\ x),\ TC_2(d_2,\ x)\}$.

We initially assume the transport densities to be the same for two trunk routes, and equal to a constant d_0: $d_1=d_2=d_0$, $\tau(d_0)=\tau_0$. Consequently, for all the firm locations, Hub 1 is preferred to Hub 2 in terms of total transportation cost, because:

$$\tau(d_1) + x < \tau(d_2) + \sqrt{c^2 + x^2} \text{ (i.e., } TC_1(d_1,\ x) < TC_2(d_2,\ x)\text{)},$$

as shown in Figure 3 (b). Therefore, we have $TC(d_1,\ d_2,\ x) = TC_1(d_1,\ x)$.

Based on the above setup, we perform a comparative static analysis by allowing an exogenous and positive shock on the transport density of Hub 2. d_2 now increased from d_0 to d_0', $\tau(d_2) = \tau(d_0') = \tau_0' < \tau_0$, while d_1 remains unchanged ($d_1 = d_0$) because the exogenous shock affects only Hub 2. Furthermore, we assume the following two inequalities are satisfied:

(1) $$\tau_0' + \sqrt{c^2 + F^2} < \tau_0 + F \text{ , or, } TC_2 < TC_1 \text{ at } (F,\ 0)$$

and

(2) $$\tau_0' + \sqrt{c^2 + 0^2} > \tau_0 + 0 \text{ , or, } TC_2 > TC_1 \text{ at } (0,\ 0).$$

This implies the shock heterogeneously affects *TC*(*x*) in the locations (*x*, 0) ($x \in [0,\ F]$). As shown in Figure 3 (c), a threshold location f_{div} exists:

$$TC(d_0,\ d_0',\ x) = \begin{cases} TC_1(d_0,\ x), \text{ if } x \in [0,\ f_{div}] \\ TC_2(d_0',\ x), \text{ if } x \in (f_{div},\ F] \end{cases}.$$[18]

For firm locations (*x*, 0) ($x \in [0, f_{div}]$), total transportation costs of container cargoes through Hub 1 are not higher than through Hub 2, while for locations $x \in (f_{div},\ F]$, related costs through Hub 2 are lower than through Hub 1 because of the exogenous shock (Figure 3 (c)). The dotted blue line in Figure 3 (c) refers to the change in *TC*(*x*) for all locations after the exogenous shock on d_2. That is, shippers in locations (*x*, 0) ($x \in (f_{div},\ F]$) may save on costs by diverting cargoes from Hub 1 to Hub 2, while for the remining locations, shippers tend to still transship the cargoes in Hub 1.[19]

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[18] If inequality (1) is not satisfied, then the transport density change in Hub 2 will not lead to a port choice change for all firm locations: all shippers still prefer Hub 1 to Hub 2. If inequality (2) is not satisfied, then the transport density change in Hub 2 will lead to a comprehensive port choice change. In other words, shippers in all firm locations will divert their cargoes from Hub 1 to Hub 2.

[19] For simplicity, we assume firms directly send container cargoes from their location to either Hub 1 or 2, that is, there are no sub-hub collecting cargoes before reaching Hub 1 or Hub 2. This assumption holds when the pair distance between the firm location and the hubs is not enough (see *distance economies* in Mori (2012), which refer to a decrease in transportation costs per distance by longer hauling). Furthermore, we assume the locations of Hub 1 and 2 are given but not endogenously determined. Consequently, the current comparative static analysis could omit the impacts of *distance economies*, since physical distance does not change due to the positive shock on d_2.

An exogenous change in the transport density of Hub 2 (trunk route) thus has heterogeneous impacts on port choice behavior among shipper locations. Two implications arise from this simple comparative static analysis:

- **[Implication 1]** Regions close to Hub 1 are not affected by the expansion of container traffic through Hub 2, while regions remote to Hub 1 benefit from the expansion;
- **[Implication 2]** Within the benefitting regions, the transportation cost saving (in absolute terms) is positively related with the location's distance to Hub 1.[20]

By extending the analysis to a multi-period setting, the container cargo diversions from Hub 1 to Hub 2 due to the exogenous shock further increase the transport density of Hub 2 (and decrease that in Hub 1 if total market container traffic does not change) and may further strengthen the density economies in Hub 2 and divert cargoes.

4. Research design and data

4.1. Research design

As per Section 2, Busan port expanded in 1995 because of the diversion of container cargoes from the earthquake-affected Kobe port, which is expected to exogenously increase its transport density. Busan port and the shock to its container traffic in 1995 are thus consistent with the specification of "*Hub 2*" in Section 3 (channel $a \rightarrow b \rightarrow c \rightarrow d$ in Figure 4). To test whether the expansion of Busan port leads to a spatial reorganization of the transport network, as predicted by the model, we focus on the locations which are initially the hinterlands of another major port area: Keihin port area (as "*Hub 1*" in Section 3). The logic of our research design is as follows (Figure 4).

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[20] As shown by the dotted line of Figure 3 (c), the cost change is equal to: $TC_1(d_0, x) - TC_2(d_0', x)$ $(x \in (f_{div}, F])$.

As assumed, to identify the change of firms' (shippers') port choice behavior stemming from the change in transport density, we need to ensure port choice behavior is not affected by other factors, except for economies of transport density. Particularly, the transport density in "*Hub 1*" should not be directly affected by the exogenous shock on "*Hub 2*" (as assumed in the model). Thus, the Hanshin port area and regions close to it do not qualify as study areas, since port choice there was directly affected by earthquake damage (i.e., exogenous shock). This would make it difficult to distinguish between the effects of density economies and of earthquake destruction on shippers' port choice behavior.[21]

Before the earthquake, northern Japan represented the hinterlands of Keihin port area, shippers here rarely using the Hanshin port area (see Section 5.1). Thus, the earthquake did not directly affect shippers' port choice in northern Japan. We may expect the diversions of port choice behavior in this region to Busan port, if any, to stem from the present channel in Section 3.

Moreover, the quasi "*X axis*" in the model represents shippers' locations in northern Japan, all being closer to Keihin port area than to Busan port (see, Figure 2). "*Firm locations (x, 0) ($x \in [0, f_{div}]$)*" in the model refer to the regions in northern Japan that are close to Keihin port area, which are not affected by the shock in terms of shippers' port choice. In the empirical analysis, these regions are set as the control group. On the other hand, "*firm locations (x, 0) ($x \in (f_{div}, F]$)*" in the model refer to the regions remote to Keihin port area, which are set as the treatment group.

As assumed, container shippers' port choice in the treatment group is affected by the expansion of Hub 2 (i.e., Busan port), since their container transportation costs will be reduced by diverting

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[21] Several existing studies examine the 1995 earthquake effects on the container traffic and hinterland of Kobe port (e.g., Chang, 2000; Itoh, 2013). They find solid evidence that the Kobe port persistently lost its shipping routes and hinterlands, particularly for international transshipment cargoes. Looking at the container traffic data on southern Japan, the stylized facts on port choice dynamics are consistent with the opinions presented in this paper. Regions in southern Japan that are close to Kobe port are still the hinterlands of Hanshin port area after the recovery of Kobe, while regions remote to Kobe (initially the hinterlands of Hanshin port area) diverted container cargoes to Busan port after the earthquake (graphical evidence is shown in the Supplementary Material).

cargoes from Keihin port area to Busan port (channel $d \rightarrow e \rightarrow f \rightarrow g$ in Figure 4). Specifically, "*Location (0, 0)*" in the model is mapping to Tokyo (closest prefecture to Keihin port area), and "*(F, 0)*" is Hokkaido prefecture (most remote prefecture to Keihin port area). The geographical locations of Keihin port area and Busan port, as well as regions within northern Japan, are thus fully matched to the model setup.

4.2. Data

As implied by the model, transport density tends to endogenously affect unit transportation costs. It is thus preferable to have generalized transportation costs (both monetary and time) for each shipping route, to test whether the transportation costs for the routes via Busan port significantly decline after the earthquake due to the higher transport density. However, the measurement of container transportation costs is complicated, and the necessary micro-level data are not available.[22] We thus test our model implications based on shippers' port choice behavior, as revealed preference. If container transportation costs are significantly reduced because of economies of transport density, we expect a partial diversion of container shipping from Keihin port area to Busan port.[23]

We identify the hub (gateway) port choice of northern Japan shippers based on the Container Cargo Flow Survey (CCFS) conducted by Japan's Ministry of Land, Infrastructure, Transportation

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[22] It is difficult to estimate the accurate container shipping freight rates (tariffs) between two ports because container transport is global, with each port as a node; most transportation by shipping companies (more than 80% of cargoes on trunk routes) is based on individual yearly contracts with large shippers. Therefore, the actual shipping tariff is not open to the public (interview with the staff of Japan Federation of Costal Shipping Associations and the Busan Port Authority). Alternatively, some organizations publish the aggregated container freight indexes on main routes for reference, such as, *Containerisation International*. However, the tariff index from these organizations represents the aggregated values on main routes such as Asia-North America and Asia-Europe, not on ports-pair. On the other hand, small shippers (less than 20% of cargoes on trunk routes) will have a contract with forwarders (not shipping company directly) because of the bargaining power of (relatively large) shipping companies. However, the contract price with forwarders includes not only shipping freight but also port handling and terminal handling charges, in addition to inland transportation and warehousing costs (interview with the staff of Japan Federation of Costal Shipping Associations and the Busan Port Authority). In the United States, import transaction-level shipment charges are available in the "US Census: Imports of Merchandise" (see applications in Hummels et al., 2009). However, related shipment charges (maritime shipping) are not available for Japan.

[23] Although micro-level container freight rate data are not available for Japan, the price advantage in Busan port could be partially observed. The transshipment at Busan has advantages against Japan's major ports (interview with Japanese forwarders). For example, the estimated shipping tariff from Busan to Los Angeles was USD 1,330 USD per TEU, and that from Yokohama to Los Angeles was USD 2,160 in 2010 (Drewry Shipping Consultants Ltd., 2010b).

and Tourism (MLIT). The database details prefecture-level trade volumes[24] (in ton base; separately for exports and imports) classified by the domestic major ports proceeding the customs clearance (i.e., Kobe, Osaka, Tokyo, Yokohama, Nagoya, and unclassified or aggregated small-scale regional ports) in 1985 and between 1988 and 2013 at five-year intervals (seven time waves).

The survey period covered by the CCFS is one month (October 1–31 in 1985, 1988, 1998, and 2003; November 1–30 in 1993, 2008, and 2013) in the selected years. It is thus necessary to verify whether it can be a proxy for annual data when calculating port-specific container handling volumes. By aggregating prefecture-port level monthly data of CCFS to port-level monthly data, and calculating the share of each port in the national monthly total container traffic, we find high correlations between the port-level handling share of monthly data (CCFS; measured in ton base) and that of yearly data (Japan Port Statistics Yearbook, various years; measured in TEU base) (Table 2). The correlation coefficients range from 0.93 to 0.99 (see the notes for Table 2), suggesting the monthly export/import data are adequate proxies of yearly data.

4.3. Identifying Japanese container cargoes transshipping in Busan

It is important for the empirical analysis to identify the expected container traffic diversion from Keihin port area to Busan port. However, we are able to identify the hub port for transshipment based on the CCFS only if the transshipment is handled by a domestic major port. For example, a container cargo originating from Miyagi prefecture in northern Japan, loading on feeder route in Shiogama port (a regional port in northern Japan), transshipping to trunk route in Tokyo port, and finally exporting to North America (NA), will be recorded as export from Miyagi prefecture and handled by Tokyo port, but not regional ports (Shiogama), because customs clearance took place at Tokyo port.

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[24] Includes only international maritime trade volumes handled by containers.

Alternatively, we are not able to directly identify the port for transshipment if the activity occurred in a foreign major port, since the CCFS does not record detailed port information for transshipment in foreign ports. That is, if this container cargo was loaded on a feeder ship in Shiogama port but transshipped to a trunk route in Busan port, it is recorded as export of Miyagi prefecture and handled by a regional port (Shiogama), based on the location performing customs clearance. As shown below, it is not possible to distinguish between Route *b* and Route *c* based on CCFS, because for both routes, the customs clearance took place at Shiogama port:

- Route *a*: Shiogama port→Tokyo port (domestic)→NA: handled by ***Tokyo port***;
- Route *b*: Shiogama port→Busan port (foreign)→NA: handled by ***regional ports***;
- Route *c*: Shiogama port→Shanghai port (foreign)→NA: handled by ***regional ports***.

However, we may partly observe the volumes of Japanese container cargoes transshipping in Busan port through the CCFS. Table 3 shows that the container shipping routes in Japan are systematically different for domestic major ports and regional ports. Approximately 80% of container traffic is directly shipped between the major ports of Japan and international origins/destinations, while for regional ports, approximately 80% of container traffic is transshipped in Busan port rather than shipped directly. For the Middle East, India, and Africa, this pattern is somewhat weak, but the trade volumes with these regions account only for 16.5% of Japan’s total trade volume (Data source: CCFS). The container traffic handled by regional ports is thus a proxy of Japan’s container traffic handled by Busan port.[25]

Additionally, CCFS records the aggregate container traffic for selected foreign major ports (e.g.,

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[25] Two regional ports are also considered international ports: Kitakyushu and Hakata, with greater scale than the general regional ports. That is, these two ports have trunk routes to some international destinations. However, these two ports are located in southern Japan; in northern Japan, the scale of all regional ports is small. Therefore, we assume the high transshipment share in Busan port (i.e., around 80%) applies for regional ports in northern Japan.

total Japanese container cargoes handled by Busan port). Table 4 presents the Japanese container cargoes handled by the ports of Busan, Shanghai, Kaohsiung, and Keelung (i.e., foreign major ports within 2,000 km of the main island of Japan), which are recorded for direct and transshipment cargoes, respectively.[26] We find that the volume of Japanese transshipment cargoes handled by Busan port was only 5,000 (15,000) tons for exports (imports) in 1993, but significantly increased to 77,000 (152,000) in 1998, and further expanded to 287,000 (550,000) tons by 2003. The related volume of Japanese direct cargoes handled by Busan port stagnated during 1993–2008 (from 522,000 to 513,000 tons). This suggests Japanese shippers significantly increased the volume of transshipment cargoes through Busan port after the Hanshin earthquake.

This trend, however, does not hold for the remaining foreign major ports close to Kobe (i.e., Shanghai, Kaohsiung, and Keelung). Although Kaohsiung and Keelung expanded the scale of Japanese transshipment cargoes in 2003, the volume declined quickly in 2008. Moreover, the ports of Kaohsiung and Keelung are relatively far away from our study area (i.e., northern Japan; the average distances between prefectures in northern Japan and Kaohsiung/Keelung are above 2,800 km), and regional ports in northern Japan rarely have liner services with the ports of Kaohsiung and Keelung (Source: Official homepages of Japanese regional ports).[27] Therefore, the container cargoes handled by the regional ports in northern Japan (i.e., they exit or enter Japan through domestic regional ports and are not transshipped in domestic major ports) are expected to mainly transship in Busan or Shanghai (which are closer to northern Japan, see Figure 2) to reach a remote international destination. As per Table 4, the total volume of Japanese transshipment cargoes handled by Shanghai

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[26] Direct cargoes refer to trade cargoes. For example, the direct cargoes handled by Busan port refer to the export (import) volumes from (to) Japan to (from) South Korea. The transshipment (or indirect) cargoes handled by Busan port refer to the volume of Japanese container cargoes transshipping in Busan port.

[27] The increase in Japanese transshipment container cargoes handled by Kaohsiung/Keelung ports in 2003 (Table 4) may stem from the increasing transshipment cargoes of regional ports in Southern Japan, and Japanese major ports.

port was only 31,000 tons in 2003, much less than that of Busan port (837,000 tons).

Therefore, we may assume that the container cargoes handled by the regional ports in northern Japan mainly transshipped in Busan port (if it is not a trade cargo to South Korea and China, otherwise it is a direct cargo and does not need transshipping). Our strategy to use the container traffic handled by the regional ports in northern Japan as a proxy for the related container traffic transshipping in Busan port is acceptable. To examine the expected diversion mechanism of port choice, as per Section 4.1, we need to test whether the share of prefecture-level container traffic handled by Keihin port area decreased and the relative share of regional ports (i.e., transshipment at Busan port) increased in the treatment group as a result of the Hanshin earthquake (exogenous shock on the transport density of Busan port).

5. Results

5.1. Descriptive evidence

Prior to the econometric analysis, we present descriptive evidence that the research design in Section 4.1 is logical. First, the distance to Keihin port area is heterogeneous for the prefectures in northern Japan, which is a necessary condition to identify heterogeneity for exogenous shock impacts (as in Figure 3 (c)). Eighteen prefectures located in northern Japan are included in our analysis, and their distances to Keihin port area range between 10 and 1000 km (Figures 2 and 5). Prefectures close to Keihin port area (below 250 km to Tokyo port, i.e., Group 1 in Figure 5)[28] represent the control group, and the remaining prefectures (i.e., Group 2 in Figure 5, more than 250 km away from

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[28] The cutoff distance (250 km) is set based on the geographical scope of Kanto region (including Tokyo, Chiba, Kanagawa, Saitama, Ibaraki, Tochigi, and Gunma). Nagano, Shizuoka, Fukushima, and Yamanashi are included in Group 1 because they are also located within 250 km from Tokyo port.

Tokyo port) constitute the treatment group. Specifically, Group 1 includes 11 prefectures (Tokyo, Chiba, Kanagawa, Saitama, Yamanashi, Nagano, Shizuoka, Fukushima, Ibaraki, Tochigi, and Gunma) and Group 2 includes seven (Hokkaido, Aomori, Akita, Yamagata, Niigata, Iwate, and Miyagi). As per the model, Groups 1 and 2 may respond differently to the expansion of Busan port, as only Group 2 tends to be affected by the Busan port expansion caused by the exogenous shock. Group 1 is the stable hinterland of the Keihin port area because of geographical proximity.[29]

Second, we need to ensure the Hanshin earthquake did not directly affect the container shipping activities in northern Japan, which is a necessary condition. The main hinterlands of Keihin and Hanshin port areas do not overlap. For these 18 analyzed prefectures, on average, more than 80% of the container cargoes (both imports and exports) were handled by Keihin port area before the earthquake (Figure A.1), scarcely using Hanshin port area. On average, the share of (container) freight traffic handled by Hanshin port area for northern Japan in 1993 was below 5% (computed based on the CCFS; see also Figure A.1).[30]

By contrast, for the remaining 29 prefectures (i.e., southern Japan; Japan consists of 47 prefectures), Hanshin port area was the largest gateway before the earthquake; they scarcely used Keihin port area, which held (on average) below 2% of the container traffic in 1993 (computed based on the CCFS, see also Figure A.2). The hinterland boundary of the two port areas is naturally set based on geographical proximity. Therefore, we may assume the port choice in northern Japan to not

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[29] One additional reason for the prefectures in Group 1 to be the stable hinterland of Keihin port area is the availability of road transportation. It is economical for local shippers to use road transportation between their locations to Keihin port area (Source: Regional Cargo Movements Survey, by MLIT). Although the unit price for road freight is much higher than for maritime transportation, road transport is preferred for short-distance freight because of its time efficiency. For example, in 2003, maritime transport accounts for 35.8% of Japan's domestic freight traffic for transportation distances of 300–500 km, 37.4% for distances of 500–750 km, and 55.9% for distances of 750–1000 km, while for distances of 100–300 km is just 18.0%, and 3% for less than 100 km (in ton base; JALT, 2005).

[30] Specifically, in 1993, 83.7% of exports and 88.4% of imports in Groups 1 and 2 were handled by Keihin port area, while for the remaining prefectures of Japan, this share was only 1.9% and 1.0%, respectively (CCFS; see also in Figures A.1 and A.2), implying that northern Japan is the only one and stable hinterland of Keihin port area in Japan. Hanshin port area is the largest international container gateway of southern Japan, followed by Nagoya port, and Busan port (via Japanese regional ports).

be directly affected by the Hanshin earthquake. The expected post-Hanshin earthquake container cargo diversion in Group 2, if any, stems from the economies of transport density in Busan port.

Figure 6 shows the trends of Group 1 and Group 2 on the share of (container) freight traffic handled by Keihin port area after the 1995 earthquake to meet model predictions. Before the earthquake, both groups are dominated by Keihin port area for both exports and imports: the average handling share was above 80% in all the three time waves (1985, 1988, and 1993). Although the share of Group 2 for 1985–1988 determinately decreased, this is solely affecting Hokkaido prefecture (Figure 6). However, after the earthquake, in 1998 and 2003, we find the related share of Keihin port area largely decreased for Group 2, while it insignificantly changed for Group 1. By contrast, the share of regional ports (i.e., cargoes transshipping in Busan port) significantly expanded after the earthquake (Figure 6) **[Implication 1]**. By depicting the disaggregated plot for these prefectures against their distances to Keihin port area, Figure 7 shows, for 1993, that the dominance of Keihin port area in Groups 1 and 2 is not correlated with the prefecture’s distance to Keihin. However, in 2003, prefectures close to Keihin port area almost stabilized regarding their container handling share to Keihin, while prefectures in Group 2 decreased their share, the more remote prefectures’ share declining more significantly **[Implication 2]**.

Table 5 presents the container handling share of Group 2 by ports in 1993 and 2003. In 1993, 81.0% of exports and 81.6% of imports in Group 2 were handled by Keihin port area, the shares largely declined by 2003. The lost market share was largely diverted to regional ports, as 51.8% for exports and 68.9% for imports from 9.7% and 15.7%, respectively. The aggregated share of Hanshin port area and Nagoya port is minor for Group 2 (and for Group 1, data being available upon request) during before and after the earthquake. Therefore, to observe expected port choice diversion, we need to only test whether the share of (container) freight traffic handled by Keihin port area in Group 2 decreased due to the exogenous shock at Busan port, which is equivalent to an increase in the market share of regional ports (i.e., the transshipment cargoes at Busan port) in Group 2.

5.2. Econometric results

Based on the stylized facts in Section 5.1, it is straightforward to conduct a DID estimation by comparing the pre- and post-earthquake scenarios, and Groups 1 and 2 regarding their container shipping market shares in Keihin port area. We conduct regressions by identifying the prefecture-port-year container traffic change as a result of the exogenous shock. The dependent variable is set as the prefecture-year level container handling share of Keihin port area (taking exports as an example): $Share_{it} = Volume_{it} / Tvol_{it}$. $Volume_{it}$ is the export container traffic of prefecture *i* in year *t* handled by Keihin port area and $Tvol_{it}$ is the total export container traffic of prefecture *i* in year *t*. The relative share of imports is calculated analogously. By testing the treatment effects on the port choice diversion with share data (i.e., $Share_{it}$) rather than absolute container traffic volume (i.e., $Volume_{it}$), we eliminate the disturbances from prefecture-year level fluctuations of trade performance and container traffic on baseline estimations.

As shown in equation R.1, *Postquake* is a dummy equal to 1 for the years after the Hanshin earthquake (1998, 2003, 2008, and 2013), and 0 for 1985, 1988, and 1993. *G2* is a dummy equal to 1 for Group 2 and 0 for Group 1. By taking Group 1 as the control group, we eliminate the impacts of the trends of regional port expansion in the entire country, as well as other unobservable factors affecting the container shipping industry in northern Japan, on the container shipping activities of Group 2. By interacting *Postquake* and *G2*, α, the DID term, captures the concerned treatment effect. δ and μ capture the prefecture and year fixed effects, respectively; ε is the error term (see the summary statistics in Table A.1):

(R.1)
$$Share_{it} = \alpha Postquake_t \times G2_i + \delta_i + \mu_t + \varepsilon_{it}.$$

The regression consists of 126 observations for exports and imports, respectively (18 prefectures and 7 time waves). Furthermore, to control for the pre-1995 trend, we estimate the year-by-year difference with equation R.2:

(R.2)
$$Share_{it} = \sum_{t=1}^{6} \beta_t Year_t \times G2_i + \delta_i + \mu_t + \varepsilon_{it}.$$

Year is a year dummy for six years, respectively (1988, 1993, 1998, 2003, 2008, 2013; 1985 is set as the reference year). Other variables are identical with those in equation R.1.

In equations R.1 and R.2, the treatment group is identified by a dummy variable (*G2*), that is, whether a prefecture is within 250 km of Keihin port area. Nevertheless, we need to test whether the setting of boundaries matters to the results, which leads to potential bias on the impact evaluation. We thus use a continuous variable (spherical distance from the core district of each prefecture to Tokyo port) to identify the proximity to Keihin port area as per R.3, where $\ln(Dist_i)$ is the logarithm of prefecture *i*'s distance to Tokyo port. Other variables are identical with those in R.2:

(R.3)
$$Share_{it} = \sum_{t=1}^{6} \gamma_t Year_t \times \ln(Dist_i) + \delta_i + \mu_t + \varepsilon_{it}.$$

Table 6 presents the estimations of equations R.1–R.3. In columns 1–2 (estimation of equation R.1), we find, after the earthquake, the share of (container) freight traffic handled by Keihin port area in Group 2 significantly declined, by 26.6% and 45.3% for exports and imports, respectively, compared with Group 1. In columns 3–4 (estimation of equation R.2), we have consistent results with the estimates of equation R.1, where a significant drop in the related share of Group 2 is observed since 1998 (post-Hanshin earthquake), but not in 1988 and 1993. This suggests the decrease of Keihin port area container handling share in Group 2 was not due to a pre-quake trend.[31]

Table 7 shows the between-year difference based on the estimates of columns 3–4 of Table 6. We find the major decrease of container handling share in Keihin port area for Group 2 occurred during 1993–2003, the period when Kobe was destroyed and the new port hierarchy was under reconstruction. Before the earthquake (1985–1993), and after the reshaping of the transport network (2003–2013; that is, the port hierarchy moves to a new steady status), we do not find a significant difference between the two groups or between periods (1985–1993, 2003–2013). We thus expect the diversion in port choice from Keihin port area to Busan port via Japanese regional ports exists only during 1993–2003. Based on the estimates in Table 7, the relative share of exports and imports declined by 31.2% and 47.2%, respectively, in 1993–2003. This can be interpreted as the exogenous expansion of Busan port's transport density by Hanshin earthquake led to a spatial reorganization of northern Japan's container traffic. Keihin port area lost part of its hinterlands in northern Japan.

Although northern Japan is dominated by Keihin port area and regional ports, a small part of the container cargoes is handled by other domestic major ports (i.e., Kobe, Osaka, and Nagoya) (Table 5). We thus replace $Share_{it}$ with the aggregated share of (container) freight traffic handled by five domestic major ports instead of the share of (only) Keihin port area. Subsequently, the estimated diversion effects stem from the traffic diversion from major to regional ports. Related estimations are shown in columns 5–6 of Table 6, the results being essentially unchanged. Finally, to avoid bias from the dummy variable setting of the treatment group, columns 7–8 of Table 6 (estimation of equation R.3) show the distance effects are highly significant from 1998, which is consistent with Figure 7.

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[31] To relieve the limitations of the present results arising from the small sample size, we test the statistical significance using bootstrapped standard errors (100 and 500 bootstrap repetitions). Results are essentially consistent with the baseline estimates in columns 3–4 of Table 6, and available upon request.

Therefore, we find, for Group 2, the share of (container) freight traffic handled by Keihin port area declined by 31.2% and 47.2% for exports and imports respectively between 1993 and 2003 (Table 7); the lost market share of Keihin port area was largely diverted to regional ports. Given that most container cargoes of Japanese regional ports are transshipped in Busan port (Tables 3 and 4), we can conclude that, for Group 2 in northern Japan, the container cargoes were diverted from Keihin port area to Busan port via Japanese regional ports due to the economies of transport density in Busan port.

5.3. Omitted variables and additional concerns

The bias of baseline estimations from omitted variables is still of concern. First, we need to confirm whether the port choice change of container shippers in Group 2 is due to the development of regional ports in this group. Our results tend to be biased if regional ports in Group 2 show better development than Group 1 after 1993. All container terminals at regional ports in both Groups 1 and 2, except major ports, have been developed and started their operations in the 1990s or earlier, although international container traffic did not significantly expand before 1995.[32] Furthermore, there were no significant policy changes or large-scale investments for regional ports in northern Japan. Therefore, regional container port development does not seem to be a valid explanation of the post-Hanshin earthquake port choice diversion in Group 2 only.

Second, the direction imbalance in transportation is concerning. Among the literature discussing the impact of endogenous transportation costs on economic geography, one additional channel, except for the economies of transport density, is the directional imbalance (e.g., Behrens and Picard,

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[32] In this context, the container traffic refers to the trade cargoes (i.e., export and import) only, as recorded in the CCFS, and does not include the cargoes loaded in regional ports and transferred in Japan's domestic major ports. For the latter, it is recorded as container cargoes handled by the domestic major ports.

2011; Jonkeren et al., 2011; Takahashi, 2011; Tanaka and Tsubota, 2017), which suggests its positive relation with transportation costs.[33] High transport density in one direction will lead to an opportunity cost of returning empty, thus increasing the freight rates charged to shippers in net exporter regions. The net effect of a change in trade volume on trade costs is therefore theoretically ambiguous, as it depends on what type of effect dominates, density economies (encourage agglomeration) or directional imbalance (encourage dispersion) (Jonkeren et al., 2011).

Since the directional imbalance also affects unit shipping costs in Busan port, it tends to be the omitted variable. Unfortunately, data for measuring the directional imbalance of container cargoes in Busan port are not available. Alternatively, we present the empty container share incidence by region to show that the condition of directional imbalance in container shipping is stable during 1980–2009 (Table A.2). There was no significant and persistent global change in the empty container incidence during 1980–2009 (relative share stabilizes around 21.0%). Therefore, port choice diversions tend to be affected by density economies rather than directional imbalance in container transportation.

Third, over-capacity in Keihin port area may potentially lead to a diversion of container cargoes in northern Japan. That is, shortly after the Hanshin earthquake, container shippers previously using Kobe port may first choose to divert their cargoes to Keihin (or Nagoya) port area, since it is relatively closer than Busan port to Japanese shippers in the prefectures along the Pacific Ocean. Consequently, container cargoes diverted from shippers in southern Japan may lead to an over-capacity in Keihin port area, the freight rate and waiting time for shipping being expected to increase. In this case, the diversion of container traffic from Keihin port area to Busan port in Group 2 may stem from the increased freight rate and transportation time in Keihin port area (because of

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[33] For example, the container freight index from Shanghai to Los Angeles, or eastbound, was USD 1,330 per TEU in January 2016 and from Los Angeles to Shanghai, or westbound, is only USD 600 per TEU because of lower demand (Drewry Shipping Consultants Ltd., 2016).

over-capacity), but not because Busan port offers lower prices and more efficient delivery (because of the density economies in transportation).

Port-level longitudinal data for container shipping rates not being available, it is impossible to compare the transportation cost changes before and after 1995 for Keihin port area. However, we can still reject the above assumption based on two stylized facts. First, as shown in Figure A.2, for all the prefectures in southern Japan (28 prefectures, excluding Okinawa), the average export/import container traffic share handled by Keihin port area is 2.5%/1.5% in 1993 and 2.9%/1.3% in 1998. The related share did not significantly increase after the earthquake. Even for the prefectures relatively close to Keihin port area (i.e., Shiga, Gifu, Mie, and Aichi) (see Figure 5), we do not find any observable increase of related share in the years after 1995 (Figure A.2).[34] In short, there is no evidence that the diverted container cargoes from Hanshin port area led to over-capacity in Keihin port area, as no prefectures in southern Japan increased their shares of Keihin port area after 1995. Second, as per Figure 1 (a), the container traffic of Keihin port area, especially Tokyo port, increased continuously during 1995–2014, although the growth rate is much lower than Busan port's. This suggests the absolute capacity of Keihin port area is not strongly stressed, otherwise, it is expected that the container traffic of Keihin port area stagnated after 1995.

We are also concerned whether the expansion of Busan port in 1995 was caused by the national trade expansion of South Korea, rather than the Hanshin earthquake. By examining the trade growth of South Korea for 1985–2011, we find the mean annual trade volume growth to be 11.0% during 1984–1994 and 10.9% during 1995–2011 (WTO, 2016; USD value terms). Before and after 1995, the trade growth rate did not change significantly. Therefore, the *leap-style growth* of Busan port in

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[34] The lost market share of Hanshin port in the southern Japan prefectures is mainly gained by regional ports (i.e., most are transshipped in Busan port) and Nagoya port (for the prefectures very close to this port, such as Aichi, Gifu, and Shiga) (see the Supplementary Material for details).

1995 is expected to mainly stem from the container traffic diversions of Kobe port, as shown in Figure 1 (a) and (c). Moreover, as per Table 4, the trade cargoes (i.e., direct cargoes) between Japan and Busan port stagnated during 1993–2008. This implies the solid increase of container traffic handled by the regional ports of northern Japan is not likely to be caused by the expanded trade volumes with South Korea, but the transshipment cargoes handled by Busan port.

Additionally, there was no significant market-oriented reform in both Japan and South Korea. As such, the institutional features are essentially unchanged and the related omitted variables do not impact the causal inference of the current analysis.

5.4. Additional results on trade volumes and manufacturing structure

A decrease in container transportation costs reflects an increase in productivity that affects industries producing heavy goods more than those producing light goods.[35] This implies that the port choice diversion of shippers in Group 2 from northern Japan may alter the patterns of its comparative advantage and lead to greater specialization in the production and trade of heavier goods (see a detailed discussion on mechanism in Duranton et al., 2014). Moreover, Ducruet and Itoh (2016) find port throughput specialization largely reflecting local economic specialization. A structural change in manufacturing production and trade pattern of Group 2 is thus expected.

Figure 8 confirms this hypothesis. By plotting the time trend of total container tonnage volume by region, we find Group 2 experienced a much higher growth since 1998, especially during 1998–2003, than Group 1, while the growth patterns of Groups 1 and 2 are similar for the earlier years (i.e., 1985–1998). We also exclude the Tokyo metropolitan area (MA) (Tokyo, Kanagawa, Saitama, and

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[35] For maritime shipping (not only container shipping), the tariff of heavy goods will be measured by weight volume, while cubic volume is suitable for light goods. Due to the limitations on data (data in the CCFS are measured in weight volume, and not in cubic volume), we focus only on the weight volume of container cargoes.

Chiba) from Group 1, since Tokyo MA is the most important industrial area of Japan, its container trade volumes and growth pattern not being comparable with the peripheral regions'. However, the trend does not essentially change (Figure 8). By replacing the dependent variable with the prefecture-year level container cargo traffic (absolute tonnage volume), we re-estimate equation R.1. The results in Table 8 are consistent with Figure 8. Column 1 implies Group 2 (excluding Tokyo MA) had 61.0% higher growth in container export traffic than Group 1 after the Hanshin earthquake; column 2 presents the results for imports, where the related impact is estimated at 57.5%. Results are unchanged by including four prefectures in Tokyo MA into the regressions (columns 3–4 of Table 8).

What worth noting is that the expansion of container export/import tonnage volume in Group 2 from 1998–2003 (Figure 8), while the diversions of shippers' port choice in Group 2 began during 1993–1998 (Figure 6). That is, port choice diversion occurred earlier than the expansion of trade volumes in Group 2. This rejects the assumption that rapid trade growth in Group 2 allowed for the rapid development of its regional ports during 1993–1998 and, thus, the container handling volume of regional ports grew more rapidly in Group 2 than Group 1 (i.e., baseline results in Table 6).

However, the trade growth from total container weight volume in Group 2 may stem from an increase in trade values, rather than the weight-to-value share. The former may be caused by other factors than the mechanism proposed by Duranton et al. (2014). For example, manufacturing products from Group 2 became popular in overseas markets during the post-Hanshin earthquake period. Since the data on weight-to-value share and value are not available, we conduct alternative tests using data on prefectures' manufacturing sector.

As Japan is a country with limited natural resources, its manufacturing sector is highly dependent on importing (foreign) intermediate goods as inputs. Furthermore, the manufacturing products are largely exported to foreign markets based on comparative advantage. The total manufacturing input and output values are thus supposed to be adequate proxies for container trade values. We estimate the impacts of Hanshin earthquake on prefecture-year level manufacturing input and output values, and manufacturing earnings per capita for Group 2 based on equation R.4:

$$\text{(R.4)} \qquad \ln(values)_{it} = \sum_{t=1}^{4} \psi_t Period_t \times G2_i + \delta_i + \mu_t + \varepsilon_{it},$$

where *values* refer to the prefecture-year level *Value of manufactured goods shipment*, *Value of raw materials used in manufacturing*, and *Manufacturing earnings per capita* in various specifications (categories). $Period_t$ ($t = 1-4$) are dummy variables for periods 1990–1994, 1995–1999, 2000–2003, and 2008–2013, where 1985–1989 is set as the reference period (for the annual data of *values* during 1985–2003 and 2008–2013, see the summary statistics in Table A.1). Other variables are identical with equation R.2.

The estimations of equation R.4 are shown in Table 9. We find no significant evidence in the impact of Hanshin earthquake and Busan port expansion on the value terms of manufacturing in Group 2, which is different from the results measured by the tonnage volume of container traffic. This result implies the weight-to-value share of trade commodities in Group 2 tends to increase after the Hanshin earthquake, which is consistent with Duranton et al. (2014), who find that more highways will lead to the cities in the US to specialize in heavy goods sectors, despite the insignificant effect of highways on total value of exports. With better accessibility to international markets, Group 2 may specialize in manufacturing sectors producing heavy goods but of high weight-to-value share. However, detailed investigations of the port diversion effect on manufacturing locations are beyond the scope of this study and will be considered in future research.[36]

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[36] We tested whether there was an industrial substitution after the earthquake, that is, some industries/firms relocated from the

6. Concluding remarks

Taking the Hanshin earthquake as an exogenous shock to the container shipping demands of Busan port, this study finds that the economies of transport density in Busan port led to an expansion of Busan's hinterlands in northern Japan. A diversion of container cargo traffic from Keihin port area to Busan port occurred in northern Japan. Precisely, the market share of Keihin port area in the container transportation of related regions declined by around 40% (Table 7). We also find that unintended port diversion on container shipping led to a structural change in the manufacturing and trade patterns of related regions. This study demonstrates the non-negligible impacts of transport density on the spatial structure of the transport network.

6.1. Implications to the evolution of port hierarchy

This study is relevant regarding the impacts of the bankruptcy of *Hanjin Shipping* (South Korea) (August 2016), South Korea's largest and one of the world's top ten container carriers, which imposed a negative shock on the container shipping industry of South Korea, particularly Busan port. South Korean ports have been rapidly losing their share in the international transshipment market after this event. For example, the transship cargo in South Korean ports from Japan's regional ports to the US in September 2016 had decreased by 33.4% compared to September 2015; additionally, the volume from China to the US decreased by 17.2%, from Vietnam to the US by 14.4%, and so on (Logistics Today, 2016). The current study implies that the bankruptcy of *Hanjin Shipping* may have led to a reorganization of the port hierarchy in Northeast Asia, rather than only South Korea. Since

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earthquake-affected regions to prefectures in Group 2. By calculating the growth rate (as value of shipment and of raw materials) of two-digit manufacturing industries after the earthquake for two regions (earthquake-affected region and Group 2), our preliminary tests did not show significant evidence that industrial substitution occurred after the earthquake (results are available upon request).

the operation of a leading hub port is important to the local economic development, various negative economic consequences (e.g., consumer price inflation, lead-time increase) of this bankruptcy on South Korea are thus expected.[37]

6.2. Limitations

An obvious shortcoming of this study is the lack of container transportation costs data for Busan port, making it impossible to identify how the container transportation costs via Busan change after the Hanshin earthquake. Therefore, the magnitude of density economies impacts cannot be estimated. Additionally, the current study cannot fully explain the polarized port hierarchy in Northeast Asia. Although the port diversions of Group 2 contribute to the decline of Keihin port area's relative scale in Northeast Asia (Figure 1 (d)),[38] they are also related to, for example, the rate of trade growth in South Korea being much higher than in Japan during the study period (mean annual trade growth rate was 3.8% for Japan and 10.9% for South Korea during 1994–2011, USD value terms) (WTO, 2016). This caused the disproportionate growth of Busan port compared with Hanshin and Keihin port areas of Japan.[39] Finally, the potential diversions of international transshipment cargoes from Keihin port area to Busan port was not considered in the current study due to data limitations.

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[37] This is the case for Hanshin earthquake. Before the earthquake, Japanese major ports were located centrally between East Asia (e.g., Hong Kong) and the west coast of US (e.g., Los Angeles) on the trans-Pacific trunk routes. However, after 1995, because of the lagged development at Kobe port, the trunk routes omitted Japanese major ports after the ship calls at Busan port; the Japanese ports partly became feeder ports for Busan port's network. This caused logistics cost appreciation and lead-time increases in Japan's manufacturing and trade industry. MLIT estimated the impacts of port hierarchy transition (from Kobe-dominated to Busan-dominated) during 1997–2002: the Japanese price of imported goods increased (2.3% for foods, 3.7% for textiles, and 1.2% for general machineries) and export volume decreased (USD 4 billion a year) (Maritime Bureau of MLIT, 2005).

[38] Based on the port diversion effects of Hanshin earthquake, as per Table 7, the container traffic volumes in Keihin port area would have increased by 4.0% on exports and 6.7% on imports in 2003 if the Hanshin earthquake did not occur (based on the coefficients of Table 7 and the CCFS).

[39] The shrank of Hanshin port area after 1995 was caused by both the container cargo diversion to Busan port and the lagged redevelopment of Hanshin industrial area. As the second largest manufacturing area of Japan, Hanshin industrial area was seriously damaged in the Hanshin earthquake. As a result, the local container shipping demands decreased, contributing to the decrease of container traffic in Hanshin port area. Specifically, Keihin (Tokyo, Kanagawa, Chiba, and Saitama) and Hanshin industrial areas (Osaka and Hyogo) are comparable with respect to the container trade volume growth during 1985–1993. For Keihin industrial area, mean annual export and import growth are -0.8% and 9.0%, respectively, during this period; for Hanshin industrial area, the figures are -0.6% and 10.4%. However, during 1993–2013, the related figures are 5.4% and 9.3% for Keihin area and 2.7% and 6.0% for Hanshin area. Therefore, the Hanshin industrial area has lagged in industrial redevelopment after the 1995 earthquake (computed based on the CCFS).

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Table 1: Number of international liner services in selected Northeast Asian ports

	Busan port	Keihin port area	Nagoya port	Hanshin port area
Europe	5 (10)	2 (11)	2 (5)	2 (10)
Mediterranean Sea	9	1	0	1
North America	43 (17)	30 (49)	9 (20)	12 (48)
South America	13	2	0	0
Australia	6	4	0	4
Middle East and India	9	1	1	1
Africa	1	0	0	0
Southeast Asia	115	70	38	57
China	136	71	32	63
Japan	89	-	-	-
South Korea	-	23	15	15

Notes: Data are based on the number of liner services in November 2012 and 1994 (in parentheses). Data source: Ocean Commerce Ltd. (1995, 2013).

Table 2: Correlation of yearly and monthly port-level container traffic data

Year	1985	1988	1993	1998	2003	2008	2013	Total
Export	0.99	0.96	0.97	0.96	0.93	0.93	0.97	0.96
Import	0.98	0.99	0.99	0.95	0.94	0.97	0.99	0.98

Notes: The correlation is between monthly (in tons) and annual (in TEUs) data for the container handling share of major ports in the national container volume. Precisely, the correlation of $volume_{it}/volume_t$ for annual and monthly data; *i*: port; *t*: year. $volume_{it}$: container volume of port *i* in year *t*; $volume_t$: national container volume in year *t*. Export and import data are presented separately. Data source: Japan Port Statistics Yearbook (various years) and CCFS.

Table 3: Japan's international container cargoes and their shipping routes

	Europe		North America		South America	
	Major ports	Regional ports	Major ports	Regional ports	Major ports	Regional ports
Direct	80.5	n.a.	96.7	n.a.	66.4	3.6
Trans. at Busan	2.7	**81.9**	1.7	**71.3**	5.4	**78.3**
Trans. at others	16.8	n.a.	1.6	n.a.	28.2	18.1
	Australia		Middle East & India		Africa	
	Major ports	Regional ports	Major ports	Regional ports	Major ports	Regional ports
Direct	82.8	n.a.	30.8	n.a.	33.2	n.a.
Trans. at Busan	3.0	**88.9**	16.9	**62.6**	< 3.0	**65.8**
Trans. at others	14.2	n.a.	52.3	n.a.	n.a.	n.a.

Notes: Related data refer to 2008. The data are in percentage point units. *Direct*: direct shipping between Japan and international origins/destinations; *Trans. at Busan*: transship at Busan port; *Trans. at others*: transship at other Asian ports: Singapore, Hong Kong, Shanghai, Kaohsiung, etc. Data regarding shipping routes between Japan and East and Southeast Asian countries are not available. Data source: Ports and Harbors Bureau, MLIT, Japan.

Table 4: The container volume of Japanese maritime cargoes at foreign major ports close to Japan

Ports	**Year**	Exports + Imports				Exports			Imports		
		Sum	Direct	Transship	Transship/Sum	Sum	Direct	Transship	Sum	Direct	Transship
Busan	1993	542	522	**20**	**3.7%**	184	179	**5**	358	343	**15**
	1998	665	436	**229**	**34.4%**	222	145	**77**	443	291	**152**
	2003	1,462	625	**837**	**57.3%**	516	229	**287**	947	397	**550**
	2008	1,463	513	**950**	**64.9%**	590	202	**388**	873	311	**562**
Shanghai	1993	340	337	3	0.9%	96	95	1	245	243	2
	1998	567	563	4	0.7%	145	145	0	422	418	4
	2003	1,790	1,759	31	1.7%	468	455	13	1,322	1,304	18
	2008	2,287	2,169	118	5.2%	539	509	30	1,747	1,660	87
Kaohsiung + Keelung	1993	726	686	40	5.5%	399	396	3	327	290	37
	1998	651	561	90	13.8%	371	347	24	279	214	65
	2003	1,029	570	459	44.6%	570	358	212	459	211	248
	2008	683	451	232	34.0%	349	223	126	334	228	106

Notes: Unit: thousand tons. Data source: CCFS. Survey period of CCFS is one month in a specific year, therefore, the related data refer to the volume of a month. *Direct* refers to the trade container cargoes (export and import) between Japan and the related country through the specific port; *Transship* to the container transshipment cargoes exporting from Japan or importing to Japan and transshipping through the specific port. For example, in 1993, the container export cargoes from Japan to South Korea (through Busan port) are 179,000 tons, and the export cargoes from Japan to other countries transshipped in Busan port are 5,000 tons. For Busan port (1993, 1998, 2003, and 2008), the present data contain the sum of container traffic of Busan and Gwangyang ports because separate data are not available. Gwangyang port of South Korea is close to Busan, its scale significantly smaller than Busan's. The data of 2008 for Shanghai (Kaohsiung + Keelung) contain the sum of container traffic of Shanghai port and Ningbo port (Kaohsiung, Keelung, and Taichung ports) because the separate data are not available for this year.

Table 5: Port-specific container traffic share of Group 2

		Keihin port area	Hanshin port area	Nagoya port	Regional ports
Export	Share_{1993}	81.0	7.7	1.6	9.7
	Share_{2003}	45.4	2.2	0.7	51.8
	Share_{2003} - Share_{1993}	**-35.6**	-5.5	-0.9	**42.1**
Import	Share_{1993}	81.6	2.6	0.1	15.7
	Share_{2003}	29.5	0.9	0.7	68.9
	Share_{2003} - Share_{1993}	**-52.1**	-1.7	0.6	**53.2**

Notes: The data are in percentage point units. $Share_{jt} = (\sum_{i=1}^{7}(volume_{ijt}/\sum_{j=1}^{4} volume_{ijt}))/7$; i =1–7 refers to seven prefectures in Group 2; j =1–4 refers to Keihin port area, Hanshin port area, Nagoya port, and the unclassified (or aggregated) regional ports; t =1993, 2003 refers to two time points; $volume_{ijt}$ is the container traffic (in tons) of prefecture i handled by port area j in year t. Data source: Computed based on the CCFS.

Table 6: Baseline estimations

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Dependent variable: Container handling share							
	Keihin Export	Keihin Import	Keihin Export	Keihin Import	Big 5 Export	Big 5 Import	Keihin Export	Keihin Import
G2×Postquake	-0.266***	-0.453***						
	(0.056)	(0.076)						
G2×y1988			-0.089	-0.098	-0.108	-0.091		
			(0.061)	(0.072)	(0.081)	(0.081)		
G2×y1993			-0.049	-0.093	-0.060	-0.100		
			(0.035)	(0.067)	(0.039)	(0.069)		
G2×y1998			-0.221**	-0.386***	-0.279***	-0.413***		
			(0.087)	(0.110)	(0.085)	(0.108)		
G2×y2003			-0.360***	-0.565***	-0.440***	-0.590***		
			(0.073)	(0.088)	(0.067)	(0.083)		
G2×y2008			-0.283***	-0.546***	-0.352***	-0.570***		
			(0.076)	(0.088)	(0.083)	(0.082)		
G2×y2013			-0.382***	-0.568***	-0.466***	-0.588***		
			(0.066)	(0.083)	(0.059)	(0.082)		
ln(*Dist*)×*y1988*							-0.034	-0.046
							(0.029)	(0.030)
ln(*Dist*)×*y1993*							-0.027**	-0.039
							(0.011)	(0.025)
ln(*Dist*)×*y1998*							-0.094***	-0.155***
							(0.033)	(0.039)
ln(*Dist*)×*y2003*							-0.127***	-0.216***
							(0.041)	(0.042)
ln(*Dist*)×*y2008*							-0.106***	-0.216***
							(0.033)	(0.037)
ln(*Dist*)×*y2013*							-0.132***	-0.217***
							(0.039)	(0.039)
Constant	0.572***	0.693***	0.600***	0.731***	0.706***	0.763***	0.613***	0.764***
	(0.032)	(0.044)	(0.040)	(0.057)	(0.048)	(0.058)	(0.047)	(0.061)
Two-way FEs	Y	Y	Y	Y	Y	Y	Y	Y
N	126	126	126	126	126	126	126	126
R^2	0.895	0.924	0.908	0.935	0.920	0.932	0.881	0.913

Notes: Keihin: Tokyo port and Yokohama port. Big 5: Tokyo, Yokohama, Kobe, Osaka, and Nagoya ports. Robust standard errors (clustered at prefecture level) are in parentheses.

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 7: Between-year difference

		(1) Export	(2) Import
Between-year Difference	1993–1985	-0.049	-0.093
		(0.035)	(0.067)
	2003–1993	**-0.312*****	**-0.472*****
		(0.068)	**(0.091)**
	2013–2003	-0.022	-0.003
		(0.057)	(0.022)

Notes: Computed based on the estimates in columns 3–4 of Table 6. Robust standard errors (clustered at prefecture level) are in parentheses.

$^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$

Table 8: Impacts on prefecture-year level export and import volumes

	(1) ln(*export volume*)	(2) ln(*import volume*)	(3) ln(*export volume*)	(4) ln(*import volume*)
G2×Postquake	0.610***	0.575***	0.581***	0.624***
	(0.208)	(0.210)	(0.192)	(0.211)
Constant	10.318***	9.059***	10.771***	9.647***
	(0.086)	(0.136)	(0.073)	(0.115)
Samples	G1 & G2 ex Tokyo MA	G1 & G2 ex Tokyo MA	G1 & G2	G1 & G2
Two-way FEs	Y	Y	Y	Y
N	98	98	126	126
R^2	0.580	0.912	0.563	0.901

Notes: Samples: G1 and G2 excluding Tokyo MA: Group 1 and Group 2, excluding the four prefectures: Tokyo, Kanagawa, Chiba, and Saitama; G1 and G2: Group 1 and Group 2. Robust standard errors (clustered at prefecture level) are in parentheses.

$^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$

Table 9: Estimates on manufacturing inputs and outputs, and earnings

	(1) ln(*Value of manufactured goods shipment*)	(2) ln(*Value of raw materials used in manufacturing*)	(3) ln(*Manufacturing earnings p.c.*)
G2×year(*1990–1994*)	0.009	-0.016	-0.016
	(0.020)	(0.025)	(0.016)
G2×year(*1995–1999*)	0.018	0.001	-0.006
	(0.039)	(0.052)	(0.025)
G2×year(*2000–2003*)	0.001	-0.003	-0.004
	(0.048)	(0.065)	(0.035)
G2×year(*2008–2013*)	0.016	0.026	0.015
	(0.057)	(0.068)	(0.043)
Constant	8.125^{***}	7.628^{***}	7.848^{***}
	(0.020)	(0.026)	(0.014)
Two-way FEs	Y	Y	Y
N	350	350	350
R^2	0.773	0.663	0.954

Notes: Samples: Group 1 and Group 2, excluding Tokyo MA. Annual data for 1985–2003 and 2008–2013; data for 2004–2007 are not available in our dataset. Robust standard errors (clustered at prefecture level) are in parentheses.

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

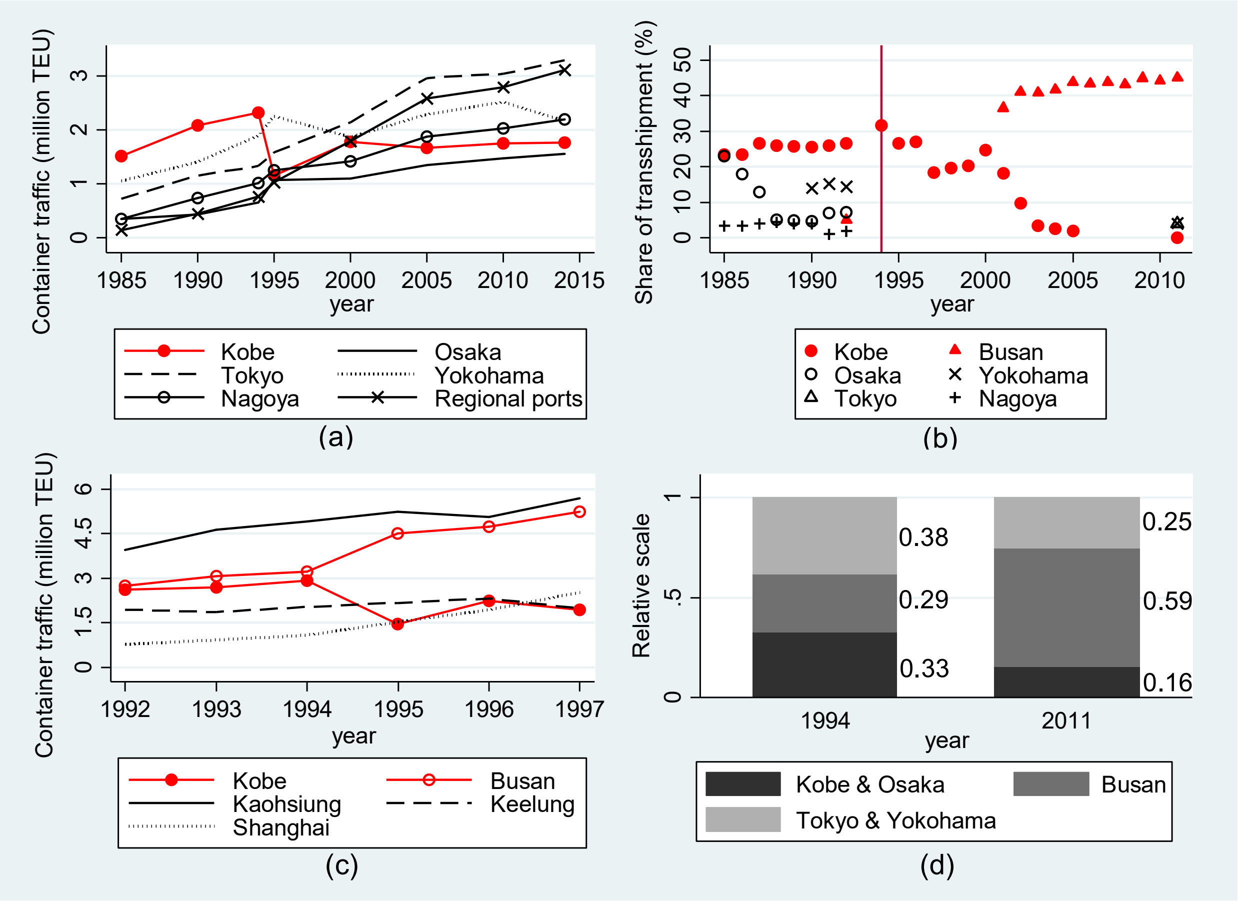


Figure 1: Dynamics of port handling in selected ports

Notes: (a): The container traffic of five major ports of Japan in selected years. "Regional ports" refer to the container traffic of all of Japan's regional ports except for the five major ports. The data contain the information only on exports and imports for 1985, 1990, 1994, 1995, 2000, 2005, 2010, and 2014. Data source: Japan Port Statistics Yearbook, various years. (b): The share of international transshipment cargoes in the total container traffic in selected ports. Data sources: Data for 1985–1992 for all ports are from Harada (1996); data on Busan port (2001–2010) are from Busan Port Authority (2011); data on Kobe port for 1994–2005 are from Guerrero and Itoh (2017) and Chang (2010); data for 2011 are from Drewry Shipping Consultants Ltd. (2012) and Port Report of Japan (2012). (c): Container traffic of selected East Asian major ports. The data include all containers cargoes landed (including trading, international transshipment, and domestic cargoes). Data source: Containerisation International Yearbook (Vol. 1994–1999). (d): The relative scale of three port areas. The data refer to: $RelativeScale_{it} = Volume_{it}/\sum_{i=1}^{3} Volume_{it}$, i: port area, t: year. i = Busan port, Hanshin port area (Kobe and Osaka), and Keihin port area (Tokyo and Yokohama). *Volume* is the annual port-level container traffic measured in TEUs. The container traffic includes all the containers cargoes landed. Data sources: Chang, 2000; Japan Port Statistics Yearbook, 2012; Drewry Shipping Consultants Ltd., 2012.

Figure 2: Major container ports close to Kobe port

Notes: Keihin port area: Tokyo and Yokohama ports; Hanshin port area: Kobe and Osaka ports. Busan port (South Korea) is the closest foreign major port to Japan, which is 200 km away from Kyushu island.

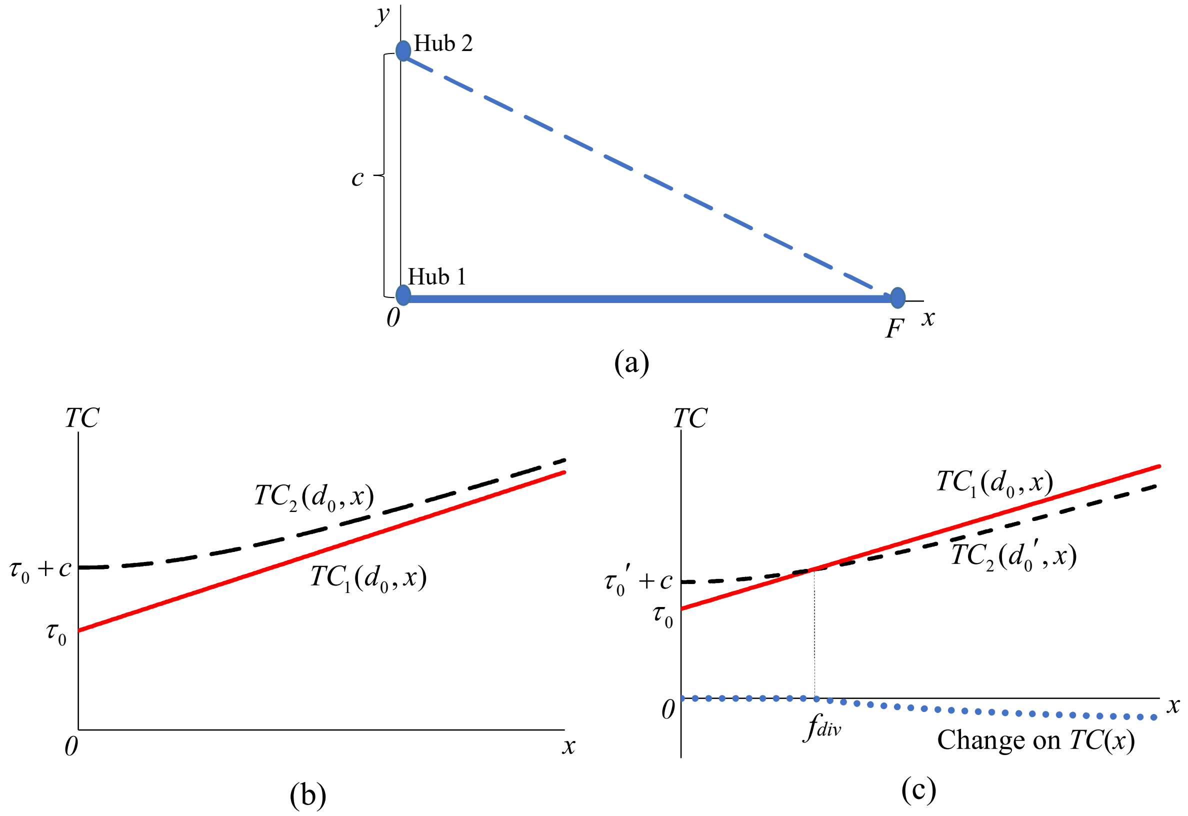


Figure 3: Determinants of transportation costs

Notes: (a) shows the locations of shippers and hub ports. Shippers (firms) are located uniformly and continuously in [0, *F*] of the horizontal axis, Hub 1 is located at (0, 0), and Hub 2 is located at (0, *c*). For a shipper located at (*x*, 0) ($x \in [0, F]$), the transport distances to freight a unit of container cargo to Hub 1 and Hub 2 are *x* and $\sqrt{c^2 + x^2}$, respectively. (b) shows the total transportation costs for a shipper to freight a unit of container cargo to the international destination (solid red line for Hub 1, and dashed line for Hub 2). (c) shows the total transportation costs for a shipper to freight a unit of container cargo to the international destination after the exogenous shock on the transport density of Hub 2 (solid red line for Hub 1, and dashed line for Hub 2). f_{div} is the threshold distance. For the firm locations (*x*, 0) ($x \in [0, f_{div}]$), total transportation costs via Hub 1 are not higher than Hub 2, while for locations that $x \in (f_{div}, F]$, total transportation costs via Hub 2 are lower than Hub 1. The dotted blue line refers to the change in *TC*(*x*) for all locations after the exogenous shock, that is, shippers in locations (*x*, 0) ($x \in (f_{div}, F]$) save on cost by diverting the cargoes from Hub 1 to Hub 2.

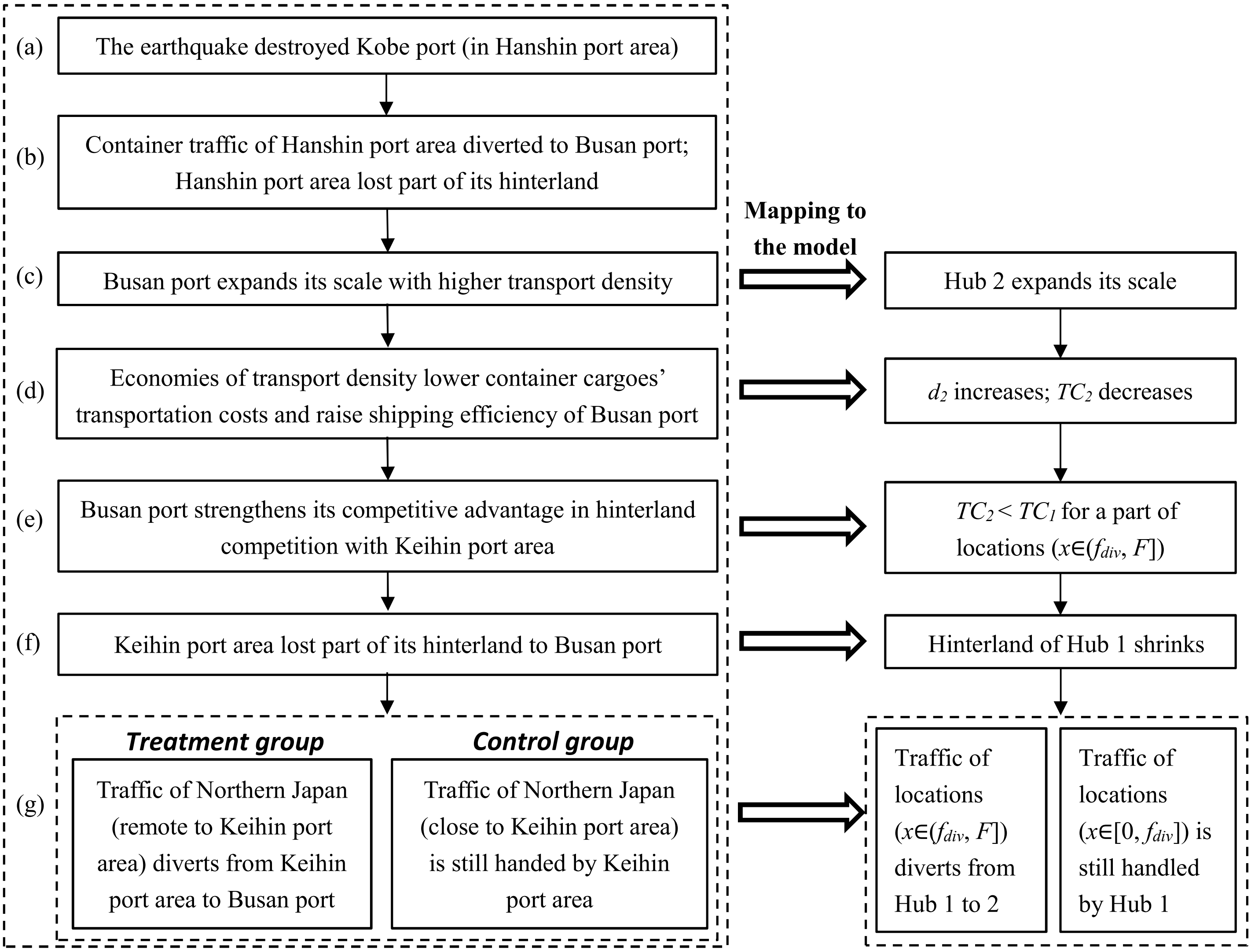


Figure 4: Mechanism description

Notes: The transportation costs refer to the generalized costs, namely, monetary and time costs. Northern Japan refers to 18 prefectures (Groups 1 and 2) as defined in Figure 5, and the remaining prefectures (except for Okinawa) are classified as southern Japan.

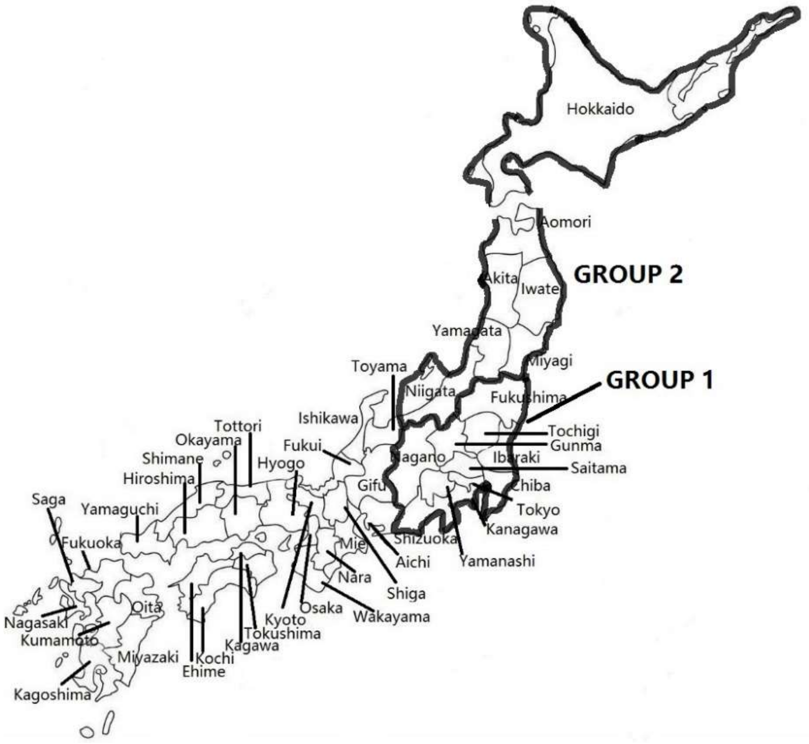
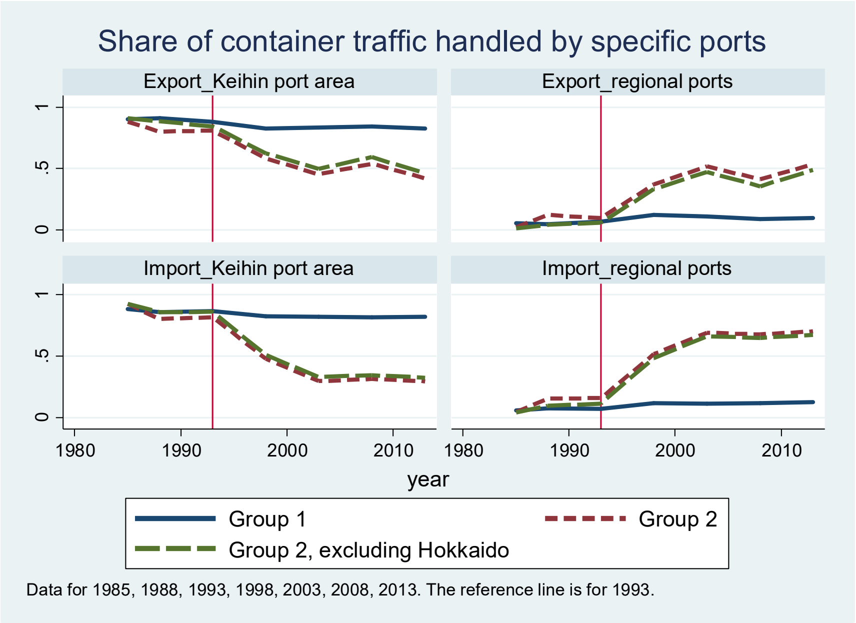


Figure 5: Locations of Groups 1 and 2

Notes: This map does not include Okinawa prefecture, which is far away from the main island of Japan.



Data for 1985, 1988, 1993, 1998, 2003, 2008, 2013. The reference line is for 1993.

Figure 6: Share of container traffic handled by Keihin port area and regional ports

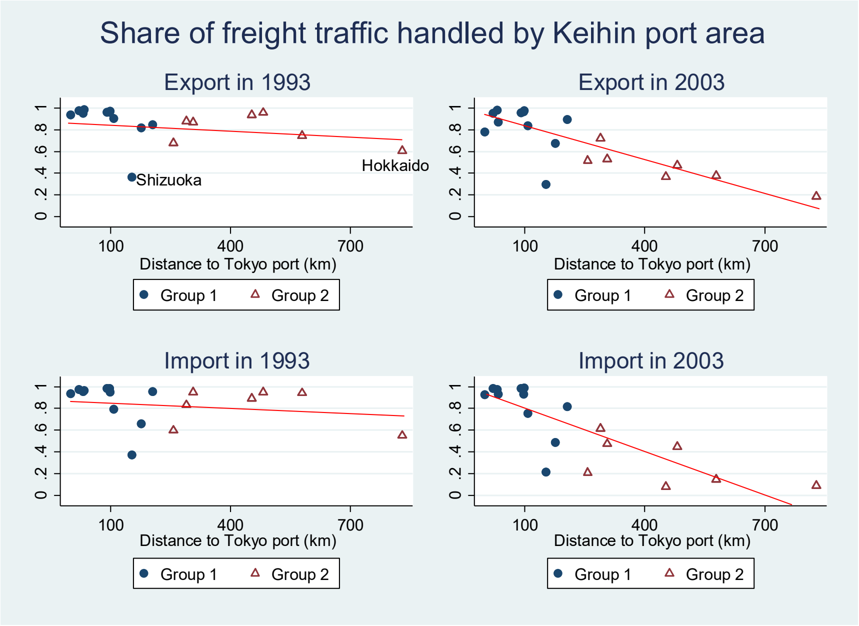


Figure 7: Gradient of share of container traffic against the distance to Tokyo port

Notes: We take the distance between a prefecture's core district to Tokyo port as the proxy of the distance between a prefecture and Keihin port area.

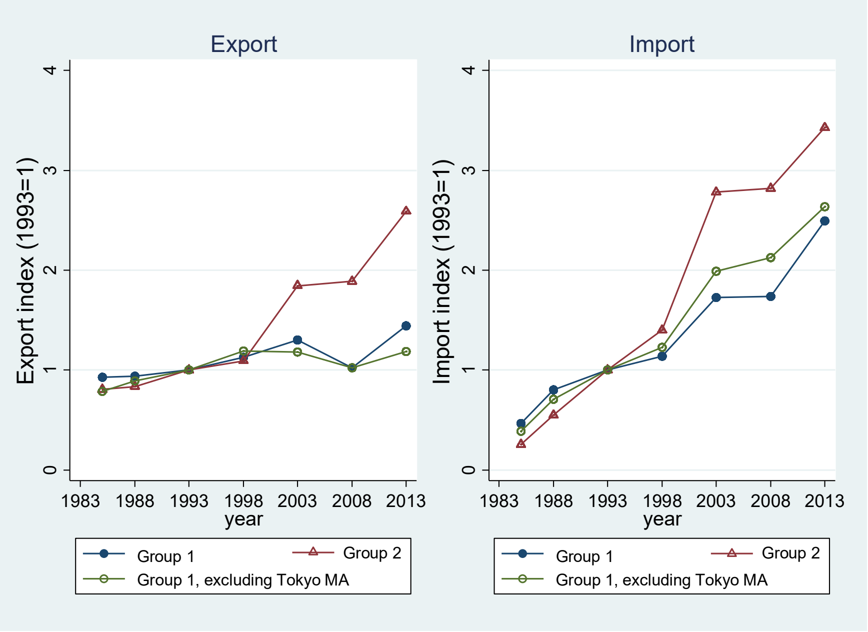


Figure 8: The growth of absolute export/import volume in northern Japan

Notes: The data are normalized based on the related export and import volume in 1993.

Appendix

Table A.1: Summary statistics

Panel A: Port choice dynamics of container shipping in Groups 1 and 2

	Group 1					Group 2				
Variables	Obs.	Mean	Std. dev.	Min	Max	Obs.	Mean	Std. dev.	Min	Max
Export_Hanshin	77	0.03	0.03	0.00	0.17	49	0.05	0.05	0.00	0.24
Import_Hanshin	77	0.02	0.03	0.00	0.15	49	0.01	0.02	0.00	0.08
Export_Keihin	77	0.86	0.18	0.23	0.99	49	0.64	0.24	0.17	0.99
Import_Keihin	77	0.84	0.22	0.18	0.99	49	0.56	0.32	0.08	1.00
Export_Big 5	77	0.92	0.15	0.38	1.00	49	0.70	0.25	0.19	1.00
Import_Big 5	77	0.90	0.15	0.38	1.00	49	0.58	0.32	0.09	1.00
Distance to Tokyo port (km)	11	94	63	10	206	7	457	188	258	829

Panel B: Trade and manufacturing dynamics in Groups 1 and 2

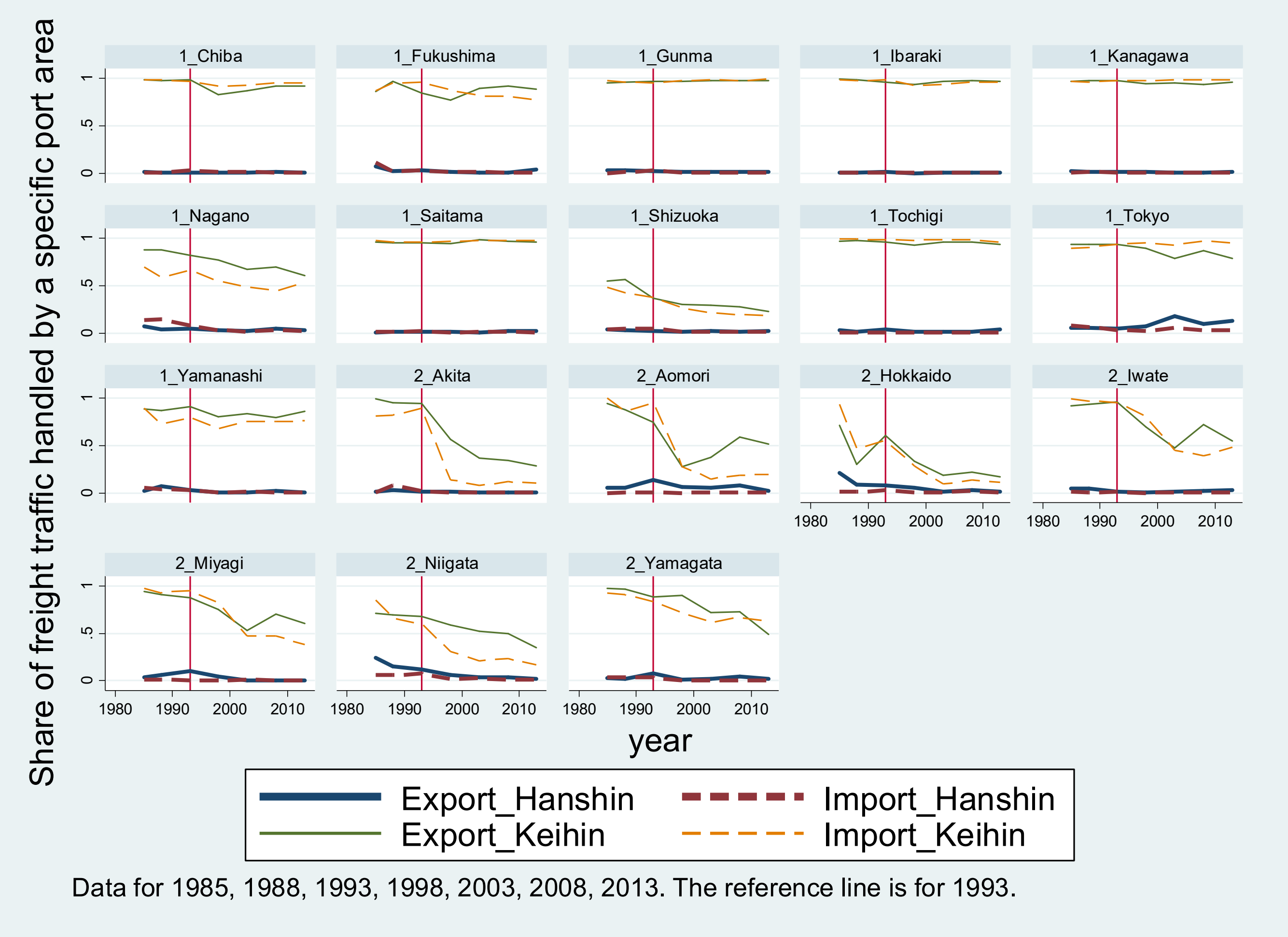
Variables	Obs.	Mean	Std. dev.	Min	Max
Export volume (ton)	126	123,817	133,220	4,460	687,709
Import volume (ton)	126	160,845	214,632	371	947,539
Value of raw materials used in manufacturing (billion JPY)	350	3,159	2,305	608	11,748
Value of manufactured goods shipment (billion JPY)	350	5,412	3,914	1,000	19,178
Manufacturing earnings p.c. (thousand JPY)	350	3,572	717	1,965	4,864

Notes: Panel A: *Export_Hanshin* refers to the share of a prefecture's container cargoes (export) handled by the ports of Kobe and Osaka. *Export_Keihin* refers to the share of a prefecture's container cargoes (export) handled by the ports of Tokyo and Yokohama. *Export_Big 5* refers to the aggregated share of a prefecture's container cargoes (export) handled by the ports of Kobe, Osaka, Tokyo, Yokohama, and Nagoya. The indicators for import are analogous. Data are for 18 prefectures in seven years (1985, 1988, 1993, 1998, 2003, 2008, 2013). For Tokyo prefecture, the distance to Tokyo port is set as 10 km. For other prefectures, the distance is measured based on the geographical distance between the prefectural core district to Tokyo port. Data source: Computed based on CCFS; distance data are calculated based on the latitude and longitude information. Panel B: *Export and Import Volume* data are for 1985 and 1988–2013 (at five-year intervals). Data source: CCFS. *Manufacturing values and earnings* data are for the time periods 1985–2003 and 2008–2013; however, data for 2004–2007 are not available. Data sources: Japan Statistical Yearbook (various years), and Historical Statistics of Japan (Statistical Bureau, Japan) (http://www.stat.go.jp/english/data/chouki/index.htm).

Table A.2: Empty container incidence by region

Region	1980	1990	2000	2007	2008	2009
North America	21.2	20.6	22.5	22.5	20.9	20.7
Latin America	30.8	38.2	33.1	25.9	26.5	27.2
West Europe	21.0	20.6	19.1	21.2	20.9	20.6
East Europe	20.3	28.2	24.2	29.3	29.1	28.2
Far East	17.9	16.1	19.5	19.5	19.6	19.5
South East Asia	18.7	15.3	18.2	16.9	16.7	17.2
South Asia	24.2	17.4	16.4	16.9	16.8	16.8
Middle East	38.3	27.1	26.8	27.1	23.2	28.5
Oceania	20.0	20.3	20.3	20.2	20.9	21.2
Africa	20.9	25.2	27.0	28.6	28.0	28.2
World	21.7	20.2	21.2	21.0	20.7	21.0

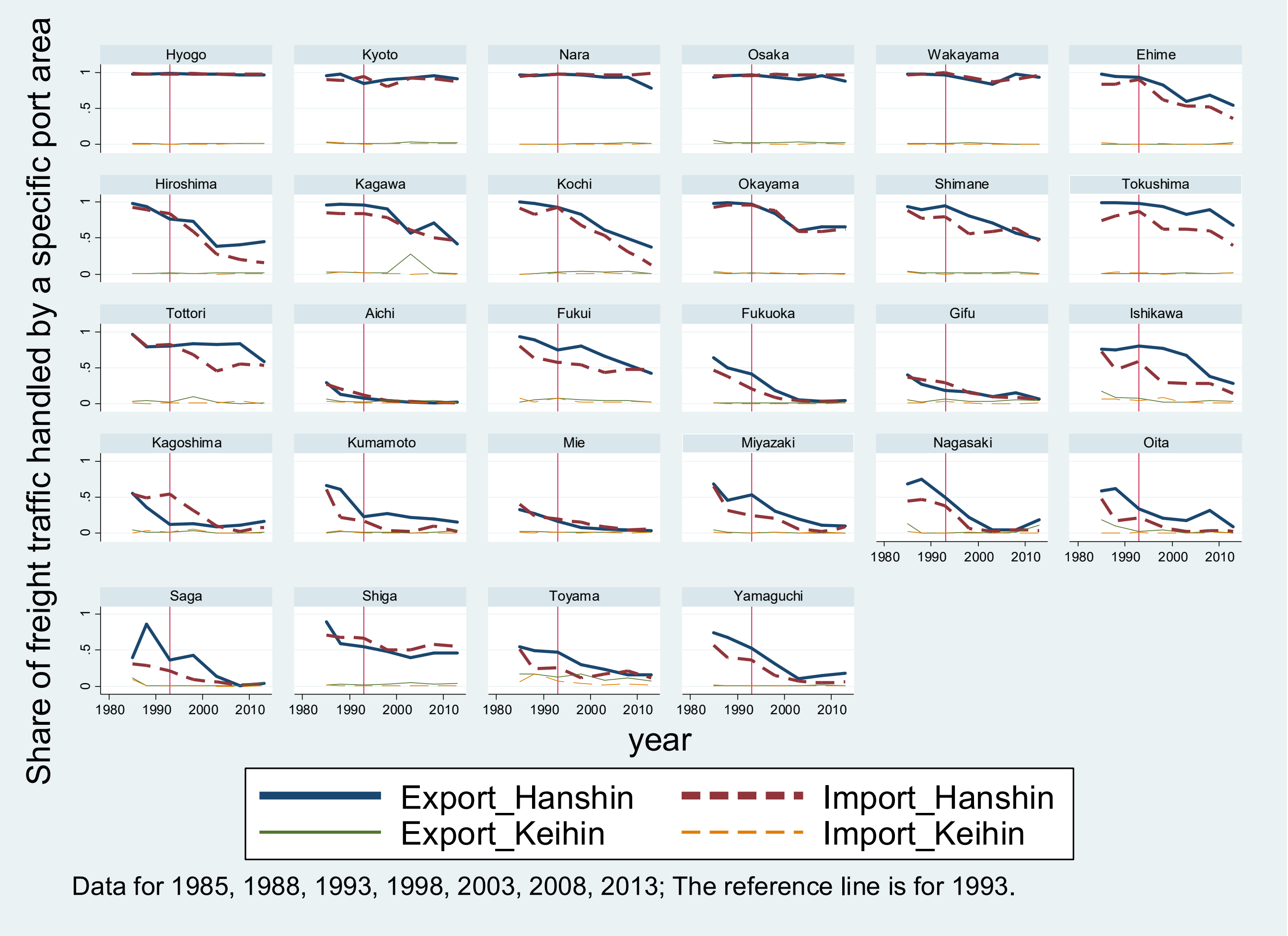
Notes: Empty container incidence is expressed in percentage points. *Region* refers to the location of traders. For example, *North America* in 1980 means the average empty container incidence in 1980 for all container cargoes departing or arriving in North America. Data source: Drewry Shipping Consultants Ltd., 2010a.



Data for 1985, 1988, 1993, 1998, 2003, 2008, 2013. The reference line is for 1993.

Figure A.1: Prefecture-level port choice dynamics in northern Japan

Notes: The locations of prefectures are as per Figure 5. The title of each plot refers to the name of a prefecture and the group it belongs to. For example, “1_Chiba” means that Chiba prefecture belongs to Group 1.



Data for 1985, 1988, 1993, 1998, 2003, 2008, 2013; The reference line is for 1993.

Figure A.2: Prefecture-level port choice dynamics in southern Japan

Notes: The locations of prefectures are as per Figure 5. Okinawa prefecture, which is more than 1,000 km away from the main island of Japan, is excluded.

Density economies and transport geography:
Evidence from the container shipping industry

Hangtian Xu and Hidekazu Itoh

Supplementary Material

(May 2017)

This section presents the descriptions of the stylized facts on port choice dynamics in southern Japan during 1985–2013. Based on the descriptive evidence in Figure A.2, we divide southern Japan into three regional groups, based on their shares of container freight traffic handled by Hanshin port area (Figure S.1 (a)).

First, the regions for which Hanshin port area serves as the dominating port before and after the earthquake are Hyogo, Osaka, Kyoto, Nara, and Wakayama. During both periods (1985–1993 and 1998–2013), the average share of Hanshin port area for these prefectures is above 80% (these prefectures represent *Group S1*) (see in Figure S.1 (b)). Second, the regions for which Hanshin port area serves as the dominating port before 1995 (related share is above 80%) are Ehime, Hiroshima, Kagawa, Koichi, Okayama, Shimane, Tokushima, Tottori (set as *Group S2*). However, their related market share significantly shrank after 1995 due to the seismic damage. The average handling share of *Group S2* in Hanshin port area declined to less than 50% in 2013 (Figure S.1 (b)). Third, the regions for which the related share of Hanshin port area decreased before 1995, and continued to decrease after the earthquake are the remaining 15 prefectures in southern Japan (set as *Group S3*). Figure S.1 (a) shows that *Group S1* represents the prefectures closest to Kobe port (within 90 km); *Group S2* the prefectures on the western side of *Group S1*; and *Group S3* consists of two parts, one part on the western side of *Group S2* (relatively far away from Kobe port) and another on the eastern side of Kobe port and close to Nagoya port. The related year-by-year plot is shown in Figure S.1 (b).

We find the shippers' port choices across groups (i.e., *Groups S1, S2, and S3*) to be highly correlated with their proximity to major ports. *Group S1* is the stable hinterland of Hanshin port area since it is relatively farther away from Nagoya port and Busan port. *Group S2* was once the stable hinterlands of Hanshin port area (i.e., before 1995); however, the related share shrank significantly after the earthquake (see Figure S.1 (b)). The decreased market share of Hanshin port area was diverted to regional ports (i.e., mainly diverted to Busan port),[40] because the locational advantage of Hanshin port area over Busan port is weaker for *Group S2* than for *S1*. For *Group S3*, shippers either diverted their cargoes to regional ports (i.e., transshipping at Busan port) or Nagoya port (for the prefectures in the eastern part of *Group S3*), because they are close to the substitute of Hanshin port area (i.e., Busan port and Nagoya port). Figure S.2 shows a similar pattern with Figure 7 for northern Japan. That is, the most unstable hinterlands of Hanshin port area are the prefectures farthest away from Kobe port. This stylized fact is consistent with the findings on northern Japan's port choice, that is, regions relatively far away from Keihin port area have higher probability to become the hinterlands of Busan port after the earthquake.

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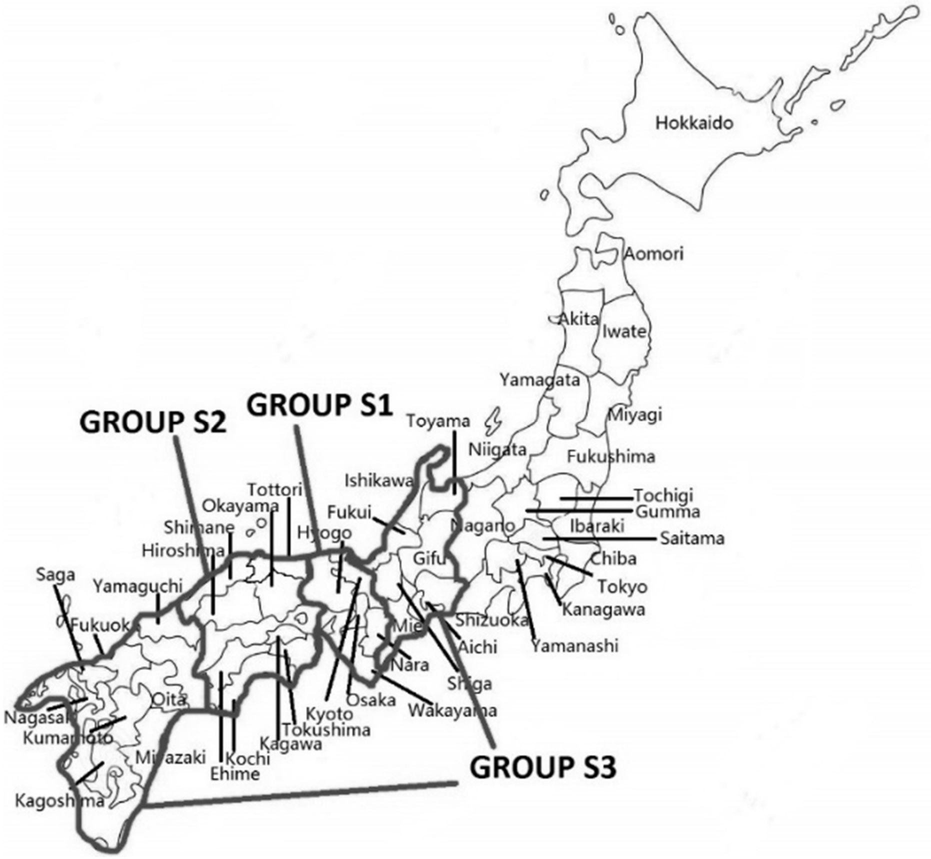
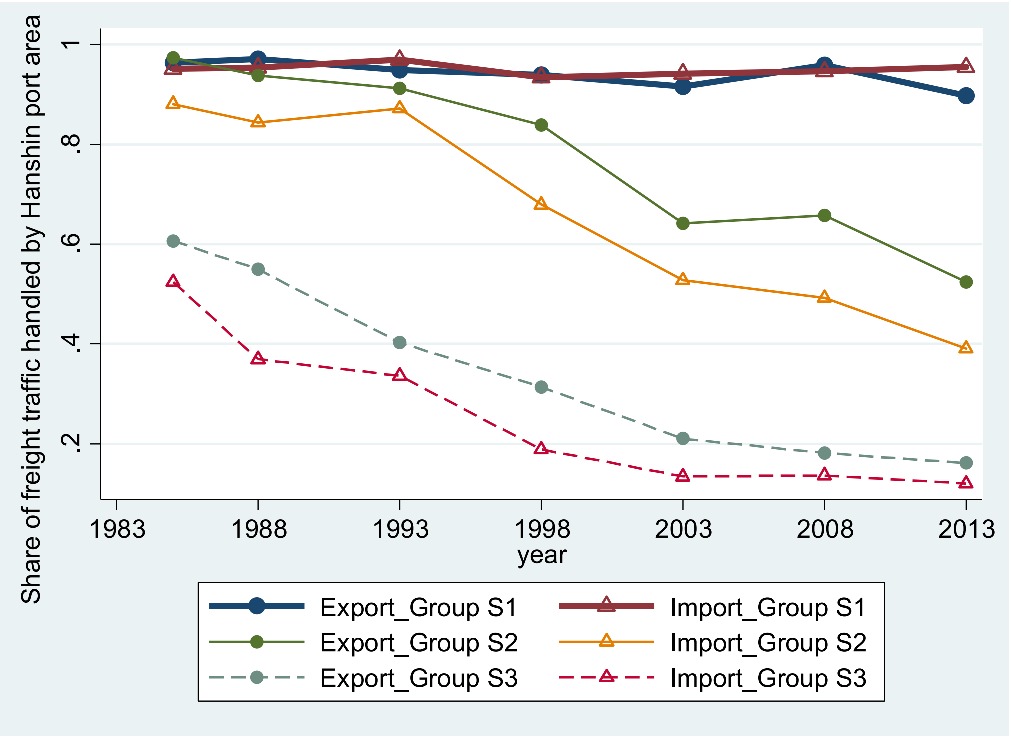
[40] See in Figures S.3 and S.4. We do not present the related plot for regional ports, since the share of container traffic handled by regional ports is equal to: 1 - Share of Hanshin port area - Share of Keihin port area - Share of Nagoya port. Figure S.4 shows the container traffic share handled by Nagoya port for prefectures in southern Japan. We find the hinterlands of Nagoya ports are limited to the prefectures close to it (i.e., Aichi, Fukui, Gifu, Mie, Shiga, and Toyama), and the market share slightly changed from before to after 1995. Together with the evidence in Figure S.3 that Hanshin port area significantly decreased its market share for specific prefectures of southern Japan, and Keihin port area did not increase its market share in these prefectures, we may infer that the lost market of Hanshin port area was absorbed by regional ports (i.e., mainly diverted to Busan port).



(a) Location of Groups S1, S2, and S3



(b) Container traffic share handled by Hanshin port area

Figure S.1: Port choice dynamics in southern Japan

Notes: The map (a) does not include Okinawa prefecture.

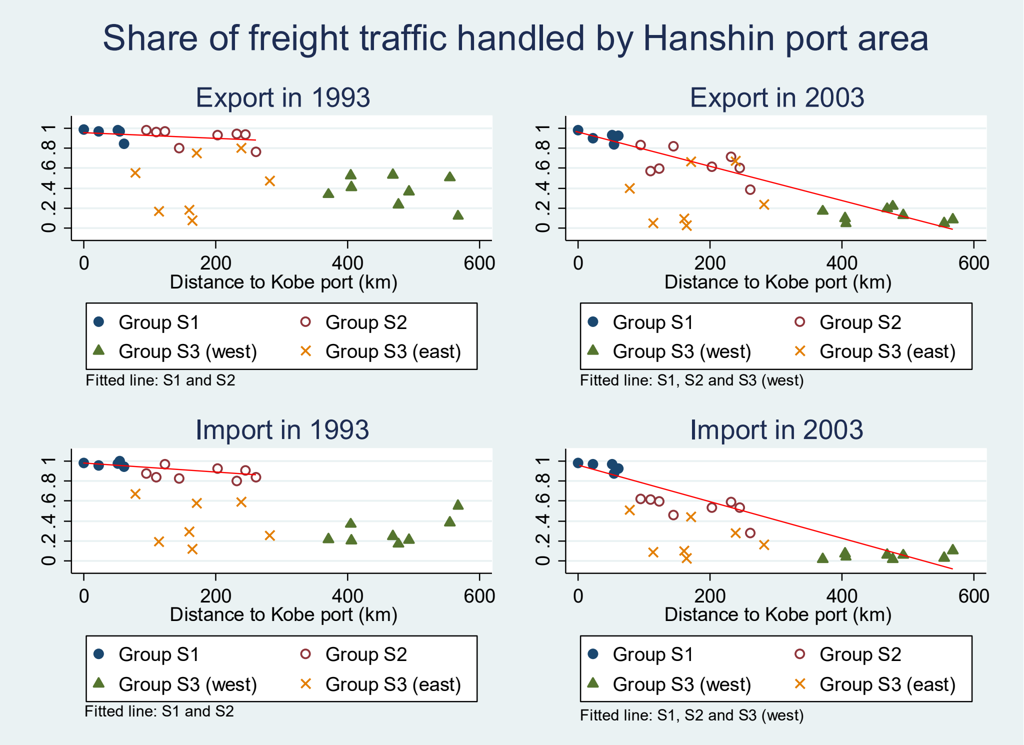
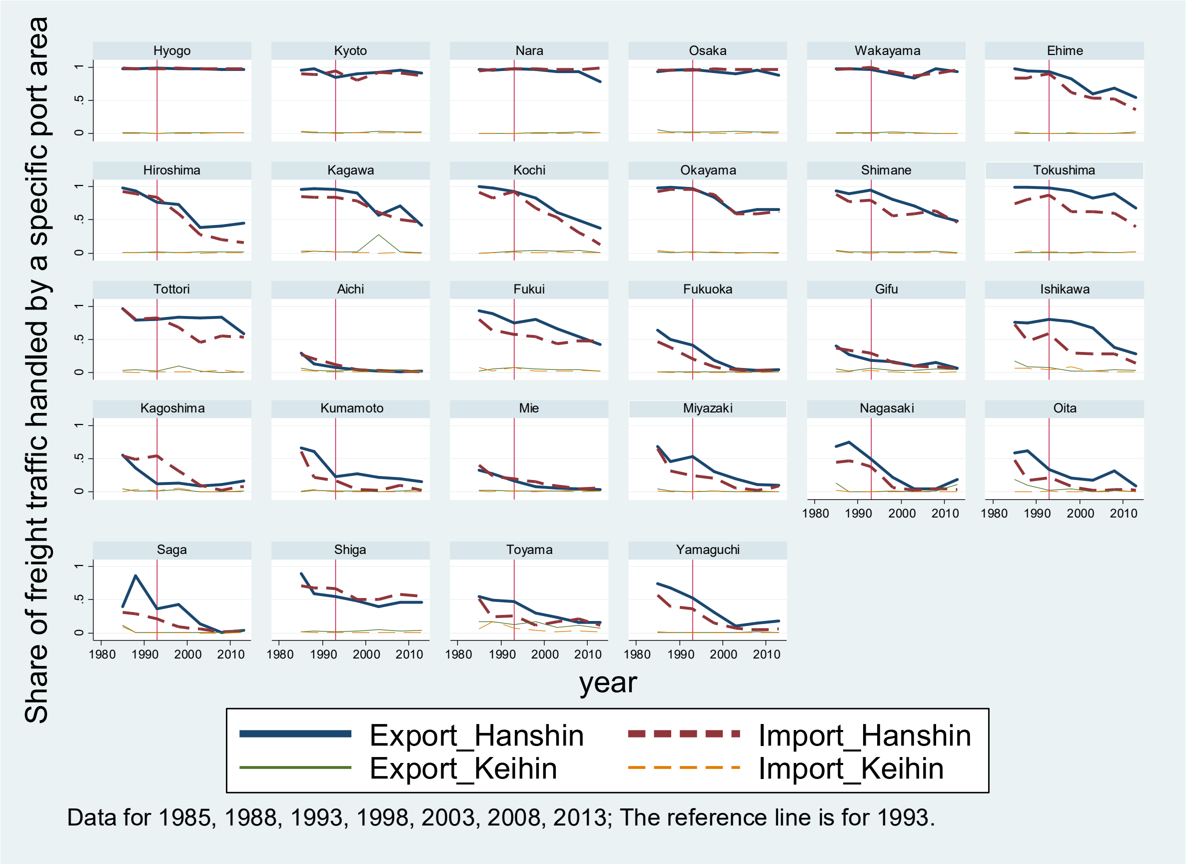


Figure S.2: Gradient of share of container traffic against distance to Kobe port (i.e., Hanshin port area)



Data for 1985, 1988, 1993, 1998, 2003, 2008, 2013; The reference line is for 1993.

Figure S.3: Prefecture-level port choice dynamics in southern Japan

Notes: This figure is identical with Figure A.2. The locations of prefectures are as per Figure S.1 (a). Okinawa prefecture, which is more than 1,000 km away from the main island of Japan, is excluded. Group S1: Hyogo, Kyoto, Nara, Osaka, Wakayama; Group S2: Ehime, Hiroshima, Kagawa, Kochi, Okayama, Shimane, Tokushima, Tottori; Group S3: the remining 15 prefectures in southern Japan.

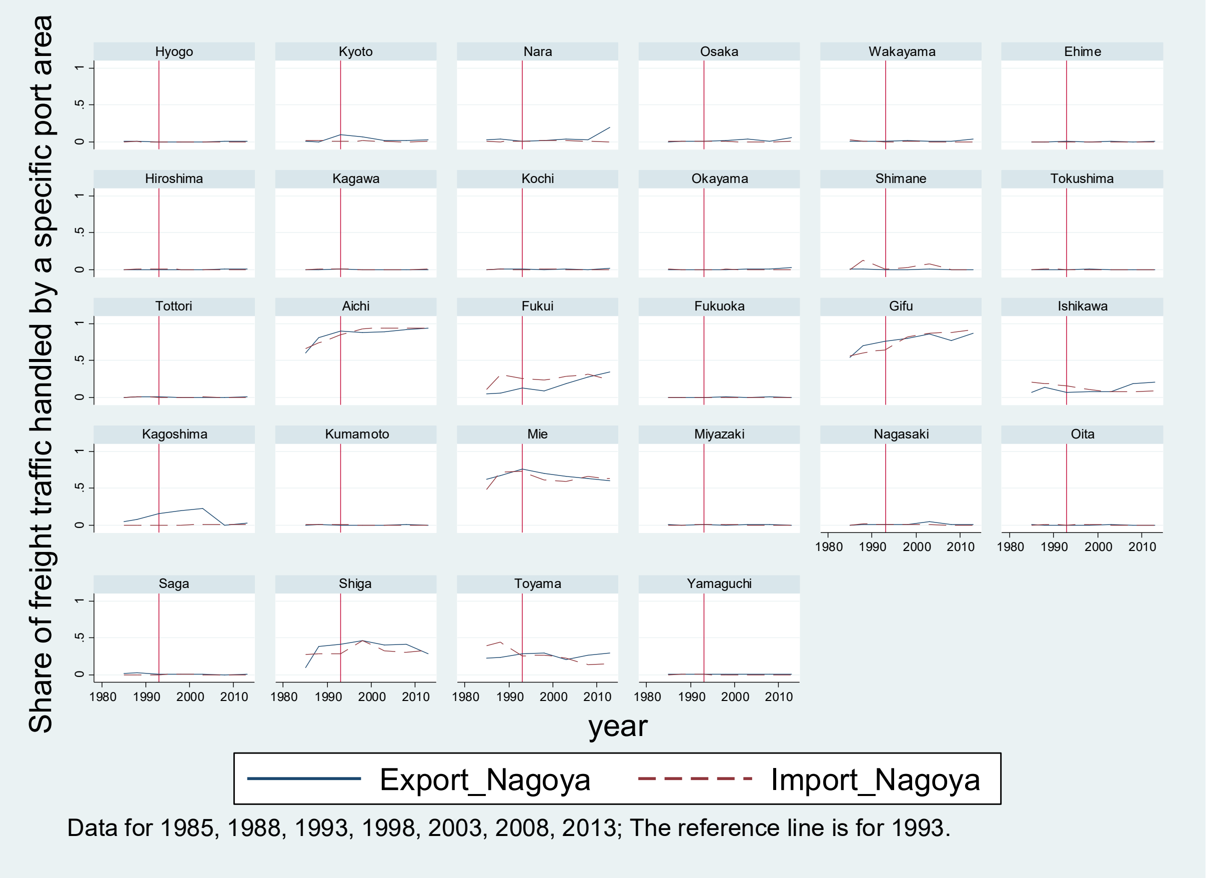


Figure S.4: Prefecture-level port choice dynamics in southern Japan (Nagoya port)

Notes: The locations of prefectures are as per Figure S.1 (a). Okinawa prefecture, which is more than 1,000 km away from the main island of Japan, is excluded. Group S1: Hyogo, Kyoto, Nara, Osaka, Wakayama; Group S2: Ehime, Hiroshima, Kagawa, Kochi, Okayama, Shimane, Tokushima, Tottori; Group S3: the remining 15 prefectures in southern Japan.