International Transport Infrastructure and Regional Economic Development*

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Abstract

We evaluate how access to international transport infrastructure promotes trade and economic development. Exploiting the gradual unfolding of transcontinental rail freight connections between China and Europe, our empirical findings indicate increasing exports from connected cities with positive spillovers to neighboring cities and other indicators economic activity. Not all products and cities are equally responsive to new rail export opportunities. We set up a multi-sector heterogeneous firms model with a rich specification of trade costs in which firms optimize trade costs by choosing alternative transportation modes and routes. Leveraging a unique data set on trade flows between Chinese cities, we calibrate our model to discuss local welfare effects, relying on sufficient statistics that quantify changes in city-level trade costs. We also highlight significant spatial distributional effects of trade infrastructure development.

JEL-Classification: F14, F15, R11, R41

Keywords: Trade, Transport infrastructure , Regional development,

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1 Introduction

Becoming a gateway to global markets can significantly promote regional economic development and welfare. Governments devote substantial resources to improve international trade infrastructure, but understanding how economic benefits unfold is far from trivial. A burgeoning literature describes the hub-and-spoke structure of international transportation networks, which entails that benefits accrue primarily to gateway cities and nearby locations.[1] A less-studied dimension in this context is the role of modal alternatives. Given their underlying transport technologies, the economic effects of a maritime port are likely to differ from those of a rail-freight terminal or airport. Further complexity arises if the impact of one modal gateway depends on the accessibility of another, or if transport modes differ in their ability to reach specific destinations or carry specific products.[2]

This paper sheds light on these mechanisms by studying the early rollout of the *China-Europe Railway Express* (CRE). The CRE established direct rail-freight connections to Europe from a number of Chinese cities on regular schedules, which offered fast but capacity-constrained rail transport as a potential alternative for slower but less-constrained sea transport. Using detailed data on trade and firm-level activity across Chinese prefecture-level cities,[3] we show that enhanced market access through this new modal gateway was followed by local export growth and firm entry into exporting. The effects are strongest where alternative access to global markets is otherwise limited and vary systematically across product categories, consistent with differences in modal suitability. We develop a micro-founded spatial equilibrium model of international trade with multiple regions and sectors to study the economic implications of these observations. In our model, firms optimize their trade routes by exporting via alternative ports and using different transport modes. The availability of new rail-freight connections from specific locations lowers exporting thresholds for certain firms and products, which entails positive aggregate welfare but also significant spatial distributional effects.

Our empirical analysis takes advantage of several features specific to the CRE rollout

[1] Hubs represent the node of a network (i.e., port locations from which goods are shipped and received) while spokes are the legs (i.e., surrounding locations that access foreign markets via these hubs). See Heiland et al. (2025), Ganapati, Wong and Ziv (2024) for characterizations of the networks. See Juhász et al. (2026) for a recent discussion of stylized facts on maritime trade and port development.

[2] A number of papers established that the modal choice depends partly on the physical characteristics of a good, which determine relative transportation costs, as well as the preferences of the buyers or seller with regards to timely delivery (See, for example, Harrigan, 2010; Hummels and Schaur, 2013).

[3] We refer to cities as a particular layer of the administrative division in China. Cities can comprise large non-urban areas and, depending on certain characteristics or their geographic location, they can be called prefectures, prefecture-level cities, autonomous prefectures, or leagues. We use the term city to indicate any of these administrative units that commonly reside at the second layer of China's administrative division, i.e. below provinces.

and convenient for identification. Unlike other infrastructure projects, the CRE connections were established within a relatively short period of time, as trains operate on already existing rail tracks that became economically relevant after administrative alignments among transit countries and some capacity building at container terminals and junction points. We interpret the CRE rollout as an infrastructure upgrade, which is different from the lengthy process of planning and constructing physical rail infrastructure. Another feature is that the market access facilitated by CRE services is destination and transport-mode specific. Terminal cities become gateways for shipments to European markets by rail. Leveraging detailed information from the China Customs Database, we analyze city-level export activity along these dimensions to identify the impact of the first CRE schedules (adopted between 2011 and 2016) on regional exports and economic activity.

Four core empirical findings characterize the mechanisms this paper focuses on. Using an extended two-way fixed effects PPML estimator, and propensity score matching for sample selection, we find that CRE connections increased city-product-group level exports to Europe by about 18%. The effect is driven by rail shipments, but is accompanied by smaller, though fragile, positive spillovers to sea and air exports. This suggests that CRE services did not merely induce substitution across transport modes, but appeared to be locally trade creating. Second, rail export growth varies substantially across products and positive effects concentrate among manufactured goods (including machinery, electrical equipment, vehicles, metal products, chemicals, and some textile sector goods). This is consistent with the idea that rail-freight occupies an intermediate position between ocean shipping and air freight, in terms of speed and capacity. Third, differential effects across cities indicate stronger responses for cities farther away from sea ports and less centrally located in the domestic expressway network experience stronger rail-export responses, in line with the idea that the accessibility of alternative export routes and modes matters. Using a concentric ring approach, we further find that cities up to a distance of 200 km from CRE terminal reveal increased rail exports to Europe, providing support of existing but limited spatial spillover effects. Finally, auxiliary firm-level information from the China Tax Survey reveals that CRE terminal cities experience significant entry into exporting after the launch of a connection, as well as (gradual) increases in other firm-level measures such as sales, profits, wages, R&D spending, and employment.

Building on our empirical findings, we develop a spatial equilibrium model of international trade with multiple sectors and regions to evaluate the welfare consequences of a destination- and transport-mode specific infrastructure. Expanding on the port-choice framework of Bonadio (2024) we incorporate sector and firm heterogeneity, as well as a more flexible choice of shipping decisions for exporters. Our model features a rich specification of trade costs

to accommodate our observations. The welfare effects of the CRE depend on the effective reduction in trade costs, which is governed by the respective elasticities of transport mode and port choices.

Putting the model to work, we follow Dekle, Eaton and Kortum (2008) and derive sufficient statistics for changes in cities' bilateral trade costs that are reminiscent of the canonical formulas for the gains from trade derived by Feenstra (1994) and Arkolakis, Costinot and Rodríguez-Clare (2012). Specifically, we demonstrate that the sector-specific share of exports transported via non-rail modes and the corresponding modal elasticity of substitution describe the effective change in trade costs. The advantage of this approach is that it only requires the estimated elasticity of substitution across transportation modes, as well as data on exports by transport mode. We thereby avoid the need to estimate the elasticity of trade costs with respect to distance and other variables, which would entail complex and daunting parametrization procedures.

For our welfare analysis, we leverage a city-level multi-regional input-output (MRIO) table of Chinese domestic trade flows, which we combine with sector-level international trade flows to compute welfare changes across Chinese cities, Europe and the rest of the world. We quantify the aggregate welfare gains from the CRE as amounting to about 0.25 percent of GDP. This number is considerably smaller than the welfare gains inferred in studies where trade costs reductions are not specific to a particular transport mode or export destination.[4] Since rail freight exports to the EU represent only a small fraction of China's total exports, we consider this estimate as a reasonable approximation. Further analyses show that these welfare gains exceed our estimate of the initial start-up costs of the CRE, which we approximate from the subsidization of CRE shipments during the first decade of its operations, by more than an order of magnitude.

Focusing on local economic outcomes across China, we highlight in our simulations that firm entry into exporting differs substantially across sectors and regions, reconciling the uneven effective reduction in trade costs. Consequently, also the welfare effects of the CRE are not evenly distributed across cities, creating winners and losers. Cities with an industrial base that is prone to utilizing rail-freight for their exports benefit directly from enhanced market access. They also benefit indirectly from general equilibrium effects, as their emerging comparative advantage attracts resources from other regions. In a counterfactual exercise, we compare our multi-sector model with a single-sector benchmark in which all sectors respond equally to the new export opportunities. While average welfare gains are similar in the

[4] Ducruet et al. (2024) estimate global welfare gains of containerization amounting to 3.4%. The same number is obtained by Tombe and Zhu (2019) when quantifying the welfare effects of decreasing external trade costs for China during 2000-2005. Fajgelbaum and Redding (2022) obtain larger gains for Argentina, amounting to 7.1%, following reductions in transatlantic freight rates during 1869-1914.

two models, the multi-sector economy reallocates firm entry across sectors and generates a markedly different incidence of gains and losses across cities. Such mechanisms are not specific to trade infrastructure development and extend beyond to carry lessons for place-based and industrial policies more generally.[5]

Related Literature. Our paper contributes to the international trade, economic development, and transportation economics literature in which infrastructure constitutes the overarching theme. Early contributions in the international trade literature have highlighted the importance of port efficiency (e.g. Clark, Dollar and Micco, 2004),[6] which has been linked broader economic welfare effects after the container revolution (Bernhofen, El-Sahli and Kneller, 2016; Ducruet et al., 2024). An important feature of international trading networks is their hub-and-spoke structure — within countries and globally (Ganapati and Wong, 2023; Ganapati, Wong and Ziv, 2024; Heiland et al., 2025) — which entail important interdependencies between trade and urban development (Ducruet, Cuyala and El Hosni, 2018). (Juhász et al., 2026) review the recent history of maritime port development, finding that major hubs may gain or lose their comparative advantage over time as technologies evolve and either substitute or complement each other. This relates also to the infrastructure and geography within a country that can decisively influence the development major transport hubs and global gateways (e.g., Duranton, Morrow and Turner, 2014; Xu and Yang, 2021; Fan, Lu and Luo, 2023; Bonadio, 2024). While this literature focuses primarily on maritime ports, which are truly "global" gateways, our paper analyses the trade effects of port efficiency from a novel angle, where modal choices between rail and maritime transport decisively impact their local and aggregate welfare implications.[7]

Our paper is also linked an economic development literature that focuses on the role of domestic and international trade infrastructure more broadly (Alder, 2016; Bonfatti and Poelhekke, 2017; Banerjee, Duflo and Qian, 2020; Demir, 2026). Focusing on physical transport infrastructure, Coşar and Demir (2016) and Martincus, Carballo and Cusolito (2017) study how domestic infrastructure matters for trade participation. Related to this, Donaldson (2018) and Coşar et al. (2022) investigate how domestic transport infrastructure shapes domestic trade and regional development and convergence. Closer to our setting is Coşar

[5]Port and infrastructure development can be seen as specific forms of place-based and industrial policies. Gateways are place-based by definition, while mechanisms that render industry-specific effects relate such interventions to industrial policies. See Juhász, Lane and Rodrik (2024), Juhász and Lane (2024), and Suedekum (2025) for recent discussions.

[6]Port efficiency is closely linked to the role of transportation costs, where Hummels (1999), Limão and Venables (2001), and Glaeser and Kohlhase (2004) made early contributions.

[7]Similarly, although in a different context, (Ghose et al., 2026) study the impact of trade infrastructure on services trade and local labor markets exploiting a unique setting that allows them to isolate this channel and distinguish it from other forms of trade.

and Fajgelbaum (2016) who analyze a stylized dual economy where locations close to international gateways specialize in export-oriented sectors while more distant locations do not trade with the rest of the world. A similar channel is analyzed by Baldomero-Quintana (2025) who studies how connecting a Colombian manufacturing region to global gateways increases their output and shapes the country's comparative advantage. Our setting is richer, featuring multiple sectors and regions, allowing us to evaluate comprehensive spatial and sectoral adjustments in a complex interplay of locally concentrated market access shocks that are shaped by China's internal economic geography and heterogeneous modal elasticities across products.

Related work in transportation, urban and spatial economics includes Faber (2014), Asturias, García-Santana and Ramos (2019), Jaworski, Kitchens and Nigai (2023), Michaels (2008), and Baum-Snow et al. (2017), which make important empirical contributions. Allen and Arkolakis (2022) provide a general quantitative framework in which route choices over a transportation network determine trade costs, traffic, and welfare. Our work links most closely to recent extensions of this framework, such as Fuchs and Wong (2026), who study multimodal transport networks and substitution across shipping modes (e.g., truck and rail) in the United States. Tolva (2026) studies modal substitution following airspace closures. While both of these papers focus on the aggregate economic welfare and environmental effects of modal substitution in a single-sector setting, our paper highlights how sector-specific elasticities can significantly alter conclusions about the magnitude and distribution of gains.

Finally, our paper relates also to research that focuses on China' s policies to promote global trade integration and economic development. This includes quantitative studies that evaluate the regional trade and welfare effects of China' s Belt and Road Initiative (BRI), such as De Soyres, Mulabdic and Ruta (2020) and Baniya, Rocha and Ruta (2020), as well as empirical work by Görg and Mao (2022), Li, Bolton and Westphal (2018), Mau and Seuren (2023), Kleimann and Schmerer (2024). In contrast to these studies, our research is based on significantly more granular data, which enables us to employ a much finer identification strategy and to assess impacts along several other dimensions compared to previous studies. Our conclusions, hence, relate also to recent findings and broader challenges that have been highlighted in the context of place-based and industrial policies (Moretti, 2024; Juhász, Lane and Rodrik, 2024; Juhász and Lane, 2024; Suedekum, 2025).

The remainder of our paper is organized as follows. Section 2 describes the context of CRE and the data used in our analysis. Section 3 investigates the effects of CRE using reduced-form estimations. Motivated by the empirical facts, Section 4 sets up a multi-sector heterogeneous-firms model with a rich specification of trade cost, which we use to estimates the cross-transportation and cross-route elasticities for each sector in Section 5. Section 6

computes the welfare effects of the CRE, based on the estimated elasticities and discusses their implications. Section 7 concludes.

2 Background and Mechanisms

Early railfreight from China to Europe. The first commercial railfreight schedule between China and Europe was adopted in 2011 with the Yu-Xin-Ou (渝新欧) railway connection from Chongqing to Duisburg (Germany). Its launch followed efforts of the Chongqing municipal government to promote its consumer electronics industry, which had attracted investments by multinational enterprises into what became the world's largest laptop production facilities. Being located in a mountainous area of Southwest China, far a way from sea ports, the successful delivery of goods produced in Chongqing required advanced integration into global transportation and logistics networks. While traditional export routes were either slow (ocean shipping) or expensive (air freight), direct access to European markets could significantly boost its exporting potential.[8]

Chongqing's municipal government pioneered the use of the New Eurasia Land Bridge corridor for its exports, which relied on existing rail tracks, spanning from Lianyungang in East China to Rotterdam in the Netherlands, and passing through six countries.[9] Regular shipments required administrative and logistical alignment among all transit countries, such as expedited customs procedures and coordination for changing rail gauges at borders. The first train running from Chongqing to Duisburg arrived on March 19, 2011, after traveling more than 11,000 kilometers in 16 days and carrying mainly electronic products and mechanical parts among other goods.[10] Subsequently, the railfreight share in Germany's laptop imports from China increased from zero to about 25 percent within one decade. The share of other transport modes decreased from 80-90 percent to 60-70 percent (airfreight) and from about 20 to less than 10 percent (ocean shipping), respectively.[11]

Development of the China-Europe Railway Express. Following Chongqing's example, other Chinese cities also adopted regular freight schedules for rail transport to Europe, which are formally administered by the *China State Railway Group Corporation* as the *China-*

[8] In the years 2007-2010, one third of China's laptop exports were shipped to the European destinations, while the EU market accounted for slightly more than 50 percent of global laptop imports. Calculations are based on data from CEPII Baci (v202301), where laptops are identified as corresponding to HS6 product code 847130.

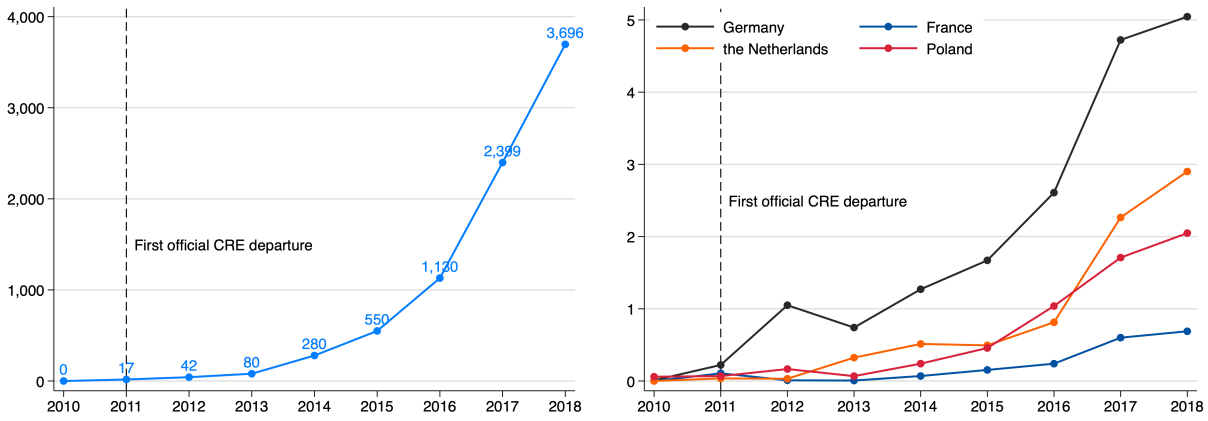
[9] CRE connections use the New Eurasian Landbridge corridor with border crossings in Kazakhstan, Russia, Belarus, and entering the EU via Poland.

[10] See www.ecns.cn (2021), accessed March 19, 2024.

[11] Calculations based on data from Eurostat (ds-058213) for the years 2005-2020.

Europe Railway Express (CRE). By the end of 2016, twelve Chinese cities had launched direct railfreight connections to Europe on a regular schedule. More cities started using CRE services in subsequent years, counting 62 in 2018 and 86 by the end of 2023 (including a few non-EU destinations in Eastern Europe or Central Asia).[12] Figure 1 presents aggregate statistics on the number of West-bound trains under the CRE and rail exports to selected EU destinations since 2010. While initial shipments are negligible, the number of train departures doubled almost every year. The differential growth in rail export volumes across destinations can be explained partly by the different terminal stations of the CRE schedules and the starting year of their operations. Germany, the first connected and most centrally located country in Europe's railfreight network, saw a five-fold increase of rail imports from China between 2013 and 2018.

Figure 1: CRE development and rail exports to major European destinations



(a) Number of CRE departures

(b) Rail exports, billion USD

Source: Belt and Road Portal and China Customs Database. The figure shows the number of CRE departures from China and rail exports from China to Germany, France, the Netherlands, and Poland, 2010–2018. The vertical dashed line marks the first official CRE departure in March 2011.

It can be assumed that the early roll-out of CRE connections did not occur randomly. The launch of a connection was partly the result of decentralized local governments' initiatives that required centrally-supervised formal approval. Reasons for local governments to establish a connection related to a mix of strategic, political, and developmental objectives,

[12]Recent statistics on the number of trains and containers shipped to and from Europe are documented on the CRE websites https://www.crexpress.cn/en/#/allTraffic (last accessed: 20 March 2024). While initial years saw a strong imbalance in the number of departures (exports) and arrivals (imports), they are almost equal today. In this paper, we focus only on the exports of goods from China to Europe via rail or other transport modes. During our investigation period (2010-2018), China's export to Europe by rail increases by over 500% while China's import from Europe by rail increases by less than 10%.

where the CRE was seen as instrumental for achieving broader economic goals.[13] Cities' exporting potential and logistical positioning, hence, likely played a role in this process. In addition to this, since 2012, China operated a decentralized subsidy system for CRE shipments to incentivize their uptake amid higher costs and lower capacity relative to ocean shipments. While we cannot directly observe or verify the amount and duration of these subsidies, we can interpret the launch of CRE connections as realizations of a place-based industrial policy program to promote regional economic development by lowering the barriers to accessing foreign markets.[14] In the analysis that follows, we focus primarily on the (reduced-form) economic outcomes and mechanisms of the CRE. A cost-benefit analysis of this policy will be presented alongside our discussion of its welfare effects.

Economic mechanisms. Abstracting from the processes underlying their approval, CRE connections introduce a new modal option for shipping goods from China to Europe. This occurs through shorter delivery times as well as lower shipping costs,[15] which is equivalent to a foreign market access shock.[16] Firms can re-optimize their shipping routes, or start exporting altogether, if (i) they are close enough to CRE terminal cities and if (ii) their goods are suitable for rail transportation.

The first prediction follows from the operational patterns documented for international trade logistics, which rely on entrepôt hubs in spatial networks and imply potential regional spillover effects (e.g. Heiland et al., 2025; Ganapati, Wong and Ziv, 2024). The fact that CRE trains do not stop on their journey between origin and destination becomes a feature that works in favor of formulating the hypothesis that cities that are starting points of CRE services, as well as those located relatively nearby, will benefit the most from improved market access. Cities located along the railway route, but far away from CRE terminals, are likely to benefit less or not at all.[17] The second prediction emphasizes that CRE services offer only

[13] Gao and Zhen (2017) provides a comprehensive overview of the early development of CRE connections, including Yu-Xin-Ou, Yi-Xin-Ou, Rong-Ou, Zheng-Ou, and Han-Xin-Ou. In some cases, CRE connectivity was actively promoted by the central government. For instance, the establishment of the Yi-Xin-Ou route resulted from direct negotiations between President Xi Jinping and the Spanish government.

[14] In fact, the importance of rail exports remained limited. For both the EU27 and Germany as its main CRE hub, the rail share in total imports from China peaked at about 2.5 and 4.5 percent, respectively, in the years 2017-2019.

[15] Anecdotal evidence suggests that railway shipping times from Shanghai/China to Hamburg/Germany decreased from 47 to only 16 days between 2006 and 2017, while the cost for a forty foot equivalent unit decreased by almost 25 percent (Table B.1). No other transport mode experienced comparable cost reductions during this period.

[16] This is distinct from other settings of trade infrastructure development which typically have prolonged extensive planning and construction periods (Ducruet et al., 2024), but conceptually similar to the idea of "port upgrades" as in Bonadio (2024).

[17] The China Customs database allows us to observe how railfreight exports to Europe are spread across different exit ports (or cities). For 2018, we observe that exports from cities we identify as CRE terminals

rail transport, which is faster but also more capacity constrained than ocean shipping.[18] The probability that CRE schedules lead to increased exports and other forms of economic activity will consequently depend on the cost (and time) elasticity of transport mode choices for exports, which can be determined by product-specific physical characteristics and customers' preferences (e.g. Harrigan, 2010; Hummels and Schaur, 2013).

The following section presents our empirical analysis, in which we correlate various measures of exporting activity across cities and industries with the CRE connection status of Chinese cities. Subsequently, we use a model to reconcile these patterns.

3 Empirical Analysis

3.1 Data

Our empirical analysis uses detailed information on the adoption of regular CRE services connecting Chinese cities to European markets between 2011 and 2016. We identify prefecture-level cities as starting points of a CRE connection.[19] Figure 2 illustrates our sample and how the differential geographic location of terminal cities may entail different effective export costs reductions, depending on their distance to seaports.

To evaluate the relationship between the adoption of CRE services and city-level trade activity, we match this information with transaction records documented in the Chinese Customs database for the years 2006-2018.[20] In the raw data, each observation provides 8-digit product level information on the value and quantity of cities' exports, disaggregated by destination country and mode of transportation. For our analysis, we aggregate products to the 2-digit HS Chapter (HS2) level and study how the value of city-level exports to Europe evolves following a change in the CRE connection status, depending on product group and transport mode. For additional outcomes related to local economic activity, we complement

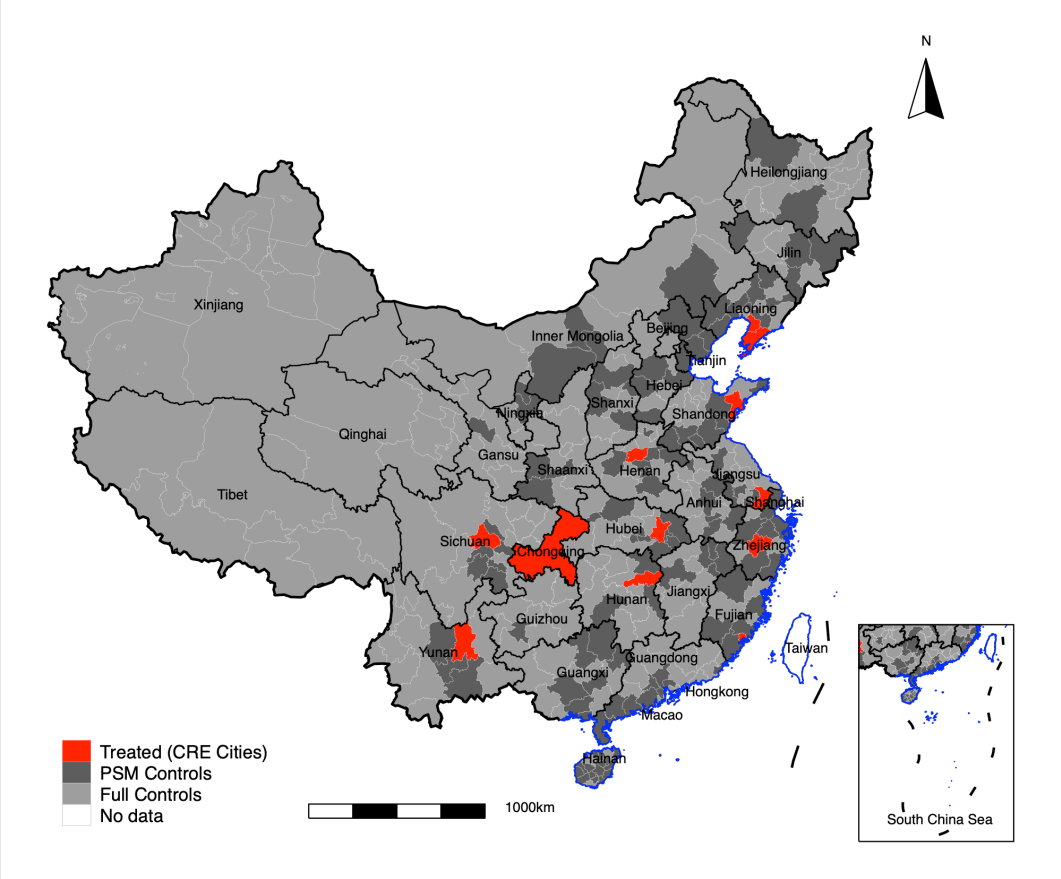
cover 67% of these shipments. This implies that about one third of railfreight exports take place on an irregular (non-scheduled) and customized basis from other cities (also see RailFreight.com, last accessed 29 Aug 2024). Considering railfreight departing from CRE cities, we further observe that 55% of these shipments originate from these cities, while the remainder comes from other cities but is shipped via CRE terminals, implying potential regional spillover effects.

[18] Statistics published on CRE shipments count a maximum of 100 containers per train, which is considerably less than the several thousands of containers that can be carried on a container ship.

[19] China's administrative division has five hierarchical levels of governance: (1) the central government at the national level; (2) provinces; (3) prefectures; (4) counties; and (5) townships. In this paper we generally refer to the second level, prefecture-level cities, which also include the four province-level cities Beijing, Tianjin, Shanghai and Chongqing. Following this convention, we assign CRE in county-level cities Yiwu and Jiaozhou to their respective superseding prefecture-level cities, Jinhua and Qingdao. See Table B.2 for an overview of all CRE terminals included in our sample.

[20] The dataset used here corresponds to the data that was purchased and harmonized by Feenstra et al. (2018), and generously provided by the Center for International Data at the University of California, Davis.

Figure 2: Geographic distribution of treated and control cities



Note: Red areas denote cities operating regular CRE services (treated). Dark gray areas denote PSM-matched control cities. Light gray areas denote full control cities (non-treated, not PSM-matched). Coastlines are shown in blue.

our data with firm-level information from the China Tax Survey.[21] Variables included in this survey concern firm-level balance sheet information, such as their foreign and domestic sales, R&D expenditures, operating profits, payrolls, and employment. Based on the reported tax-ID and information on firms' city-level location, we are able to construct a firm-level panel dataset for the years from 2010 to 2016 that matches our information on CRE connectivity, despite a somewhat shorter time window. Table A.1 reports summary statistics for our main variables of interest.

[21]The survey covers about 600,000 firms per year, including different types such as exporters, manufacturing enterprises, as well as small-scale service sector firms and individual businesses. See Appendix A for further details on the data sources used in this paper.

3.2 Econometric specification

To assess the impact of CRE operations on city level export performance, we employ an extended two-way fixed effects (ETWFE) estimator within a Poisson Pseudo Maximum Likelihood (PPML) framework. This enables us to employ high-dimensional fixed effects while taking into account the information contained in export zeros, i.e. observations without documented trade activity (Santos Silva and Tenreyro, 2006, 2011). In addition, it is well suited for staggered treatment adoption settings (Wooldridge, 2025), where conventional two-way fixed effects estimators may be biased in the presence of heterogeneous treatment effects across cohorts or over time. Our baseline specification takes the following form:

$$Export_{ikt}^{EUR} = \exp\left(\sum_{g\in G}\sum_{\tau\neq -1}\theta_{g,\tau}CRE_{ikg\tau(t)} + \mu_{ik} + \mu_{kt}\right) \times \epsilon_{ikt} \tag{1}$$

The dependent variable, $Export_{ikt}^{EUR}$, measures the value of exports to Europe produced in city i, industry k and year t. Since all our CRE routes enter European destinations via the same railway corridor (Mau and Seuren, 2023), we do not distinguish between destinations inside Europe. Our main variable of interest is the cohort- and event-time-specific treatment indicator, $CRE_{ikg\tau(t)} = \mathbb{1}\{G_i = g\} \cdot \mathbb{1}\{t - g = \tau\}$. It equals one if city i belongs to treatment cohort g and is observed τ years after the opening of its first CRE connection, and zero otherwise. We thereby obtain estimates of cohort- and event-time-specific treatment effects, $\theta_{g,\tau}$, which can be interpreted as group-time average treatment effects on the treated (ATTs).

In our baseline specification, we consider only the directly connected cities as treated and consider all other cities in our sample as control units. Potential caveats of this approach and our strategies to mitigate them will be discussed alongside with our empirical results. To minimize omitted variable bias, we include city-industry (μ_{ik}) and industry-year (μ_{kt}) fixed effects to control for cities' sector-specific supply capacities and comparative advantages, as well as aggregate industry dynamics, respectively.

Identification. A core challenge of identification is the non-random selection of cities into the CRE network, so that cities in the control group are likely very different along several dimensions. We therefore complement our baseline specification with a propensity score matching (PSM) approach. Doing so, we construct a set of matching covariates based on export performance prior to the launch of the first regular CRE services. These variables capture average annual growth in exports to Europe before 2011, as well as corresponding growth rates for maritime and air exports to Europe. To allow for greater flexibility in pre-treatment trends, we additionally include alternative growth measures computed over

different pre-treatment windows. Treated cities are then matched to the 20 nearest untreated cities with similar propensity scores, subject to a caliper restriction of 0.05. Because one treated city is matched to multiple control cities, the matched sample is organized into matched groups rather than one-to-one pairs. Each group consists of one treated city and its matched controls. Since the same control city may be selected into more than one matched group, some control observations appear multiple times in the matched sample. To account for this structure, we include matched-group-by-year fixed effects, so that identification comes from comparisons within matched groups over time.

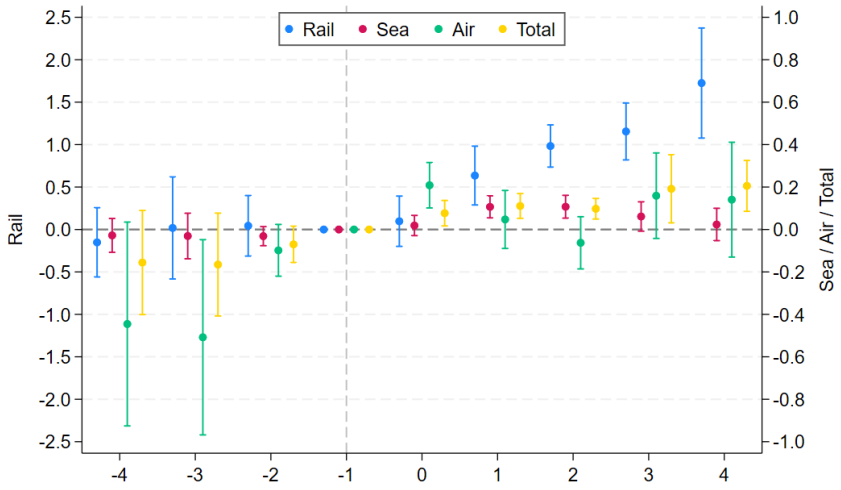
3.3 Main empirical findings

Finding 1: Increasing exports to Europe, mainly through rail freight

Our first main finding is summarized in Figure 3, which displays how average city-HS2 level exports to Europe evolve. Both rail and total exports to Europe increase significantly after the launch of a CRE connection, where differences in the estimated magnitudes reflect the fact that rail-freight started out from a significantly lower base level. Interestingly, also sea and air-freight appear to indicate some temporary adjustments. Although less precisely estimated, airfreight exports seem to increase one or two years before the launch of a CRE connection, but stop growing post-CRE, which could reflect anticipation effects or trial shipments.[22] For sea exports, we observe a temporary expansion from and a subsequent reversal to initial levels after the launch of a connection. Although we cannot formally test the underlying mechanisms, an explanation could be that initial congestion or capacity constraints of CRE transport induced exporters to use alternative transport modes.

[22] Anecdotal evidence suggests that several CRE routes were preceded by public planning, trial operations, or early freight services. For example, Chongqing tested the domestic section of the CRE Yu-Xin-Ou route in 2010 before the first regular train departed in March 2011 (https://www.yidaiyilu.gov.cn/p/159807.html, accessed May 7, 2026). Chengdu's CRE had experimental operations in December 2012 and entered trial operation in April 2013 before formal operation in May 2013 (https://www.sc.gov.cn/10462/10464/10465/10595/2013/4/27/10259781.shtml, accessed May 7, 2026). For Suzhou, official materials indicate that the CRE freight line was opened in November 2012, while regular export train operations started in September 2013 (https://commerce.suzhou.gov.cn/szdoc/szsswj/uploadfile/xk5noc2bykg.pdf, accessed May 7, 2026).

Figure 3: Dynamic effects of CRE connections



Note: The figure reports ATTs obtained from the ETWFE-PPML estimator using the matched sample. Coefficients trace the evolution of export outcomes in connected cities relative to their matched controls, with the year before their connection ($\tau = -1$) serving as the reference period. Each coefficient is a weighted average treatment effect at event time τ. Estimates are shown separately for total exports, rail exports, sea exports, and air exports. Coefficients for rail exports are scaled to the left axis, while all other coefficients are scaled to the right axis. Vertical lines indicate 95% confidence intervals. Standard errors are two-way clustered at the matched-group and industry-year levels.

Table B.3 reports the aggregated ATTs for our different specifications and confirms our first main finding, including statistically significant (temporary) modal spillover effects. As a robustness check we also employ a Synthetic Control Methods (SCM) approach (see Appendix Figures B.1 and B.2).[23] In at least nine of our twelve treated cities we observe positive deviations relative to their synthetic control group after the start of CRE operations. Overall, our estimates suggest that the establishment of the CRE has been followed by increased export volumes from connected cities, relative to pre-CRE periods and similar (but not directly connected) cities.

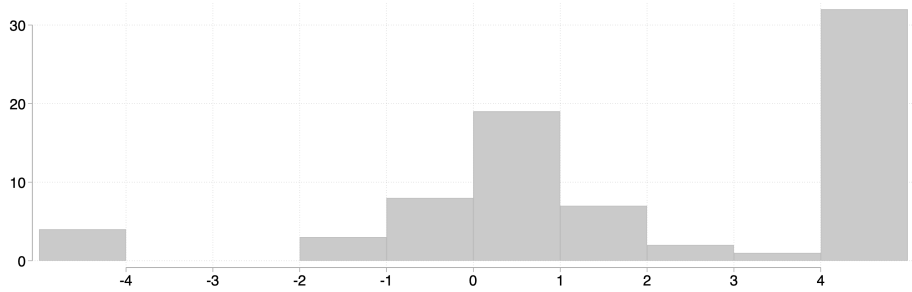
Finding 2: CRE effects on rail-exports differ across product groups

Our second key finding is summarized in Figure 4, showing that the responsiveness of rail-freight shipments to Europe differs across HS2-level product groups. While many product groups reveal only modest or even insignificant responses, strong positive effects are found among a range of manufactured products. Such differences due to product-specific characteristics as well as their suitability for different transport modes. As pointed out in early studies by Harrigan (2010) and Hummels and Schaur (2013), transport-mode choice

[23]We construct synthetic controls using data from 2001-2018 to predict city-level exports to Europe based on revealed pre-trends and other variables that capture their general export and manufacturing sector performance.

can systematically depend on product characteristics such as value-to-weight ratios or time sensitivity. In terms of carrying capacity and transport speed, rail freight resides in an intermediate position between sea and air transport and most likely to be valuable for the transport of goods where faster delivery is beneficial, but air shipment is too costly.

Figure 4: Distribution of estimated coeffecients for CRE impact on rail exports to Europe across HS2 Chapters



Note: Figure displays the frequency of estimated ATTs displayed on the horizontal axis, obtained from separate ETWFE regressions at the HS2 level using the matched sample. All specifications are estimated using a PPML estimator with city-industry, industry-year, and matched-group-year fixed effects. ATTs greater than 4 and less than or equal to -4 are grouped into the correpoding upper and lower tail bins. Estimates based on less than 1,000 observations or missing coefficients are excluded from the figure.

Appendix Figure B.3 reports the corresponding distributions for total exports, as well as sea and air shipments, where the resulting distributions are much more homogeneous. In Figure B.4, we further report the coefficient estimates and confidence intervals for each HS2 industry and transport mode.

Finding 3: Stronger effects in initially less connected cities and spatial spillovers

Considering the different locations of CRE terminals across China, we ask whether cities in geographically more remote locations, with less access to seaports or domestic transport routes, respond differently to CRE connections. To analyze this, we revert to a conventional differences-in-differences model, which allows us to use interaction terms with city characteristics. Columns (1)-(2) of Table 1 show that a generally observable post-CRE increase in rail exports to Europe is quantitatively larger in cities that are farther way from sea ports. The point estimate in column (1) suggests that for every 100 kilometers between a city and a seaport, the estimated response in export growth increases by 20 percent. For the cities in our sample this implies quite different market access shocks, as their distances to sea ports range from less than 10km to up to 1,000km (see Table B.2). Columns (3) and (4) corroborate this result using cities' eigenvector centrality in the domestic transportation network as

an alternative measure of connectedness.[24] Here, the initially more connected cities appear to show significantly slower export growth after CRE operations started. Overall, this finding suggests that CRE terminals have relatively larger effects on exports in relatively more remote Chinese cities.

Table 1: Distance to seaports and centrality in domestic transportation networks

Dep. Var.: $Export_{ikt}^{EUR,rail}$	(1)	(2)	(3)	(4)
	Distance to ports		Road network centrality	
CRE_{it}	0.441	0.622***	1.717***	2.064***
	(0.277)	(0.224)	(0.484)	(0.526)
× minimum distance (in km)	0.002***			
	(0.000)			
× distance > 200 km		1.619***		
		(0.565)		
× centrality			-0.903*	
			(0.481)	
× centrality > median				-1.409***
				(0.539)
Observations	317,772	317,772	293,813	293,813
City-Industry FE	✓	✓	✓	✓
Industry-Year FE	✓	✓	✓	✓
Group-Year FE	✓	✓	✓	✓

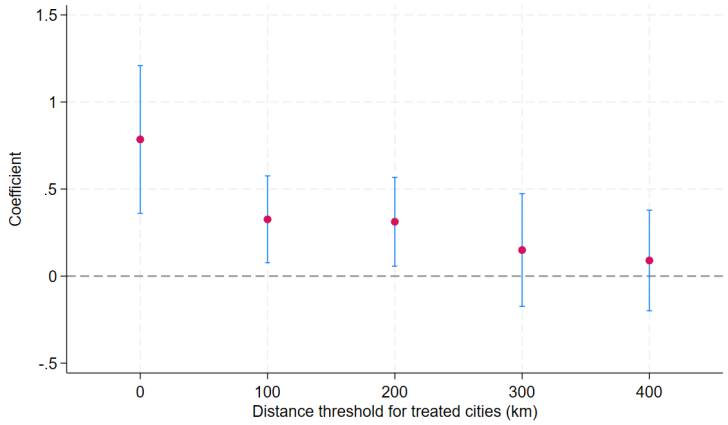
Note: Table reports estimated effects of CRE connections on rail exports to Europe, where CRE_{it} is an indicator equal to one if city i is connected to the CRE network in year t or after, and zero otherwise. Interaction terms indicate differential effects of CRE connections depending on cities' connectedness to domestic transport and foreign trade infrastructure. All specifications include city-industry, industry-year, and matched-group-year fixed effects. Standard errors in parentheses are two-way clustered at the matched-group and industry-year levels. Statistical significance: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

Besides the heterogeneity concerning cities' location within China, we also consider the location of non-connected cities relative to CRE terminals. Since CRE railfreight provides non-stop services to their respective destinations, we consider potential spillover effects to be most likely in cities nearby the terminals. We evaluate this with a concentric ring approach and allocate cities into bins of 100, 200, 300 and 400 kilometers from a terminal city, to estimate the export response for each group. Figure 5 summarizes the results suggesting that, next to CRE terminal cities, also locations within a range of 200 kilometers reveal elevated exporting activity post-CRE.[25] While the magnitude and precision of the CRE effect declines with distance from terminal cities, the existence of such spillover effects indicate potentially larger trade-creation effects compared to our first main finding.

[24] We calculate a city's eigenvector centrality in the 2010 expressway network, which reveals that cities in East China as well as adjacent inland cities are most centrally located. See Appendix A.

[25] Precise coefficients of these regressions are reported in Appendix Table B.6

Figure 5: CRE effects by distance to terminal cities



Note: Figure plots estimated effects of CRE connections on rail exports to Europe across distance bins from the nearest CRE terminal city. Markers indicate point estimates and the vertical lines indicate 95% confidence intervals. Coefficients correspond to estimates from a PPML model within a TWFE framework, where cities located more than 400 km from the nearest CRE terminal are treated as control units. All specifications include city-industry and industry-year fixed effects, as well as city-year level control variables, including cities' GDP, secondary industry output, total and secondary sector employment, as well as city-industry-year level global exports. Standard errors are clustered at the city level.

Finding 4: Firm entry into exporting

Our final main finding concerns firm-level responses to the establishment of CRE connections. To analyze this, we use data from the Chinese Tax Surveys which allows us to construct a firm-level panel for years 2010-2016. Table 2 presents the results for a number of firm-level outcomes. For our baseline specification in Panel A, we find that the introduction of CRE connections to Europe is associated with a significantly higher entry rate into exporting among firms that operate in the connected cities. Similarly, their R&D expenses, profits, and total payroll increases. Total sales and employment appear to be insensitive to CRE connectivity, initially, but increase (slowly) over time, as shown in columns (2) and (6) in Panel B. These findings indicate that cities with CRE terminals experience also broader changes in local economic activity and effectively lower barriers for firms to enter foreign markets.

Overall, our empirical analysis suggests that CRE connections have been locally trade-creating and facilitated entry into exporting by firms. Increased exporting activity appears to be geographically concentrated around CRE terminal locations, while there are also heterogeneous responses across products. In the following section, we incorporate these findings into a quantitative framework to analyze what locally concentrated and sector-specific market access shocks imply for overall economic activity and welfare.

Table 2: Firm-level estimates

	(1)	(2)	(3)	(4)	(5)	(6)
Dep. Var.:	$Exporter_{jt} = 1$	$\ln Sales_{jt}$	$\ln R\&D_{jt}$	$\ln Profit_{jt}$	$\ln Payroll_{jt}$	$\ln Emp_{jt}$
Panel A: $CRE_{it} = 1$	0.104***	0.013	0.106***	0.056***	0.086***	-0.005
	(0.003)	(0.010)	(0.035)	(0.012)	(0.008)	(0.005)
Panel B: Years since $CRE_{it} = 1$	0.070***	0.024***	0.100***	0.042***	0.048***	0.010***
	(0.002)	(0.007)	(0.022)	(0.007)	(0.005)	(0.003)
Observations	2,850,236	1,575,008	87,232	1,414,756	2,466,588	2,794,388

Note: Table reports estimated effects of local CRE connections on firm-level outcomes using data from Chinese Tax Surveys for 2010-2016. Dependent variables are indicated in column titles, while variables of interest are specified as a dummy variable in Panel A and as a continuous measure in Panel B. All specifications include firm and year fixed effects, as well as city-year control variables (incl. GDP, secondary-industry output, employment, and employment in the secondary sector). Standard errors are clustered at the firm level. Statistical significance: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

4 A Model of Transportation Mode Choice

This section develops a quantitative general equilibrium model which features multiple regions and sectors, matching the margins of adjustment documented in our empirical analysis. Doing so, we combine elements from related work, in which firms choose optimal transport modes (Fuchs and Wong, 2026) and export ports (Bonadio, 2024), and further enrich these by introducing heterogeneous firms (Melitz, 2003) and different degrees of modal substitutability across sectors. After describing and characterizing our model, Section 5 takes it to the data to estimate its unknown parameters and to quantify effective reductions in trade costs between Chinese cities and European markets. Section 6 examines how these reductions in trade costs affect city-level and aggregate welfare.

4.1 Model Environment

We consider a world economy consisting of $N+2$ regions (indexed by either i or j, depending on whether the region in question is the origin i or the destination j of a shipment). A region can be a Chinese city, Europe, or the rest of the world (ROW). There are S sectors, indexed by s.

Although our model is static, it is convenient to think of it as unfolding in four sub-periods. In the first sub-period, firms considering to start producing decide whether to pay the fixed market entry cost so as to get a quality draw in their respective sector. Following this, firms with good enough quality stay in the market and decide on the quantity they produce and whether to export or not. This decision is based on the *expected* trade costs. In the third step, exporters choose the optimal transportation mode and ports after learning

about their idiosyncratic productivity (quality) that affects shipping costs via specific routes. Finally, in the fourth sub-period, the production and consumption of all goods take place. In the following, we describe these steps and the relevant features of the economic environment and refer to Appendix C for more detailed derivations.

Consumer Preferences. Each region j is home to a mass L_j of identical agents, who have Cobb-Douglass preferences over sectors s,

$$U_j = \prod_{s=1} \left(Q_j^s\right)^{\alpha^s}, \tag{2}$$

where α^s is the expenditure share of sector s so that $\sum_{s=1}^{S} \alpha^s = 1$, and Q_j^s is a constant elasticity of substitution (CES) aggregator of a continuum of goods, with the elasticity of substitution σ^s:

$$Q_j^s = \left[\sum_i \int_{\omega \in \Omega_{ij}^s} \left(z(\omega) q_{ij}(\omega)\right)^{\frac{\sigma^s - 1}{\sigma^s}} d\omega\right]^{\frac{\sigma^s}{\sigma^s - 1}}. \tag{3}$$

Each variety is denoted by ω and $z(\omega)$ captures the quality of that variety. $q_{ij}(\omega)$ denotes how much of the variety that is supplied from region i is consumed in region j.

Each consumer inelastically supplies one unit of labor. Labor income $w_j L_j$ is the only source of revenue which consumers spend on varieties from different regions and sectors:

$$\sum_s \sum_i \int_{\omega \in \Omega_{ij}^s} p_{ij}(\omega) q_{ij}(\omega) d\omega = w_j L_j. \tag{4}$$

In the above budget constraint, $p_{ij}(\omega)$ denotes the price of variety ω of sector s, supplied from region i to region j. w_j denotes the wage rate in region j.

Production and Market Structure. Each differentiated variety can be produced by a firm (indexed k or z) using a constant returns to scale production technology in which labor is the only factor of production. Firms compete in a monopolistically competitive environment and all differentiated goods are tradable.

In each region i, firms produce a single variety of a differentiated good of sector s that has quality z. Following convention, we will use the quality of the variety z also to index each producer. Specifically, upon entry, for which firms pay a fixed cost equal to f_E units of domestic labor, a firm's quality draw z is obtained from an unbounded Pareto distribution whose c.d.f. and p.d.f. are $H_i(z) = 1 - (b_i/z)^{\kappa}$ and $h_i(z) = \kappa b_i^{\kappa}/z^{\kappa+1}$, respectively. κ and b_i are positive constants that govern the shape and the position of the distribution. In addition to fixed entry costs (f_E), the firms face fixed operating costs (f_j) in each market to which

they sell. As a result of these fixed costs, less efficient producers supply to fewer markets, while some do not operate at all. Only a mass J_i^s of firms establishes and pays the fixed entry cost f_E that is measured in home labor units. Free entry drives expected operating profits to $w_i f_E$.

Firms in region i produce their goods with the same marginal cost c_i. Once a firm decides to sell to region j, it pays a fixed cost f_j in destination labor units, i.e., $w_j f_j$. Upon entering j, firms optimize their production based on the expected bilateral trade cost d_{ij}^s that differ by sector and depend on logistical infrastructure that is used to ship goods from i to j. In our setting, firms can choose from alternative transportation modes and routes, as we detail below. Substituting the inverse demand function into firm k's revenue function, we derive its net profits from exporting to region j:

$$\pi_{kij}(z) = L_j \left[\frac{\alpha^s w_j}{\left(Q_j^s\right)^{\frac{\sigma^s-1}{\sigma^s}}} z^{\frac{\sigma^s-1}{\sigma^s}} q_{kij}(z)^{\frac{\sigma^s-1}{\sigma^s}} - c_i w_i d_{ij}^s q_{kij}(z) \right] - w_j f_j, \tag{5}$$

In the given environment, the price a firm with quality z charges in destination j is determined by a constant markup over its marginal costs of production and delivery. The revenues of exporting from region i to j can be described as follows:

$$r_{kij}(z) = \frac{L_j (\sigma^s - 1)^{\sigma^s - 1} (\alpha^s w_j)^{\sigma^s}}{(\sigma^s)^{\sigma^s - 1} \left(Q_j^s\right)^{\sigma^s - 1}} \left(c_i w_i d_{ij}^s\right)^{-(\sigma^s - 1)} z^{\sigma^s - 1}. \tag{6}$$

Evidently, the value of trade from i to j is affected by the expected trade costs d_{ij}^s a firm faces, which further depends on the firm's optimal choice of transportation mode and port, which we specify in the following.

Trade Costs and Optimal Transportation Mode Choice. Trade of goods between regions is costly but costs nothing within a region. The sector-specific expected bilateral trade costs d_{ij}^s $(i \neq j)$ depend on firms' choice of transportation mode and ports in shipping. For simplicity, we first focus on an exporter k from i, and assume that it faces the following iceberg trade cost when exporting to destination j, using transportation mode m and port ρ:

$$\tau_{kij,\rho m}^s = \frac{\tau_{ij,\rho m}^s}{\varepsilon_{kij,\rho m}}. \tag{7}$$

In the numerator of this expression, $\tau_{ij,\rho m}^s$ captures all the costs that are common to firms when using mode m and port ρ for shipping goods from i to j. In line with our empirical findings, the common cost component can vary across sectors, depending on product char-

acteristics that determine their suitability for alternative transport modes. Furthermore, $\tau^s_{ij,\rho m}$ captures heterogeneity in port quality, which can result in firms' decision to export via more distant ports. The denominator is a random firm-specific productivity shifter $\varepsilon_{kij,\rho m}$, which allows for the possibility that two identical firms choose different ports and transport modes, even if they sell the same (amount of the same) good from i to j. The idiosyncratic productivity shifter becomes known to a firm after it decided to produce and sell to market j.

We assume that firms draw $\varepsilon_{kij,\rho m}$ simultaneously and independently from the following multivariate nested Fréchet joint distribution:

$$F^s(\boldsymbol{\varepsilon}_{kij}) = \exp\left[-\sum_m \left(\sum_\rho \left(\varepsilon^{-\vartheta^s}_{kij,\rho m}\right)^{\frac{1}{\theta^s}}\right)^{\theta^s}\right], \tag{8}$$

where ϑ^s denotes a dispersion parameter. A smaller value of ϑ^s implies that firms are more heterogeneous in their ε across ports. Parameters θ^s govern the degree of within-transportation mode correlation in productivities, which is decreasing in θ^s. As in Bonadio (2024), when $\theta^s = 1,\ \forall s$, these productivities are independent. After realizing the productivity shifter, firms choose the transportation mode (m^*) and port (ρ^*) to minimize their export cost $\tau^s_{kij} = \min_{\rho,m}\{\tau^s_{kij,\rho m}\}$.

Using the properties of the Fréchet distribution, we derive the probability of using transport mode m and port ρ in shipping goods to the final destination in the following equation:

$$\mu^s_{ij,\rho m} = \underbrace{\frac{\left(\tau^s_{ij,\rho m}\right)^{-\frac{\vartheta^s}{\theta^s}}}{\sum_{\rho'}\left(\tau^s_{ij,\rho' m}\right)^{-\frac{\vartheta^s}{\theta^s}}}}_{\equiv \mu^s_{ij,\rho|m}} \times \underbrace{\frac{\left(d^s_{ij,m}\right)^{-\vartheta^s}}{\sum_{m'}\left(d^s_{ij,m'}\right)^{-\vartheta^s}}}_{\equiv \mu^s_{ij,m}}. \tag{9}$$

The unconditional probability of shipping goods with mode m via port ρ equals the probability of using port ρ conditional on using the mode m, i.e., $\mu^s_{ij,\rho|m}$ times the probability of using transportation m, i.e., $\mu^s_{ij,m}$. The latter is affected by $d^s_{ij,m} \equiv \left(\sum_{\rho'}\left(\tau^s_{ij,\rho' m}\right)^{-\frac{\vartheta^s}{\theta^s}}\right)^{\frac{-\theta^s}{\vartheta^s}}$, which captures the average trade cost for mode m. In the exponents of the two partial probabilities, ϑ^s/θ^s indicates the elasticity of substitution across ports within a given transportation mode, while ϑ^s measures the sector-specific elasticity of substitution across transport modes. Greater values of these elasticities entail a higher responsiveness of firms to a change in the mode- and port-specific costs $\tau^s_{ij,\rho m}$.

Following the characterization above, the expected costs of shipping goods from sector s

from a Chinese region i to a foreign destination j are given by:[26]

$$d_{ij}^{s} = E\left[\min_{\rho,m} \frac{\tau_{ij,\rho m}^{s}}{\varepsilon_{kij,\rho m}}\right] = \xi^{s}\left[\sum_{m'}\left(\sum_{\rho'}\left(\tau_{ij,\rho' m'}^{s}\right)^{-\frac{\vartheta^{s}}{\theta^{s}}}\right)^{\theta^{s}}\right]^{-\frac{1}{\vartheta^{s}}} = \xi^{s}\left[\sum_{m'}\left(d_{ij,m'}^{s}\right)^{-\vartheta^{s}}\right]^{-\frac{1}{\vartheta^{s}}}. \quad (10)$$

It depends on firms' transportation mode and port choice, which is determined by common costs $\tau_{ij,\rho m}^{s}$ and the shape parameters $\theta^{s}, \vartheta^{s}$ of the nested Fréchet distribution. The parameter ξ^{s} reflects a sector-specific constant, which involves the Gamma function and ϑ^{s}.

To reconcile the importance of the elasticity ϑ^{s}, we consider a change in the costs for using a specific mode m and characterize its impact on the costs of exporting faced by a firm. Using a second-order approximation of the log change in d_{ij}^{s}, we can decompose this effect into two components:

$$d\ln d_{ij}^{s} \approx \underbrace{\mu_{ij,m}^{s}(d\ln d_{ij,m}^{s})}_{\text{direct impact}} - \underbrace{\vartheta\mu_{ij,m}^{s}\left(1-\mu_{ij,m}^{s}\right)\left(d\ln d_{ij,m}^{s}\right)^{2}}_{\text{indirect impact from mode switching}}. \quad (11)$$

The first component captures the direct effect, which depends on the share of shipments that is already carried via that mode, $\mu_{ij,m}^{s}$. The second term captures the indirect impact, which results from switching to the now relatively lower-cost mode. A larger ϑ^{s} implies a higher responsiveness to the cost change and more exporters adjusting their modal choice, implying a greater reduction in the overall bilateral trade costs. However, for products that can only be shipped via a certain mode of transport, ϑ^{s} is small and a reduction in the costs of using other modes will result in minor or no adjustments of the overall bilateral trade costs (both directly and indirectly). The parameter ϑ^{s} therefore co-determines how reductions in modal trade costs result in actual improvements of market access of regions, as their prevalent industry structure and specialization patterns might not necessarily reflect products that can easily switch to a different mode.

4.2 Equilibrium

Before moving on to calibrating and evaluating our model, we describe its equilibrium and discuss two propositions that follow.

Zero Profit Cutoff Condition and Free Entry of Firms. Due to the presence of fixed operating costs, we can use the equilibrium conditions for prices and quantities derived

[26] For trade across Chinese regions, across foreign countries, and from foreign countries to Chinese regions, we assume constant trade costs common to all firms and exogenously determined. See Equation (C.5) for a full specification of bilateral trade costs.

before to determine the threshold quality level at which a firm's profits are exactly equal to zero. That is, considering the case where $i \neq j$ and setting $\pi_{kij}(\bar{z}^s_{ij}) = 0$, we obtain

$$\bar{z}^s_{ij} = \left(\frac{(\sigma^s)^{\sigma^s} \left(Q^s_j\right)^{\sigma^s - 1}}{L_j (\sigma^s - 1)^{\sigma^s - 1} (\alpha^s w_j)^{\sigma^s}} \right)^{\frac{1}{\sigma^s - 1}} c_i w_i d^s_{ij} \left(w_j f_j\right)^{\frac{1}{\sigma^s - 1}}, \tag{12}$$

which suggests that a reduction in shipping costs d^s_{ij} results in more firms exporting from i and in an overall increase in the variety of exports.

Since firms pay a fixed cost for entering the market and to make their quality draw from the known distribution $H_i(z)$, free entry implies that the expected operating profits of a firm are equal to these entry costs. Using Equations (5) and (12), and the assumption that $H_i(z)$ is Pareto distributed, we derive the following equilibrium condition

$$E_z \left[\pi_{kij}(z)\right] = \sum_j (b_i)^\kappa \left(\bar{z}^s_{ij}\right)^{-\kappa} \bar{\pi}^s_{ij} = \frac{\sigma^s - 1}{\sigma^s \kappa} \sum_j (b_i)^\kappa \left(\bar{z}^s_{ij}\right)^{-\kappa} \bar{r}^s_{ij} = w_i f_E. \tag{13}$$

which relates the zero profit cutoff levels of quality to the fixed costs of operating in a specific market (f_j) and the fixed entry costs (f_E).

Trade Balance and Market Clearing. To close the model, we require that all entities obey their budget constraints, that markets clear, and that trade is balanced (see Appendix C).

Let λ^s_{ij} denote the share of region j's total expenditure in sector s on goods from market i. In this share, integrating over sales of all firms in s from i to j yields the numerator, and summing over all markets i gives the denominator. We can obtain the following expressions for the expenditure share:

$$\lambda^s_{ij} = \frac{J^s_i (b_i)^\kappa \left(d^s_{ij} c_i w_i\right)^{-\kappa}}{\sum_v J^s_v (b_v)^\kappa \left(d^s_{vj} c_v w_v\right)^{-\kappa}} \tag{14}$$

where J^s_i is the number of entrants in sector s and region i, d^s_{ij} is the expected sector-specific trade cost, c_i and w_i denote the region-specific marginal production costs and the wage rate. The parameter b_i denotes the lower bound of the Pareto distribution.

Combining the free entry condition with the market clearing condition, we solve for the equilibrium mass of entrants:

$$J^s_i = \frac{\sigma^s - 1}{\sigma^s \kappa w_i f_E} \sum_j \alpha^s \lambda^s_{ij} w_j L_j, \tag{15}$$

while, with trade balanced, the market clearing condition can be derived as followings:

$$\sum_s \sum_j \alpha^s \lambda_{ij}^s w_j L_j = w_i L_i, \tag{16}$$

where α^s is the share of sector s in total expenses.

Without loss of generality, we normalize the wage of region j to unity and use its labor as the numéraire. The equilibrium is pinned down by equations (14)-(16), which endogenously determines the equilibrium values of λ_{ij}^s, J_i^s, and w_i. In the system b_i, c_i, σ^s, α_s, f_E and d_{ij}^s are model primitives. Notably, the expected trade cost d_{ij}^s is determined by the set of mode- and port-specific transport costs $\tau_{ij,\rho m}$ and their respective elasticities, ϑ^s and ϑ^s/θ^s.

Comparative statics. To develop intuition on how CRE connections affect exports, overall and for different transport modes, we discuss comparative statics of a simplified version of our model. Considering only one sector and full symmetry across regions in terms of their initial economic conditions, we can set $L_i = L$, $c_i = c$, $b_i = b$, $f_i = f, \forall i$. This symmetry implies equal equilibrium wages across regions, which we normalize to unity, i.e., $w_i = w = 1$. Also trade costs are the same across regions initially.

We model the start of a CRE connection as a reduction in railfreight-specific trade costs, starting from an initial scenario without any rail exports. Cities connected to the CRE now face lower costs when exporting their goods via their railway ports, and their expected bilateral trade costs. Proposition 1 summarizes this result:

Proposition 1 *In the simplified model with a single sector and initially symmetric regions, a reduction in trade costs for a specific mode of transport (i.e., rail freight) and port of exit results in lower average bilateral exporting trade costs for port cities and increases the proportion of their exports that are carried by that mode.*

As the mass of entrants is fixed in the single-sector model, declining trade costs lower the entry quality cutoff and increase exports at both the intensive and extensive margin, as in Melitz (2003). Rising exports and rail-freight shares also increase the volume trade that is shipped through this mode. However, also shipment through other transportation modes might be affected, while the direction of their adjustment is *a priori* ambiguous:

Proposition 2 (Spillover effect on sea transportation) *In the simplified model with a single sector and initially symmetric regions, a reduction in trade costs for a specific mode of transport (i.e., rail freight) and port of exit can increase or decrease the volume of exports carried by other modes (e.g. sea), depending on the elasticity of substitution across transportation modes and dispersion parameters.*

While we provide formal proofs of these propositions in Appendix C.5, the intuition behind Proposition 2 follows from the overall increase in export volumes and the fact that firms decide on transport modes and routes only after they decide to export. Indeed, lower railfreight costs result in larger proportion of exports via rail, and correspondingly declining shares for other transport modes. However, as total exports increase and more firms start exporting, their idiosyncratic trade-route productivity draw $\varepsilon_{ijk,\rho m}$, as well as the modal and port-specific transport cost elasticities, can result in increased utilization of all transportation modes[27]. Our model, hence, describes a mechanism that rationalizes (potentially temporary) modal spillovers of the CRE, which we documented in our empirical analysis.

5 Model Calibration

5.1 Estimation strategy

To calibrate our model and subsequently apply it to welfare analyses, we estimate its key parameters, θ^s and ϑ^s. The estimation procedure broadly follows Bonadio (2024) and is implemented in two steps. We first estimate trade costs $\tau^s_{ij,\rho m}$, relying on our auxiliary model structure and observable trade data in a fixed effects regression. With those at hand we recover the average mode-specific trade costs, $d^s_{ij,m}$, as well as expected export costs, d^s_{ij}. In the second step, we plug our trade cost estimates into the mode-port-choice equation (18), to estimate θ^s, and subsequently into the exports equation (C.11), to back out ϑ^s.

Trade Costs. Our procedure requires an assumption on the structure of general trade costs $\tau^s_{ij,\rho m}$, namely that it can be separated into two components:

$$\tau^s_{ij,\rho m} = \tau^s_{i,\rho m}\tau^s_{j,\rho m}. \tag{17}$$

The first portion, $\tau^s_{i,\rho m}$, captures the cost of shipping a good from its origin i to port ρ to use mode m. The second component, $\tau^s_{j,\rho m}$, captures the cost of shipping the good from the port of exit to destination j using mode m.[28] The conditional probability of port choice becomes $\mu^s_{ij,\rho|m} = \left[\tau^s_{i,\rho m}\tau^s_{j,\rho m}/d^s_{ij,m}\right]^{-\frac{\vartheta^s}{\theta^s}}$, which corresponds to the expected value of a dummy variable

[27] The utilization of alternative modes can be explained by co-ordination or de-congestion effect between difference choices, as in Brancaccio, Kalouptsidi and Papageorgiou (2024), who document that investment in one port can decongest a wider set of ports.

[28] Unlike Bonadio (2024), as we do not focus on quality of ports, there is also no port-specific term in (17). Instead, our analysis focuses on a reduction in shipping costs from port ρ to Europe, $\tau^s_{j,\rho m}$. Consistent with our empirical findings, our assumption implies that a uniform decrease in $\tau^s_{j,\rho m}$, has a relatively stronger effect on overall trade costs for regions located closer to the port, i.e. where $\tau^s_{i,\rho m}$ is smaller.

that indicates firm k's choice to use port ρ for exporting a good using mode m.

Taking this port-choice equation to the data, we evaluate it separately for each transport mode using a Poisson pseudo-maximum-likelihood (PPML) estimator with high dimensional fixed effects:

$$E\left[1_{kij,\rho}|m\right] = \frac{\left(\tau^s_{i,\rho m}\tau^s_{j,\rho m}\right)^{\frac{-\vartheta^s}{\theta^s}}}{\left(d^s_{ij,m}\right)^{-\frac{\vartheta^s}{\theta^s}}} = \exp\left(\underbrace{-\frac{\vartheta^s}{\theta^s}\ln\tau^s_{i,\rho m}}_{f^s_{i\rho m}\text{FE}} \underbrace{-\frac{\vartheta^s}{\theta^s}\ln\tau^s_{j,\rho m}}_{f^s_{j\rho m}\text{FE}} + \underbrace{\frac{\vartheta^s}{\theta^s}\ln d^s_{ij,m}}_{f^s_{ijm}\text{FE}}\right) \tag{18}$$

The dependent variable, $1_{kij,\rho}$, is a dummy variable that equals unity if firm k from region i uses port ρ to export to destination j, given that it chooses transportation mode m.

The sum of the estimated fixed effects $f^s_{i\rho m}$ and $f^s_{j\rho m}$ have the structural interpretation of $\frac{\vartheta^s}{\theta^s}\ln(\tau^s_{i,\rho m}\tau^s_{j,\rho m})$.[29] We construct average modal export costs by aggregating over ports, using $g^s_{ij,m} = \sum_\rho \exp\left(f^s_{i\rho m} + f^s_{j\rho m}\right)$, where $\left(g^s_{ij,m}\right)^{-\frac{\theta^s}{\vartheta^s}}$ converges in probability to $d^s_{ij,m}$, since $(f^s_{i\rho m} + f^s_{j\rho m})$ converges to $\frac{\vartheta^s}{\theta^s}\ln(\tau^s_{i,\rho m}\tau^s_{j,\rho m})$ and the definition implies that $d^s_{ij,m} \equiv \left(\sum_{\rho'}\left(\tau^s_{ij,\rho' m}\right)^{-\frac{\vartheta^s}{\theta^s}}\right)^{\frac{-\theta^s}{\vartheta^s}}$. The expected bilateral trade costs d^s_{ij} can, hence, be written as a function of the estimated average modal costs $d^s_{ij,m}$, with unknown parameters ϑ^s and ξ^s, as specified in Equation (10).

Estimating Shape Parameters. To avoid estimating the constant term ξ^s, we take the ratio of the share of exports carried by the rail to that by the sea. We take logs on both sides, which derive the regression equations for estimating the unknown shape parameter θ^s and ϑ^s:

$$\ln\left(\frac{\mu^s_{ij,Sea}}{\mu^s_{ij,Rail}}\right) = -\vartheta^s\ln\left(\frac{d^s_{ij,Sea}}{d^s_{ij,Rail}}\right) = -\theta^s\ln\left(\frac{g^s_{ij,Sea}}{g^s_{ij,Rail}}\right). \tag{19}$$

The first equality holds since $\mu^s_{ij,m} = \left(d^s_{ij,m}\right)^{-\vartheta^s} / \left(d^s_{ij}/\xi^s\right)^{-\vartheta^s}$, while the second equality comes from the fact that $\left(g^s_{ij,m}\right)^{-\theta^s/\vartheta^s}$ converges in probability to $d^s_{ij,m}$, as explained above. Since $g^s_{ij,m}, \quad m \in \{Rail,\ Sea\}$ are observable, we estimate θ^s using the second equation of (19), by regressing the relative share of rail transportation $\ln(\mu^s_{ij,Sea}/\mu^s_{ij,Rail})$ on $\ln(g^s_{ij,Sea}/g^s_{ij,Rail})$.

Having obtained estimates of θ^s, we can construct $h^s_{ij} = \sum_m (g^s_{ij,m})^{\theta^s}$, where $\xi^s(h^s_{ij})^{-1/\vartheta^s}$ converges in probability to d^s_{ij}. In the last step, we substitute d^s_{ij} with $\xi^s(h^s_{ij})^{-1/\vartheta^s}$ into the

[29] As discussed in Weidner and Zylkin (2021); Bonadio (2024), the fixed effects f^s_{ijm} are not consistent estimators of $\frac{\vartheta^s}{\theta^s}\ln d^s_{ij,m}$ and cannot be directly used. A consistent estimator of $\frac{\vartheta^s}{\theta^s}\ln(\tau^s_{i,\rho m}\tau^s_{j,\rho m})$ also requires a large number of destination or origin regions while the number of ports remains constant, which holds in our sample.

bilateral exports equation:

$$E\left[r_{kij}(z)\right] = \underbrace{\frac{L_j(\sigma^s-1)^{\sigma^s-1}\left(w_j\right)^{\sigma^s}}{\left(\sigma^s\right)^{\sigma^s-1}\left(Q_j^s\right)^{\sigma^s-1}}}_{\equiv\beta_j^s}\underbrace{\left(c_i w_i\right)^{-(\sigma^s-1)}\xi^s(z)^{\sigma^s-1}}_{\equiv\alpha_k^s}\left(h_{ij}^s\right)^{\frac{\sigma^s-1}{\vartheta^s}} \tag{20}$$

The set of parameters summarized by α_k^s captures marginal costs of a firm producing in sector s. The ratio summarized under β_j^s captures the aggregate demand conditions in destination j. Equation (20) provides a way to estimate $(\sigma^s-1)/\vartheta^s$, by regressing exports on h_{ij}^s in a log-linear model, while controlling for the exporter (α_k^s) and destination (β_j^s) fixed effects. Using estimates of trade elasticities σ^s from the literature, we can recover our own estimates of the shape parameter ϑ^s, which characterizes how easily exports of a particular sector s can switch from one transport mode to another.

5.2 Implementation

To implement the estimation strategy outlined above, we use information from the China Customs database, where we observe disaggregated transactions at the origin-port-destination level. As we do not observe individual firms k, we proxy these by considering the distinct 8-digit product codes of the Chinese combined nomenclature. Exploiting the hierarchical nature of this nomenclature, and its compatibility with the Harmonized System (HS) at 6-digits or higher, we define sectors s as higher-level groups of products whose code starts with same digits. These will form the basis of our sector-specific parameters $\hat{\theta}$ and $\hat{\vartheta}$. To back out the latter parameter, we use estimates of σ^s from Macedoni and Xu (2022) who adopt the same preference structure and industry classification in their calibration. Finally, since our empirical strategy relies on exploiting different transport modes, we focus on a subset of cities that features sufficient observations and variation across all relevant dimensions. Our calibration, hence, relies on a sample that comprises China's top 30 exporting cities in 2018 that ship their exports via 10 main ports, using either rail freight or sea transport. The top 30 exporting cities account for nearly 69.6% and 76.2% of China's exports carried by sea and rail, respectively, while the 10 main port cities account for 86.6% and 77.3% of China's total export using these modes.[30]

Table 3 presents the results of our calibration exercise. Column (4) indicates the estimated transport-mode elasticities, while column (5) reports port elasticities. The latter are typically quite large, which can be explained by the low estimates of θ, in column (1), implying a high correlation in port productivities, all other things equal (see Eq. (8)). This

[30] In 2018, their percentages of exports to the EU by sea and by rail were 72.6% and 4.6%, respectively.

suggests that, for a given transport mode, ports have very similar capacity and efficiency, making them close substitutes.[31] In contrast to this, the substitutability of transport modes is much lower, which may partly reflect capacity constraints of rail versus sea transport.[32]

Table 3: Estimated trade-cost elasticities of transport modes (ϑ^s) and port-choice (ϑ^s/θ^s)

		(1)	(2)	(3)	(4)	(5)
Industry Category	2-digit HS codes	θ^s	$(\sigma^s-1)/\vartheta^s$	σ^s	ϑ^s	ϑ^s/θ^s
Vegetable Products	06-15	0.039	0.687	1.777	1.131	29.000
Foodstuffs	16-24	0.006	0.832	1.844	1.014	169.071
Chemicals & Allied	28-38	0.012	0.990	2.729	1.746	145.539
Textiles	50-63	0.130	1.795	1.685	0.382	2.936
Metals	72-83	0.019	2.653	1.913	0.344	18.113
Machinery & Electrical	84-85	0.015	2.465	2.252	0.508	33.861
Transportation	86-89	0.057	1.660	2.000	0.602	10.569
Miscellaneous	≥90	0.014	2.704	1.746	0.276	19.706

Note: Values reported in columns (1), (2), (4) and (5) are estimated by the authors. Values in column (3) are borrowed from Macedoni and Xu (2022).

Considering the across sector differences in estimated modal elasticities $\hat{\vartheta}^s$, we can relate these to our earlier estimates of heterogeneous responses of exports to CRE adoption presented in Section 3. Relatively higher elasticities for Vegetable Products, Foodstuffs, and Chemical products in Table 3 coincide with the occurrence of relatively larger coefficient estimates for changes in rail-exports to the EU in Figure B.4. Textiles, Metals, and Miscellaneous products reveal lower cross-modal elasticities, whereas Machinery and Electronics, as well as Transport Equipment range in the middle. Intuitively, these pattern seem related to the "time sensitivity" of products (Hummels and Schaur, 2013): those with a higher modal elasticity estimate appear to be relatively more perishable and to have shorter shelf times.[33]

Altogether, our calibration exercise suggests that the introduction of a new modal choice

[31] Seaport capacities along China's extensive coastline reveal remarkable similarities. For instance, the Port of Shenzhen in the south, the Port of Ningbo-Zhoushan in the east, and the Port of Qingdao in the north have similar annual container throughput—27.7 million TEUs for Shenzhen, 27.5 million TEUs for Ningbo-Zhoushan, and 18.26 million TEUs for Qingdao. The workforce sizes of these ports are also similar, approximately 12,454 for Shenzhen, 17,425 for Ningbo-Zhoushan, and 9,218 for Qingdao. These figures demonstrate a notable uniformity in operational capacity and closely matched scale of these ports. For detailed information, see "Top Major Ports in China" at https://www.gocomet.com/blog/top-major-ports-in-china/..

[32] As reported in https://containerfaqs.com/how-many-containers-cargo-ship/ and https://traintrackshq.com/how-many-containers-can-a-train-carry/, the average number of containers carried on a ship is around 15,000, while the maximum loading capacity of trains is 200 containers, much smaller than that of a ship.

[33] Figure D.1 illustrates how our estimated modal elasticities relate to products' physical characteristics emphasized by Harrigan (2010) and time-sensitivity (Hummels and Schaur, 2013). Despite only a few data points a higher $\hat{\vartheta}$ seems to coincide with higher value-to-weight ratios or time-sensitivity.

for exporting to the EU may have had only limited effects on aggregate trade volumes, due to relatively low trade cost elasticities of transport modes. For the welfare analysis that follows, this implies that the benefits from CRE connections could be locally concentrated and driven by the suitability of local industries for long-distance railfreight transport.

6 Quantification of welfare effects

With the results from the previous section we can examine how CRE connections affect trade costs and welfare across Chinese regions. To do so, we express the equilibrium conditions of our model in relative changes, using the "hat" notation for the ratio of after-versus-before levels of a variable in response to a given perturbation: $\hat{x} \equiv x'/x$ for any variable x (Dekle, Eaton and Kortum, 2008).[34]

6.1 Data requirements

Sufficient statistics for $\widehat{\mathbf{d}}^{\mathbf{s}}_{\mathbf{ij}}$. To evaluate the general equilibrium effects of CRE connections, we first have to determine how much it has effectively changed the costs of exporting in every location. To achieve this, we derive a sufficient statistic.

We start with the notion that introduction of CRE connections enabled terminal cities to ship their goods to Europe directly via rail-freight, while previously only non-rail transport modes (primarily ocean shipping) were available. Hence, the initial costs of exporting from Chinese city i to a destination j equal $d^s_{ij} = \xi^s \left[\sum_{m\in\mathbb{M}}(d^s_{ij,m})^{-\vartheta^s}\right]^{-1/\vartheta^s}$, where $\mathbb{M}$ is the set of transport modes *excluding* rail freight. After a CRE connection is established, exporters have additional transportation mode choices and the trade cost becomes $d^{s\prime}_{ij} = \xi^s \left[\sum_{m\in\mathbb{M}\cup\{Rail\}}(d^s_{ij,m})^{-\vartheta^s}\right]^{-1/\vartheta^s}$. The ratio $d^{s\prime}_{ij}/d^s_{ij}$ denotes the change in bilateral trade costs due to the CRE introduction and can be charcterized as follows:

$$\hat{d}^s_{ij} = \begin{cases} \left(\mu^{s\prime}_{ij,\mathbb{M}}\right)^{\frac{1}{\vartheta^s}} & \text{if } i \in CHN \text{ and } j \in Europe \\ 1 & \text{Otherwise} \end{cases} \tag{21}$$

where $\mu^{s\prime}_{ij,\mathbb{M}}$ is the share of non-rail exports in sector s from city i to destination j in total exports. Whenever the destination of a shipment is not in Europe, transport mode choices and exporting costs remain unchanged and $\hat{d}^s_{ij} = 1$.

The above equation suggests that with our estimated elasticities of substitution between transportation modes ϑ^s, the non-rail share in i's total shipments to j is sufficient to deter-

[34] As shown in Appendix C.6, relating observed allocations to a given base year, we can solve the model without having to rely on estimates of fixed costs and other parameters that are not directly observable.

mine the change in bilateral trade costs. It is based on the (reasonable) assumption that before regular CRE schedules were taken up, the share of exports to Europe by rail was zero. This solution is reminiscent of the simple and canonical formulas for the gains from trade derived by Feenstra (1994) and Arkolakis, Costinot and Rodríguez-Clare (2012), where initial expenditure shares and substitution elasticities provide sufficient statistics and share a common structure. All we need to implement this approach are the elasticities of substitution across transportation modes $\hat{\vartheta}^s$ from Section 5 and information on exports from Chinese cities by sector, destination, and mode of transport.

Additional data for welfare analyses. For our full welfare analysis, we supplement our information on trade costs changes, with data on regions' populations and trade shares. In our model, *regions* comprise Chinese cities, Europe and the RoW, which implies that trade shares must also include Chinese domestic transactions. As intra-national trade is typically not systematically monitored and documented by national customs or other authorities, we recover this information from a city-level multi-regional input-output (MRIO) table for 2012, which the authors of Zhong et al. (2026) generously shared with us. The table records bilateral trade flows between Chinese prefecture-level regions across 42 industries and was estimated from China's official input-output tables using an entropy-based procedure that disaggregates inter-provincial trade flows to the city level (see Zheng et al. (2022)).[35] Because the MRIO table refers to 2012, we set 2012 as the base year of our welfare analysis.

We combine this information with international trade data. The China Customs database provides sectoral trade flows between Chinese cities and Europe and the rest of the World (RoW) in 2012, while WTO data provides sectoral trade flows between Europe and RoW.[36] We aggregate the 42 MRIO industries into the eight sector categories of Table 3, as detailed in Table D.1, and convert international trade flows and foreign GDP, which are reported in U.S. dollars, to RMB at the average 2012 exchange rate of 6.31 ¥/$. Together, these data yield the initial trade shares λ_{ij}^s, the final consumption shares α^s, as well as regional population for the base year 2012. To obtain the sufficient statistics for the change in bilateral trade costs to Europe, we use the China Customs data and compute city-sector-transport mode specific shipments for 2018.

[35] Our final sample retains regions that are covered by the MRIO in 2012 and by the China Customs database in 2012 as well as 2018. For a few provinces (Hainan, Yunnan, Tibet, Qinghai), prefecture-level units are aggregated to the province level.

[36] WTO data record cross-country shipments only and therefore exclude countries' sales to their own market. We therefore complete the diagonal (own-region) flows of Europe and the RoW in two parts: (i) the within-region shipments that the bilateral WTO data do report, such as shipments between individual European countries, and (ii) each region's own-country sales, which we measure by the region's GDP in 2012 and allocate across the eight sectors using the sectoral expenditure shares implied by China's MRIO table.

We also supplement this MRIO-based measure of domestic trade flows with transaction records from the online retail platform *Taobao* as a robustness check.[37] The *Taobao* data offer two advantages: they are available from 2011 onwards, and they record actual transactions rather than estimated trade flows. However, they cover only China's top-100 exporting cities and mainly capture online consumer purchases, which correspond only imperfectly to the sector classification of the customs data. We therefore rescale these flows, within each sector, to match the MRIO-based domestic trade totals of the same cities.

6.2 Trade cost reductions and welfare effects of the CRE

Figure 6 illustrates how our model predicts CRE connections to affect trade costs and welfare across Chinese cities. Panel (a) focuses on the reduction of bilateral trade costs to Europe, which are obtained as the export-flow weighted average of the reductions in sector-specific bilateral trade cost.[38] The average reduction amounts to about 9 percent, but is quite unevenly distributed across cities: the median city experiences a decline of about 6 percent, and the reduction exceeds 11 percent for the quarter of cities with the strongest trade cost reductions.[39]

Solving the endogenous variables in our model, we obtain the implied welfare effects of CRE connections. These are displayed in Figure 6(b) and reveal both winners and losers. While some cities report large gains, equivalent to more than 3 percent of their local GDP, some cities (including ones with a CRE connection) experience welfare losses.[40]

The general equilibrium mechanics built into our model can explain this result: cities with only minor trade costs reductions end up in an inferior competitive position relative to cities with larger trade cost reductions. Labor demand and wages adjust accordingly and generate these nuanced economic consequences of the CRE. Despite these distributional effects, reductions in export costs are generally positively related with welfare changes, adding up to a GDP-weighted average welfare gain of 0.25 percent. This number plausibly reflects the overall limited scope of rail-freight trade and the fact that exports to the EU account

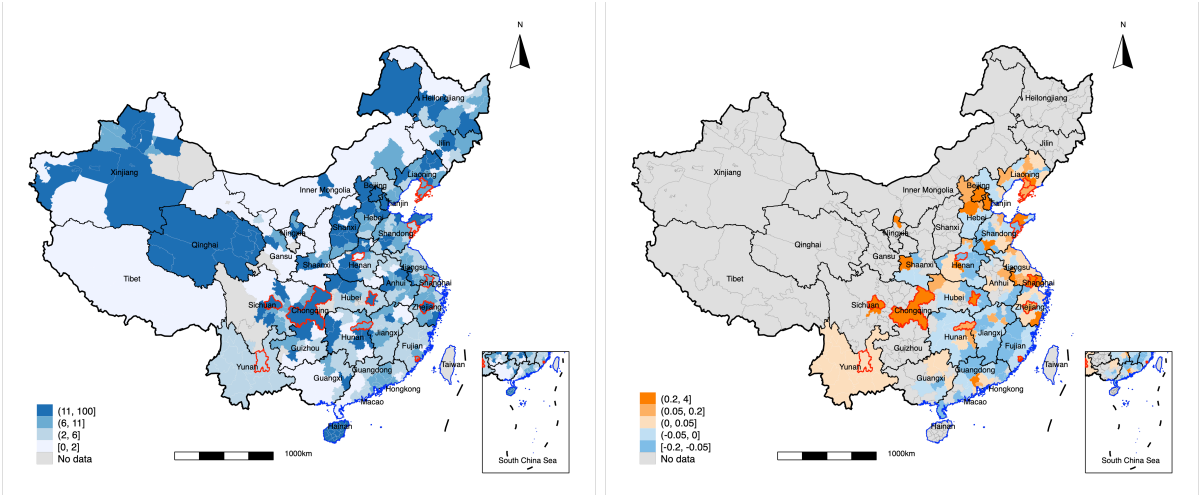
[37] *Taobao* platforms include a B2C platform (Tmall.com) and a C2C platform (Taobao.com). While these omit potentially important B2B transactions we assume that relative magnitudes of city-to-city trade transactions are broadly aligned.

[38] Weights are cities' sector-specific exports to Europe in 2012.

[39] Consistent with our empirical findings, Figure D.2 suggests that larger reductions can be observed for cities that are farther away from seaports.

[40] In a robustness check, we recalculate the welfare effects using domestic trade shares constructed from *Taobao* transactions, proportionally rescaled to match the MRIO-based domestic trade totals. Figure D.3 compares the implied city-level welfare changes across the 87 cities covered by both specifications; the correlation amounts to 0.50, and the *Taobao*-based specification implies welfare changes that are about three times as large. This comparison confirms the robustness of our findings with respect to who gains and who loses, despite a small number of significant deviations for individual cities.

Figure 6: Trade cost reductions and welfare effects of CRE adoption



(a) Trade cost reduction (b) Welfare change in GE

Note: Authors' calculation based on data and procedures outlined in Sections 5 and 6. Panel (a) shows sector-specific trade cost reductions to Europe, weighted by cities' export flows. Regions without positive trade shares to at least two destinations in every sector are excluded from the model solution and shown in gray. Cities with CRE connections are outlined in red. Coast lines indicated in blue.

only for a fraction of China's total exports and GDP.

Cost-benefit Analysis. Our reduced-form estimates as well as our model implicitly considers the CRE as a form of trade liberalization that made exporting less costly for firms. While this assumption conveniently simplified the empirical analysis and subsequent quantification, a complete evaluation of the CRE warrants an acknowledgment also of the public expenditures it entailed. As discussed in Section 2, in its early years, CRE connections were heavily subsidized to incentivize firms' uptake of railfreight to Europe and to scale these services to economically sustainable levels.

Although there exists no complete or systematic information about the amount and allocation of CRE subsidies, we can approximate the total subsidy costs based on their average rates and rail-freight capacities during our period of investigation. Taking the average subsidy rate of \$2,500 per forty-foot equivalent unit (FEU) container from Besharati et al. (2017),[41] and a total of 335,954 FEU shipments, we arrive at \$840 million in subsidy costs during the period 2011–2018. Our simulations imply an equivalent variation of welfare gains of about 111 billion CNY for the cities in our sample,[42] which, converted at the average 2012

[41] In some studies, the reported numbers are higher for individual cities and that average subsidy rates peak in 2018 at around \$5,000 per container (FEU) (ERAI, 2022). They nevertheless, differ remarkably across time and cities, at rates of \$6,400 per FEU in Chongqing, \$7,000 in Chengdu, \$7,400 in Zhengzhou, \$5,600 in Wuhan, but only \$1,000 in Suzhou (Jiang et al., 2018).

[42] The equivalent variation aggregates cities' welfare changes weighted by their 2012 GDP; see Appendix

exchange rate of 6.31 ¥/$, amounts to about $17.5 billion. Welfare gains thus exceeded subsidy costs by more than an order of magnitude already during the initial period of the CRE's operations, suggesting that the CRE can be seen as an economically viable industrial policy.

Regional convergence. The overall positive welfare effect masks substantial heterogeneity across cities, raising the question of whether cities that gain catch up with those that lose in terms of GDP per capita, or whether the distributional effects of the CRE increase or reduce regional inequality in China. To evaluate this, we relate cities' simulated welfare changes to their initial GDP per capita in 2012, and compare it to the implied GDP per capita based on our simulations (Figure D.4). The relationship between welfare gains and initial income is remarkably weak. The largest gains accrue to middle-income inland terminal cities such as Chengdu and Chongqing, but gains of comparable magnitude also accrue to rich coastal cities such as Beijing, Shanghai and Suzhou. Notably, older industrial and resource-based cities such as Anshan and Pingdingshan emerge among the main beneficiaries, with welfare gains of about 1.5 percent. Accordingly, the Gini coefficient of the implied GDP per capita distribution across our sample cities is essentially unchanged, rising marginally from 0.382 to 0.383. Hence, while the welfare effects of the CRE are geographically concentrated, they are not systematically tilted towards richer or poorer locations.

6.3 Firm entry and sectoral reallocation

We next examine how the CRE affects welfare and how sectoral heterogeneity shapes the incidence of these gains across cities. A key implication of the multi-sector model is that the CRE not only improves access to European markets but also reshapes effective comparative advantage across sectors within cities. Because the reduction in trade costs differs across sectors, some industries experience substantially larger improvements in export opportunities than others. These differences induce changes in European-market participation, local labor demand, wages, and ultimately the allocation of firm entry across sectors.

Figure D.7 illustrates the changes in bilateral firm participation in the European market, $\hat{N}^s_{iE}$, across cities and sectors. Lower trade costs make serving the European market more attractive, but the magnitude of this response differs substantially across city-sector pairs. These differences reflect both heterogeneous reductions in bilateral trade costs and differences in initial market exposure. Importantly, $\hat{N}^s_{iE}$ is a destination-specific margin: it captures changes in the number of firms from city i in sector s serving the European market.

C.6 for the construction of the monetary equivalent.

The corresponding changes in sectoral entry, $\hat{J}_i^s$, shown in Figure D.6, display a different margin of adjustment. Whereas $\hat{N}_{iE}^s$ concerns participation in a particular destination, $\hat{J}_i^s$ is determined in general equilibrium by sectoral revenues relative to the common local wage. Sectors that experience larger improvements in market access tend to expand their sales and increase local labor demand, putting upward pressure on wages. Because all sectors within a city face the same local wage, sectors receiving smaller gains in market access may contract even when their own trade costs do not increase. The CRE therefore induces reallocation toward relatively favored sectors rather than a uniform expansion of entry across all sectors. The substantial spatial and sectoral variation in Figure D.6 is consistent with this reallocation mechanism.

This sectoral adjustment matters for welfare. In the multi-sector model, welfare can be written as

$$\hat{U}_i = \underbrace{\prod_s (\hat{J}_i^s)^{\alpha_s/\kappa}}_{\hat{U}_i^J} \underbrace{\prod_s (\hat{\lambda}_{ii}^s)^{-\alpha_s/\kappa}}_{\hat{U}_i^\lambda}, \tag{22}$$

where $\hat{U}_i^J$ captures the entry and sectoral-reallocation component, while $\hat{U}_i^\lambda$ captures the component associated with changes in domestic expenditure shares. On average across Chinese cities, the latter component raises welfare by about 0.122 percent, whereas the entry/reallocation component is about -0.042 percent, leaving an average welfare gain of approximately 0.076 percent.[43] Thus, improved market access is the main source of the aggregate welfare gain, while endogenous sectoral reallocation partially offsets it.

To assess more directly the role of sectoral heterogeneity, we compare the baseline multi-sector economy with a single-sector benchmark. In the single-sector model, the entry and wage equilibrium conditions jointly imply $\hat{J}_i = 1$, so there is no cross-sector entry reallocation. Welfare therefore depends entirely on the change in the aggregate domestic expenditure share. We calibrate the single-sector trade elasticity using $\sigma = 1.826$, which produces an average welfare effect close to that of the multi-sector model and therefore provides a useful benchmark for isolating differences in the distribution and transmission of the CRE shock.[44] The single-sector specification fixes $\hat{J}_i = 1$ by construction, whereas the multi-sector model allows entry to reallocate across sectors within each city.

Table D.2 shows that the main difference between the two models is not the average magnitude of the welfare effect. The multi-sector model generates an average welfare gain of

[43] Because $\hat{U}_i = \hat{U}_i^J \hat{U}_i^\lambda$, the decomposition is multiplicative. In levels, the corresponding interaction term is small.

[44] For comparison, we also consider the conventional calibration $\sigma = 5$. Under this specification, the average welfare gain is substantially smaller, at about 0.017 percent (0.054 percent when GDP weighted), illustrating the sensitivity of the level of welfare gains to the aggregate trade elasticity.

0.076 percent, compared with 0.079 percent in the single-sector benchmark. GDP-weighted average gains are similarly close, at 0.248 and 0.265 percent, respectively. Their cross-city standard deviations are also nearly identical.

The shape of the welfare distribution, however, differs considerably. In the multi-sector model, the 10th percentile of welfare changes is -0.076 percent, compared with -0.036 percent in the single-sector model, while the 90th percentile rises from 0.191 percent in the single-sector benchmark to 0.262 percent in the multi-sector model. The median welfare change is also more negative in the multi-sector economy. Sectoral heterogeneity therefore reshapes the incidence of the CRE shock: cities at the upper end of the distribution experience larger gains, while losses are more pronounced toward the lower end. Importantly, this need not show up as a larger overall standard deviation, since the two distributions can have similar second moments while differing in their location and tail behavior.

The comparison highlights a distinction that is obscured by aggregate welfare effects alone. A single-sector model can generate an average welfare gain similar to that of the multi-sector model, but it does so without any cross-sector adjustment in entry. In the multi-sector economy, heterogeneous improvements in market access alter relative sectoral profitability, generate competition for a common local labor pool, and reallocate entry across sectors. Similar average welfare effects can therefore mask substantially different mechanisms of adjustment and a different incidence of gains and losses across cities.

7 Conclusion

In this paper, we analyzed the trade and economic development effects of enhanced access to foreign markets, facilitated by an improved international transport infrastructure. Focusing on the CRE, a new transport route for rail freight between China and Europe, we consider an infrastructure that is only locally accessible, destination-specific and (to some extent) also product-specific. Leveraging these unique features we study novel margins of adjustment, which provide insights beyond the specific case we have analyzed and shed light on mechanisms that are difficult to observe and disentangle.

Utilizing information from a comprehensive China Customs Database, reporting trade flows at the city-level and by mode of transportation, we document that Chinese cities becoming connected to Europe via the CRE experience significant export growth, which materializes largely at the extensive firm margin. Increased market access and exporting activity can be observed within connected and geographically nearby cities, while, overall, cities located in inner China and farther away from coastal sea ports benefit the most. Next to increased exporting activity, we document positive changes also in firms' total sales,

profits, employment and wage payments. Altogether, these findings suggest that improved market access increases economic activity along various dimensions not only in "port" cities, but also in their surroundings.

A specific feature of the CRE is that it enables us to identify a heterogeneous responsiveness to rail-based market access across products. In particular, we document that very heavy and very light goods (i.e. goods with high or low weight-value ratios) produce similar coefficients, while products ranging at intermediate levels are significantly more responsive. A similar relationship is documented for the "time-sensitivity" of goods (Hummels and Schaur, 2013), which suggests that firms face different trade-offs when deciding which transport mode to choose depending on the goods they produce. We incorporate this mechanism together with our other empirical findings into a spatial quantitative general equilibrium model of international trade with multiple regions, sectors, transport modes and ports, to analyze the complex mechanisms at work. We calibrate the model to estimate sector specific trade-cost elasticities of transport mode and route choices that determine the effective change in trade costs for every Chinese cities, depending on their location within China and the goods they desires to sell abroad.

Results from calibrating our model suggest that firms can switch between different ports relatively easily, which suggests that domestic transportation costs play a minor role and that ports are qualitatively similar in terms of their efficiency and capacity (Bonadio, 2024). On the other hand, we find that modal switching, e.g. from ocean shipping to rail freight, is much less common and feasible, while there is also dispersion across sectors.

We further demonstrate that our model yields a solution for the effective change in modal trade costs between two locations, which summarizes sufficient statistics in a simple expression that is reminiscent of the canonical formulas for the gains from trade derived by Feenstra (1994) and Arkolakis, Costinot and Rodríguez-Clare (2012). Applying this formula to moments in our data, our model predicts an uneven distribution of effective trade cost reductions across Chinese, following the CRE, which is in line with our earlier empirical findings. Combining these results with a city-level multi-regional input-output table of Chinese domestic trade flows, we calculate the implied changes in city level and aggregate welfare, following the introduction of CRE services.

The most noticeable finding of our quantification exercise are the pronounced distributional effects, which imply winners and losers of the CRE. The reasons for this result can be found in the sectorial and spatial heterogeneity of effective trade cost reductions, but also in general equilibrium effects that induce a reallocation of resources from one city to another. Cities with only modest trade cost reductions face a comparative disadvantage, which has real implication as labor demand and wages decline, while cities whose industries are well

suited to rail freight gain up to several percent of their local GDP. The overall magnitude of these effects is moderate in the context of our study (0.25 percent of GDP in the aggregate, with local gains of up to about 3 percent offset by small losses elsewhere), but the underlying mechanisms are important as they are likely at work also in other contexts, such as place-based policies that aim to promote local economic activity.

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Supplemental Appendix

A Details on Data

Belt and Road Portal

The Belt and Road Portal is an official website run by the China Economic Information Service and the State Information Center, under the supervision of China's National Development and Reform Commission and Xinhua News Agency. The website (https://www.yidaiyilu.gov.cn) provides comprehensive information on China-Europe Railway Express (CRE) operations. We accessed this source in September 2022. For each regular CRE route, we extract the following information: origin city in China, destination city in Europe, route name, start date (month and year), transit time (in days) and route length (in kilometers). Table B.2 lists the 12 regular CRE routes, which were launched between 2011 and 2016. A city is considered connected starting from the year when the first CRE service departed from that city.

China Customs Database

Information on city exports and imports is derived from the China Customs Database, which covers the universe of Chinese exports and imports, and was harmonized and generously provided by the University of California, Davis, Center for International Data (Feenstra et al., 2018). The export data reports the annual trade information on values, quantities, and destination countries at the HS 8-digit level for all Chinese cities in the period under investigation (i.e., 2001 to 2018). Besides, we can also observe transport modes, the ports from which the exporting goods leave China and city-level location of exporter. In similar structure, the import data reports the annual trade information on values, quantities, and origin countries at the HS 8-digit level for all Chinese cities during 2001-2018.

China Tax Survey

The China Tax Survey is an annual survey jointly administered by the Ministry of Finance and the State Administration of Taxation, with local tax authorities responsible for data collection and verification. The survey covers approximately 600,000 enterprises per year. About 80% of the sample consists of key surveyed enterprises, which include essential tax sources and export-oriented entities. The remaining 20% are selected through stratified sampling. The survey encompasses a wide range of businesses, from large manufacturing enterprises to smaller-scale service establishments and individual operators. The data provide comprehensive firm-level financial information, including tax identification number, location, industry, number of employees, and indicators from tax declaration forms, cash flow statements, balance sheets, and income statements. For our analysis, we use the following variables: firm's tax ID (for matching across years), city location, industry code, number of employees, domestic sales revenue, export sales revenue, operating profit, total payroll, and R&D expenditures. Our sample covers the period 2010–2016.

China Stock Market & Accounting Research (CSMAR) Database

We obtain city-level economic indicators from the China Regional Economy Research Database provided by CSMAR. CSMAR collects these data from authoritative sources including the National Bureau of Statistics and the China Statistics Yearbook. The database covers the period 2001–2018 and includes GDP, the share of secondary industry in GDP, total employment, the share of secondary industry employment, and total freight volume.

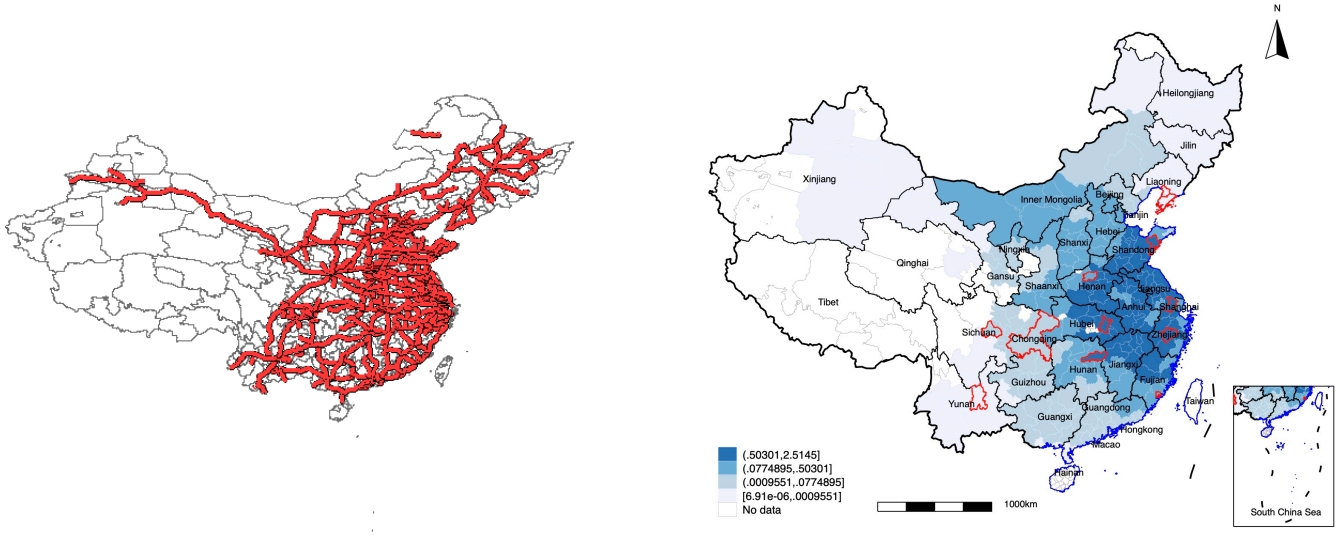
Taobao Database

Taobao operates China's largest e-commerce platform, encompassing both business-to-consumer (Tmall.com) and consumer-to-consumer (Taobao.com) marketplaces. Together, these platforms accounted for 82 percent of China's online retail sales in 2014 (Fan et al., 2018). We obtain city-to-city trade flow data for 2011, constructed from all online transaction records and aggregated by origin and destination cities of delivery.

Eigenvector Centrality

We construct city-level eigenvector centrality from the 2010 Chinese expressway network. First, we build an adjacency matrix where each element equals 1 if two cities are connected by an expressway (panel (a) of Figure A.1) and 0 otherwise . We then compute the principal eigenvector, which captures each city' s relative centrality within the network, normalize it by its norm, and scale by 100. Panel (b) displays the resulting centrality values. Cities without expressway connections are excluded.

Figure A.1: City centrality from the 2010 Chinese expressway network



(c) Expressway network

(d) Eigenvector centrality

Table A.1: Summary Statistics

Panel A: Sample Summary

# of cities	392
# of CRE cities (treated)	12
# of control cities	380
# of PSM controls	121
# of HS2 industries	97
Sample period	2006–2018
Total observations	494,312

Panel B: Export Variables (city-industry-year level)

	mean	sd	min	max	N
Exports to EU (total)	9.33	169.42	0.00	23,478.65	494,312
Exports to EU (rail)	0.19	8.28	0.00	2,323.48	494,312
Exports to EU (sea)	7.07	97.08	0.00	11,642.85	494,312
Exports to EU (air)	1.73	84.88	0.00	15,552.46	494,312
Exports to RoW (total)	39.19	778.96	0.00	144,589.32	494,312

Panel C: Treated vs Control (Pre-treatment city-level averages)

	Treated	PSM Control	Full Control	Diff (PSM)	Diff (Full)
Exports to EU	4,716.89	1,228.96	580.86	3,487.93	4,136.03
Exports to RoW	14,525.71	4,026.94	2,175.53	10,498.78	12,350.19

Note: Export values are in million USD. Panel A reports the sample composition at the city-industry-year level. Panel B reports summary statistics for export variables. Panel C reports pre-treatment city-level average exports (averaged across years 2006–2010, then across cities). PSM controls are propensity-score matched; full controls include all non-treated cities.

B Additional tables and figures

Table B.1: Trade costs and trade flows from China to Germany, by transport mode

	2006			2017		
Transport mode	Sea	Rail	Air	Sea	Rail	Air
Transport time (days)	30	47	5	32	16	4
Transport cost (dollars/FEU)	2,740	8,450	25,000	2,410	6,350	32,490
Share in total imports (%)	57.7	0.05	37.7	62.3	4.38	31.9

Note: Data are from Schramm and Zhang (2018) and Eurostat. The table reports transport time and transport cost for shipping one forty-foot equivalent unit (FEU) from Shanghai to Hamburg via sea, rail, and air in 2006 and 2017. Import shares refer to the modal shares of Germany's imports from China.

Table B.2: Regular CRE services

Origin	Operating since	Destination	Route	Duration (days)	Length (km)	Seaport (km)
Chongqing	2011/03	Duisburg, GER	YuXinOu	16	11,179	893
Wuhan	2012/10	Melink Pardubice, CZE	HanXinOu	23	10,863	454
Chengdu	2013/04	Lodz, POL	RongOu	11	9,826	1,091
Zhengzhou	2013/07	Hamburg, GER	ZhengOu	15	10,245	527
Suzhou	2013/09	Warsaw, POL	SuManOu	18	11,800	10
Yingkou	2014/10	Moscow, RUS	YingManOu	14	10,500	44
Changsha	2014/10	Duisburg, GER	XiangOu	18	6,476	569
Yiwu	2014/11	Madrid, ESP	YiXinOu	21	13,000	168
Jiaozhou	2015/07	KAZ	Qingdaohao	8	7,900	4
Xiamen	2015/08	Lodz, POL	XiaRongOu	15	12,733	4
Kunming	2015/10	POL	KunRongOu	12	10,198	695
Dalian	2016/07	Moscow, RUS	LiaoManOu	12	8,600	4

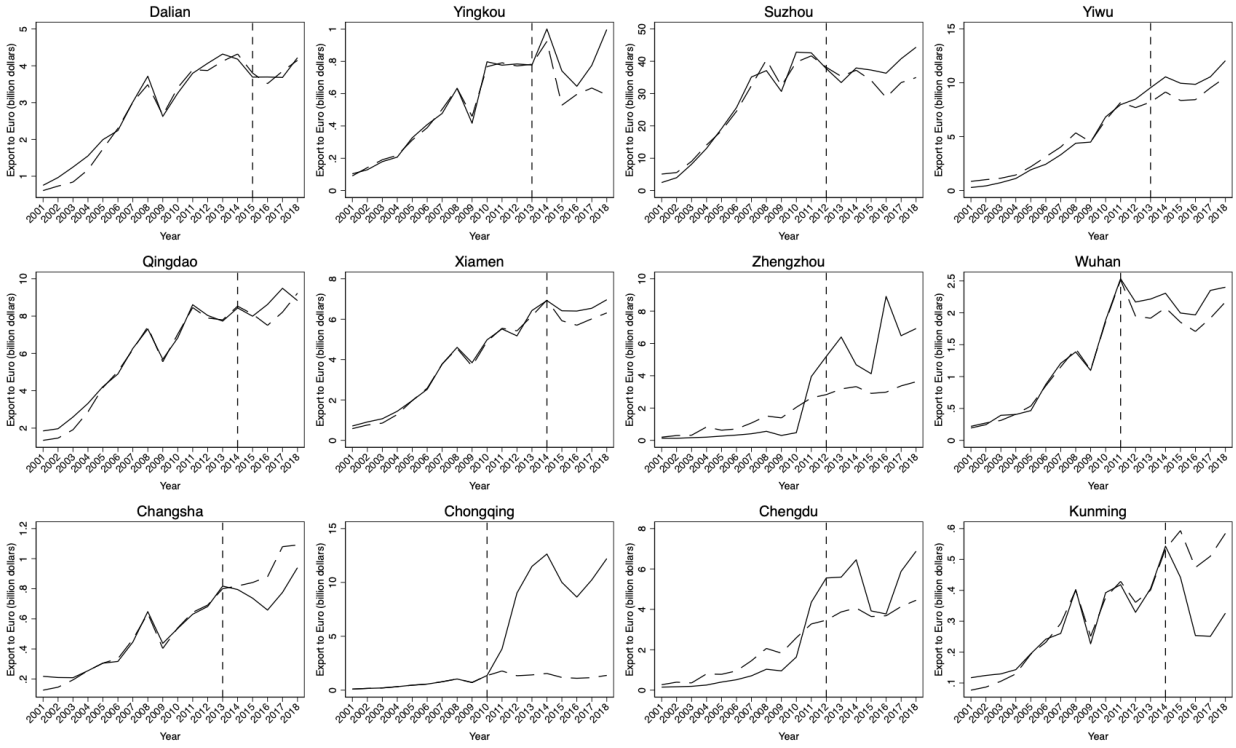
Note: Data are from the Belt and Road Portal. The table reports regular CRE services, including the start date of operation, origin, destination, route name, transit time, route length, and distance from the origin city to the nearest seaport. Transit time for the XiangOu service ranges from 16 to 18 days according to the Belt and Road Portal; the upper bound is reported in the table. Distances to seaports are based on the *China Coastal Port Layout Planning* issued in 2006.

Table B.3: CRE connections and exports to Europe

Dep. var.: $Export_{ikt}^{EUR}$	(1)	(2)	(3)	(4)	(5)
Sample	Full	PSM			
Transport mode	Any	Any	Sea	Rail	Air
ATT	0.242***	0.183***	0.077***	1.133***	0.142**
	(0.040)	(0.033)	(0.016)	(0.183)	(0.066)
Observations	494,312	317,772	317,772	317,772	317,772
City-Industry FE	✓	✓	✓	✓	✓
Industry-Year FE	✓	✓	✓	✓	✓
Group-Year FE		✓	✓	✓	✓

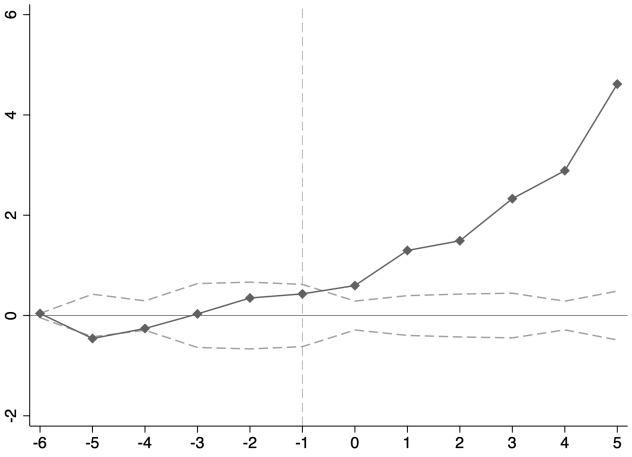
Note: Table reports ATTs from regressing exports to Europe on city-level CRE connections, using a staggered DiD (ETWFE) estimator with PPML. Column (1) uses the full sample, while columns (2)-(5) rely on a PSM based selection of matched cities. All specifications include city-industry and industry-year fixed effects. Matched-sample specifications additionally include matched-group-year fixed effects. Standard errors are clustered at the city level in the full-sample specifications, and two-way clustered at the matched-group and industry-year levels in the matched-sample specifications. Statistical significance: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

Figure B.1: Treated and synthetic control groups



Note: The solid line represents exports to Europe for the treated city, measured in billion USD, while the dashed line represents the corresponding synthetic control. The vertical dashed line indicates the final pre-treatment year.

Figure B.2: Average treatment effects from SCM analysis



Year	ATE	S.D.
-6	0.041	0.022
-5	-0.458	0.217
-4	-0.259	0.150
-3	0.032	0.325
-2	0.350	0.340
-1	0.432	0.317
0	0.597	0.147
1	1.297	0.202
2	1.491	0.218
3	2.330	0.227
4	2.889	0.146
5	4.616	0.249

Notes: Panel (a) plots average treatment effects by event year, where year 0 denotes the establishment of a regular CRE connection. Treatment effects are defined as the difference in exports to Europe between treated cities and their synthetic controls. Panel (b) reports the corresponding estimates and placebo-based standard deviations. ATE denotes the average treatment effects Dashed lines in Panel (a) indicate ±1.96 placebo standard deviations, computed from 50 resampling repetitions.

B.1 Additional empirical results

Table B.4: Local exports and inter-city trade intermediation

Dep. Var.: $Export_{ikt}^{EUR}$	(1)	(2)	(3)	(4)
Intermediary	local		non-local	
CRE_{it}	0.124***		-0.126	
	(0.038)		(0.166)	
Years since $CRE_{it} = 1$		0.057***		-0.044
		(0.020)		(0.080)
Observations	192,565	192,565	192,565	192,565
Controls	✓	✓	✓	✓
City-Industry FE	✓	✓	✓	✓
Industry-Year FE	✓	✓	✓	✓

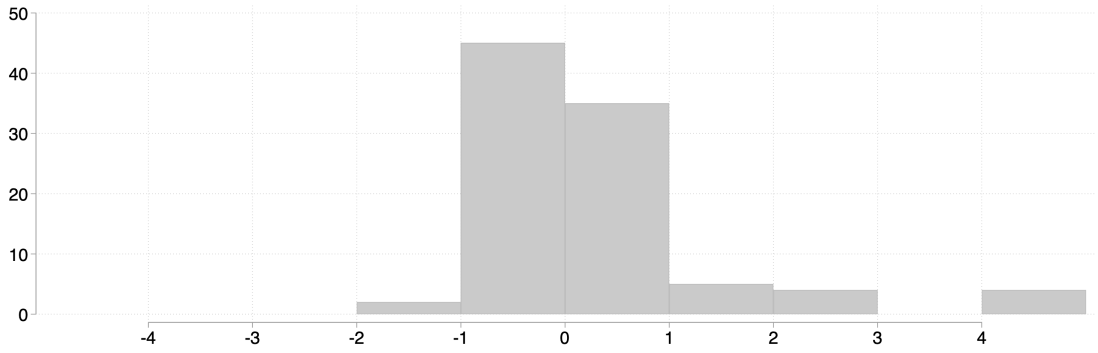
Note: This table reports CRE effects on exports to Europe by exporter location. "Local" exports: producer and exporter in same city. "Non-local" exports: producer and exporter in different cities. All specifications use PPML within TWFE framework with 2010–2018 data. $CRE_{it} = 1$ if city i is a CRE origin and year t exceeds first operating year (0 otherwise). Years since $CRE_{it} = 1$ counts years since operation (0 if before or non-origin). All include city-industry and industry-year fixed effects, city-year controls (GDP, secondary-industry output, employment), and city-industry-year global exports. Standard errors clustered at city level. Statistical significance: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

Table B.5: Firm ownership

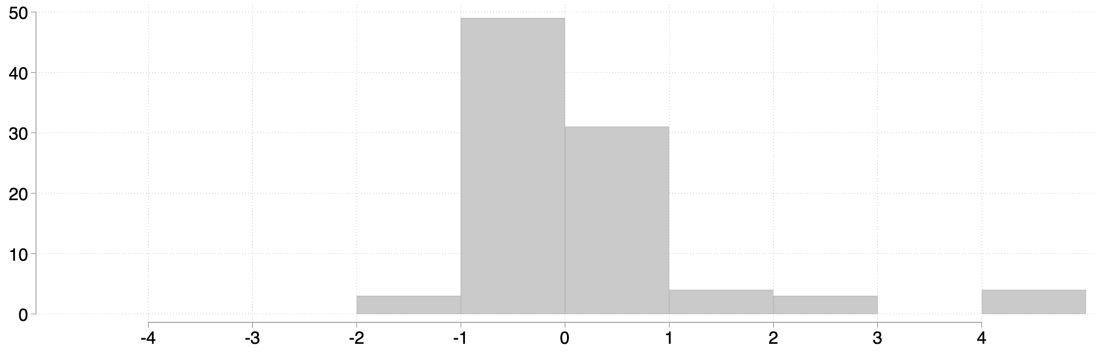
Dep. Var.: $Export_{ikt}^{EUR,rail}$	(1)	(2)	(3)	(4)	(5)	(6)
Ownership	SOE		Foreign		Domestic private	
CRE_{it}	-0.524		1.619***		0.730***	
	(0.324)		(0.274)		(0.185)	
Years since $CRE_{it} = 1$		-0.122		0.490***		0.488***
		(0.143)		(0.106)		(0.104)
Observations	192,565	192,565	192,565	192,565	192,565	192,565
Controls	✓	✓	✓	✓	✓	✓
City-Industry FE	✓	✓	✓	✓	✓	✓
Industry-Year FE	✓	✓	✓	✓	✓	✓

Note: This table reports CRE effects on rail exports to Europe by firm ownership. All specifications use PPML within TWFE framework with 2010–2018 data. $CRE_{it} = 1$ if city i is a CRE origin and year t exceeds first operating year (0 otherwise). Years since $CRE_{it} = 1$ counts years since operation (0 if before or non-origin). All include city-industry and industry-year fixed effects, city-year controls (GDP, secondary-industry output, employment), and city-industry-year global exports. Standard errors clustered at city level. Statistical significance: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

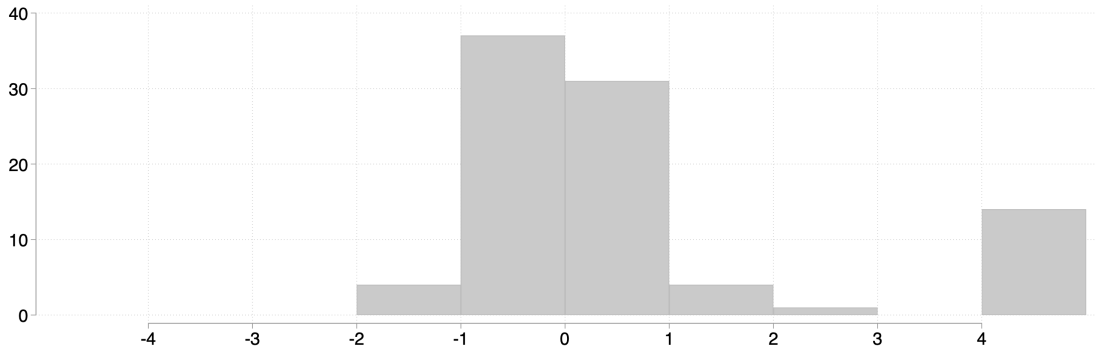
Figure B.3: Industry-level effects of CRE connections across transport modes



(a) Total export



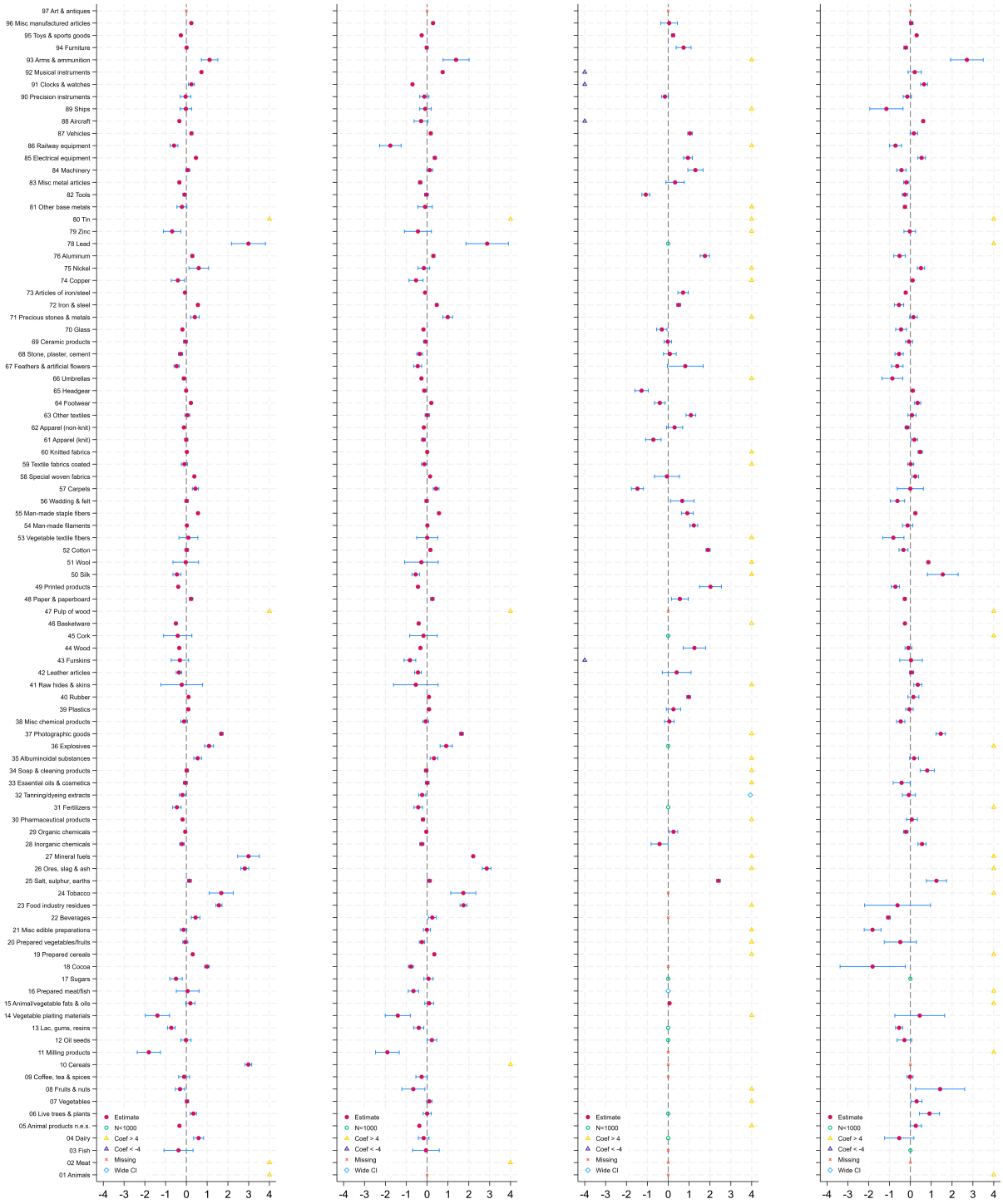
(b) Sea export



(c) Air export

Note: The figure displays the distribution of industry-level treatment effects across HS2 sectors for different transport modes. Each observation corresponds to an estimated ATT obtained from separate ETWFE regressions at the HS2 level using the matched sample. All specifications are estimated using a PPML estimator with city-industry, industry-year, and matched-group-year fixed effects. Panel (a) reports results for total exports to Europe, panel (b) for sea exports, and panel (c) for air exports. Coefficients are grouped into bins of width one, and bars indicate the number of industries falling into each coefficient range. To improve readability, coefficients greater than 4 and less than or equal to -4 are grouped into the upper and lower tail bins, respectively. Industry labels are overlaid to identify individual HS2 sectors. Estimates based on fewer than 1,000 observations or missing coefficients are excluded from the figure.

Figure B.4: Industry-level effects of CRE connections on exports to Europe



(a) Total export (b) Sea export (c) Rail export (d) Air export

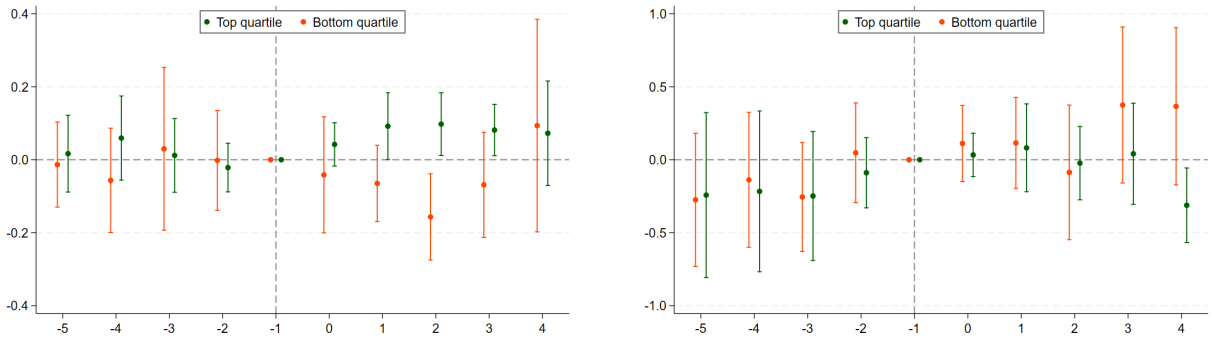
Note: Figure shows point estimates and 95% confidence intervals of HS2-sepcific ATTs, obtained from separate ETWFE estimations using the matched sample.

Table B.6: Regional spillovers of railfreight exports to Europe

Dep. Var.: $Export_{ikt}^{EUR,rail}$	(1)	(2)	(3)	(4)	(5)
Dist. from CRE terminal	0 km	0<dist.≤100	100<dist.≤200	200<dist.≤300	300<dist.≤400
CRE_{it}	0.785***	0.326**	0.312**	0.150	0.090
	(0.217)	(0.127)	(0.130)	(0.165)	(0.147)
Observations	140,165	153,648	172,563	179,741	171,011
Controls	✓	✓	✓	✓	✓
City-Industry FE	✓	✓	✓	✓	✓
Industry-Year FE	✓	✓	✓	✓	✓

Note: The table reports estimates of the effect of CRE connections on rail exports to Europe across distance bands from the nearest CRE terminal city. All specifications are estimated using a PPML estimator within a TWFE framework. CRE_{it} is an indicator equal to one if city i is connected to the CRE network in year t or thereafter, and zero otherwise. Cities located more than 400 km from the nearest CRE terminal are treated as control units. All specifications include city-industry and industry-year fixed effects, as well as city-year level controls, including GDP, secondary industry output, employment, and employment in the secondary sector, obtained from the CSMAR database. In addition, we control for city-industry-year level global exports constructed from Chinese customs data. Standard errors in parentheses are clustered at the city level. Statistical significance: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

Figure B.5: Exports to the rest of the world by industry rail dependence



(a) Sea exports to RoW

(b) Air exports to RoW

Note: The figure reports event-study estimates of the impact of CRE connections on exports to the rest of the world (RoW), using the 2006–2018 customs sample and the ETWFE-PPML specification with propensity-score-matched controls. Industries are grouped by their reliance on rail transport, measured as the share of rail in total exports at the HS2 industry level in 2018. The figure compares industries in the top quartile and bottom quartile of the rail share distribution. Panel (a) reports results for sea exports and Panel (b) for air exports. Event time $\tau = 0$ denotes the year when a city becomes connected to the CRE network. Dots represent point estimates and vertical lines indicate 95% confidence intervals. Standard errors are two-way clustered at the matched-group and industry-year levels.

C Model Derivations

C.1 Inverse Demand Function

Maximizing consumer's utility yields the inverse demand for variety ω in sector s and region j, supplied from i:

$$p_{ij}(\omega) = X_j^s \left(Q_j^s\right)^{\frac{1-\sigma^s}{\sigma^s}} z(\omega)^{\frac{\sigma^s-1}{\sigma^s}} q_{ij}(\omega)^{-\frac{1}{\sigma^s}}, \tag{C.1}$$

The term X_j^s denotes the total expenditure on sector s varieties, such that $X_j^s = \alpha^s w_j L_j$.

C.2 Expectation of Export Cost

For the export from China to Europe, the CDF of minimum export cost is given by:

$$\begin{aligned} G(b) &= \mathbb{P}\left(\min_{\rho,t} \frac{\tau_{ij,\rho t}^s}{\varepsilon_{kij,\rho t}} < b\right) = 1 - \mathbb{P}\left(\frac{\tau_{ij,\rho t}^s}{\varepsilon_{kij,\rho t}} \geq b, \forall \rho, t\right) = 1 - \mathbb{P}\left(\varepsilon_{kij,\rho t} \leq \frac{\tau_{ij,\rho t}^s}{b}, \forall \rho, t\right) \\ &= 1 - \exp\left[-\sum_t \left(\sum_\rho \left(\frac{\tau_{ij,\rho t}^s}{b}\right)^{-\frac{\vartheta^s}{\theta^s}}\right)^{\theta^s}\right] = 1 - \exp\left[-b^{\vartheta^s} \sum_t \left(\sum_\rho \left(\tau_{ij,\rho t}^s\right)^{-\frac{\vartheta^s}{\theta^s}}\right)^{\theta^s}\right]. \end{aligned} \tag{C.2}$$

So the PDF of the export cost is given by:

$$g(b) = \vartheta^s b^{\vartheta^s - 1} \sum_t \left(\sum_\rho \left(\tau_{ij,\rho t}^s\right)^{-\frac{\vartheta^s}{\theta^s}}\right)^{\theta^s} \exp\left[-b^{\vartheta^s} \sum_t \left(\sum_\rho \left(\tau_{ij,\rho t}^s\right)^{-\frac{\vartheta^s}{\theta^s}}\right)^{\theta^s}\right]. \tag{C.3}$$

We denote $A = b^{\vartheta^s} \sum_t \left(\sum_\rho \left(\tau_{ij,\rho t}^s\right)^{-\frac{\vartheta^s}{\theta^s}}\right)^{\theta^s}$, then $g(b) = \exp(-A)\frac{\mathrm{d}A}{\mathrm{d}b}$.

The expectation of export cost is given by:

$$\begin{aligned} E\left[\min_{\rho,t} \frac{\tau_{ij,\rho t}^s}{\varepsilon_{kij,\rho t}}\right] &= \int_0^\infty b \cdot g(b)\mathrm{d}b = \int_0^\infty b \exp(-A)\frac{\mathrm{d}A}{\mathrm{d}b}\mathrm{d}b \\ &= \left[\sum_t \left(\sum_\rho \left(\tau_{ij,\rho t}^s\right)^{-\frac{\vartheta^s}{\theta^s}}\right)^{\theta^s}\right]^{-\frac{1}{\vartheta^s}} \int_0^\infty A^{\frac{1}{\vartheta^s}} \exp(-A)\mathrm{d}A \\ &= \Gamma(1 + \frac{1}{\vartheta^s}) \left[\sum_t \left(\sum_\rho \left(\tau_{ij,\rho t}^s\right)^{-\frac{\vartheta^s}{\theta^s}}\right)^{\theta^s}\right]^{-\frac{1}{\vartheta^s}}. \end{aligned} \tag{C.4}$$

Combined with trade costs across Chinese regions, across foreign countries and from foreign countries to Chinese regions, the bilateral trade cost is summarized in the following

equation:

$$d_{ij}^s = \begin{cases} 1 & \text{if } i = j, \\ m_{ij}^s & \text{if } i, j \in CHN \text{ or } i, j \notin CHN, \\ \tilde{m}_{ij}^s & \text{if } i \notin CHN \text{ and } j \in CHN, \\ \xi^s \left[\sum_{m'} \left(\sum_{\rho'} \left(\tau_{ij,\rho' m'}^s \right)^{-\frac{\vartheta^s}{\theta^s}} \right)^{\theta^s} \right]^{-\frac{1}{\vartheta^s}} & \text{if } i \in CHN \text{ and } j \notin CHN. \end{cases} \tag{C.5}$$

C.3 Firm's Problem

Solving firm's problem, i.e., maximizing equation (5), yields optimal price given by:

$$p_{kij}(z) = \frac{\sigma^s}{\sigma^s - 1} c_i w_i d_{ij}^s. \tag{C.6}$$

Substituting the optimal price into the demand function which is implicitly given by equation (C.1) and into the profit function equation (5), we derive the optimal (expected) quantity and profit:

$$q_{kij}(z) = z^{\sigma^s - 1} \left[\frac{\sigma^s - 1}{\sigma^s} \frac{\alpha^s w_j}{c_i w_i d_{ij}^s \left(Q_j^s \right)^{\frac{\sigma^s - 1}{\sigma^s}}} \right]^{\sigma^s}, \tag{C.7}$$

$$\pi_{kij}(z) = \frac{L_j (\sigma^s - 1)^{\sigma^s - 1} (\alpha^s w_j)^{\sigma^s}}{(\sigma^s)^{\sigma^s} \left(Q_j^s \right)^{\sigma^s - 1}} \left(c_i w_i d_{ij}^s \right)^{-(\sigma^s - 1)} z^{\sigma^s - 1} - w_j f_j. \tag{C.8}$$

We define the quality cutoff that sets profits to zero as:

$$\bar{z}_{ij}^s = \left(\frac{(\sigma^s)^{\sigma^s} \left(Q_j^s \right)^{\sigma^s - 1}}{L_j (\sigma^s - 1)^{\sigma^s - 1} (\alpha^s w_j)^{\sigma^s}} \right)^{\frac{1}{\sigma^s - 1}} c_i w_i d_{ij}^s \left(w_j f_j \right)^{\frac{1}{\sigma^s - 1}}. \tag{C.9}$$

Then the expected profits and revenues can be written as:

$$\pi_{kij}(z) = w_j f_j \left[\left(\frac{z}{\bar{z}_{ij}^s} \right)^{\sigma^s - 1} - 1 \right], \tag{C.10}$$

$$r_{kij}(z) = \sigma^s w_j f_j \left(\frac{z}{\bar{z}_{ij}^s} \right)^{\sigma^s - 1}. \tag{C.11}$$

Average revenues and profits in the sector equal to:

$$\bar{r}_{ij}^s = \int_{\bar{z}_{ij}^s}^{\infty} r_{kij}(z) h_i(z | \bar{z}_{ij}^s) \mathrm{d}z = \frac{\sigma^s \kappa w_j f_j}{\kappa - \sigma^s + 1}, \tag{C.12}$$

$$\bar{\pi}_{ij}^s = \int_{\bar{z}_{ij}^s}^{\infty} \pi_{kij}(z) h_i(z|\bar{z}_{ij}^s) \mathrm{d}z = \frac{(\sigma^s - 1) w_j f_j}{\kappa - \sigma^s + 1}. \tag{C.13}$$

The free entry condition in each sector is given by:

$$E_z\left[\pi_{kij}(z)\right] = \sum_j (b_i)^\kappa \left(\bar{z}_{ij}^s\right)^{-\kappa} \bar{\pi}_{ij}^s = \frac{\sigma^s - 1}{\sigma^s \kappa} \sum_j (b_i)^\kappa \left(\bar{z}_{ij}^s\right)^{-\kappa} \bar{r}_{ij}^s = w_i f_E, \tag{C.14}$$

where $(b_i)^\kappa \left(\bar{z}_{ij}^s\right)^{-\kappa}$ is the probability of entering the market (destination) j, and the $\bar{\pi}_{ij}^s$ is the expected profits conditional on market entry. We plug in $\bar{\pi}_{ij}^s = \frac{\sigma^s - 1}{\sigma^s \kappa} \bar{r}_{ij}^s$, implied by equation (C.12) and (C.13). The right-hand side stands for the establishment cost.

C.4 Aggregation and Equilibrium

Aggregate revenues are given by:

$$R_{ij}^s = J_i^s (b_i)^\kappa \left(\bar{z}_{ij}^s\right)^{-\kappa} \bar{r}_{ij}^s, \tag{C.15}$$

which is trade flow of sector s. J_i^s is the number of entrants in sector s, and $J_i^s (b_i)^\kappa \left(\bar{z}_{ij}^s\right)^{-\kappa} \triangleq N_{ij}^s$ is the number of exporters to destination j. The trade by rail is then given by $\mu_{ij,Rail}^s \cdot R_{ij}^s$.

The trade shares within sector is given by:

$$\lambda_{ij}^s = \frac{R_{ij}^s}{\sum_v R_{vj}^s} = \frac{J_i^s (b_i)^\kappa \left(\bar{z}_{ij}^s\right)^{-\kappa} \bar{r}_{ij}^s}{\sum_v J_v^s (b_v)^\kappa \left(\bar{z}_{vj}^s\right)^{-\kappa} \bar{r}_{vj}^s}. \tag{C.16}$$

Plugging equation (12) and (C.12) plugged into trade shares, we derive equation (14) in the equilibrium. With equation (C.15) plugged in, the free entry condition can be written as:

$$\begin{aligned} E_z\left[\pi_{kij}(z)\right] &= \frac{\sigma^s - 1}{\sigma^s \kappa} \sum_j \frac{R_{ij}^s}{J_i^s} \\ &= \frac{\sigma^s - 1}{\sigma^s \kappa} \sum_j \frac{\alpha^s \lambda_{ij}^s w_j L_j}{J_i^s} \\ &= w_i f_E. \end{aligned} \tag{C.17}$$

Here we use $R_{ij}^s = \lambda_{ij}^s \sum_v R_{vj}^s = \lambda_{ij}^s X_j^s = \lambda_{ij}^s \alpha^s w_j L_j$, where $\sum_v R_{vj}^s = X_j^s$, the expenditure of region j on sector s.

The trade balance condition is given by:

$$\sum_s \sum_j R_{ij}^s = \sum_s \sum_j \alpha^s \lambda_{ij}^s w_j L_j = w_i L_i \quad \forall i = 1, \ldots, I. \tag{C.18}$$

The left-hand side is total revenue and the right-hand side is total expenditure of region i.

C.5 Simple Case

In the simplified version of the model, trade costs are homogeneous across regions and are specified by the following equations:

$$d_{ij}^{s}=\begin{cases}1 & \text{if } i=j,\\ \xi^{s}\left[\sum_{t'}\left(\sum_{\rho'}\left(\tau_{ij,\rho't'}^{s}\right)^{-\frac{\vartheta^{s}}{\theta^{s}}}\right)^{\theta^{s}}\right]^{-\frac{1}{\vartheta^{s}}}=\xi^{s}\left[\sum_{t'}\left(\sum_{\rho'}\left(\tau_{\rho't'}^{s}\right)^{-\frac{\vartheta^{s}}{\theta^{s}}}\right)^{\theta^{s}}\right]^{-\frac{1}{\vartheta^{s}}} & \text{if } i\neq j,\end{cases} \tag{C.19}$$

where $\tau_{ij,\rho t}=\tau_{ji,\rho t}=\tau_{\rho t},\forall i\neq j$.

Regions have the same measure for wage rate in the equilibrium due to symmetry. Plugging the market clearing condition (with $S=1$) into the free entry condition, we solve out that the mass of entrants is fixed for each region:

$$J_i=\frac{L}{f_E}\frac{\sigma-1}{\sigma\kappa}\triangleq J,\forall i=1,\ldots,I, \tag{C.20}$$

Substituting the wage rate and the fixed entrants into the trade shares, we have:

$$\lambda_{ij}=\frac{\left(d_{ij}\right)^{-\kappa}}{\sum_{v}\left(d_{vj}\right)^{-\kappa}}=\begin{cases}\frac{1}{1+(N+1)d^{-\kappa}} & \forall i=j,\\ \frac{d^{-\kappa}}{1+(N+1)d^{-\kappa}} & \forall i\neq j,\end{cases} \tag{C.21}$$

where $d\triangleq\xi\left[\sum_{t'}\left(\sum_{\rho'}\left(\tau_{\rho't'}^{s}\right)^{-\frac{\vartheta}{\theta}}\right)^{\theta}\right]^{-\frac{1}{\vartheta}}$ denotes the inter-region trade cost.

Proof of Proposition 1

The average rail transport cost is represented by:

$$d_{Rail}=\left(\sum_{\rho'}\left(\tau_{\rho',Rail}\right)^{-\frac{\vartheta}{\theta}}\right)^{-\frac{\theta}{\vartheta}}. \tag{C.22}$$

We derive $\frac{\partial d_{Rail}}{\partial\tau_{\rho,Rail}}>0$ easily. The connections to CRE, modeled by decline in $\tau_{\rho,Rail}$, are captured by a uniform reduction in rail transportation trade costs.

The average trade cost is given by:

$$d=\xi\left[\sum_{t'}\left(\sum_{\rho'}\left(\tau_{\rho't'}\right)^{-\frac{\vartheta}{\theta}}\right)^{\theta}\right]^{-\frac{1}{\vartheta}}=\xi\left[\sum_{t'}\left(d_{t'}\right)^{-\vartheta}\right]^{-\frac{1}{\vartheta}}. \tag{C.23}$$

Hence $\frac{\partial d}{\partial d_{Rail}}>0$ (or $\frac{\partial d}{\partial\tau_{\rho,Rail}}>0,\forall\rho$). The average bilateral exporting trade costs decreases.

The share of rail transport is:

$$\mu_{Rail} = \frac{(d_{Rail})^{-\vartheta}}{\sum_{t'}(d_{t'})^{-\vartheta}}. \tag{C.24}$$

By the chain rule, we derive $\frac{\partial \mu_{Rail}}{\partial \tau_{\rho,Rail}} = \frac{\partial \mu_{Rail}}{\partial d_{Rail}} \cdot \frac{\partial d_{Rail}}{\partial \tau_{\rho,Rail}} < 0, \forall \rho$. The proportion of exports carried by rail increases.

Plugging the equilibrium $w_j = 1$, $R_{ij} = \lambda_{ij} w_j L_j = \lambda_{ij} L$, we derive

$$\frac{\partial R_{ij}}{\partial \tau_{\rho,Rail}} = \frac{\partial R_{ij}}{\partial \lambda_{ij}} \cdot \frac{\partial \lambda_{ij}}{\partial \tau_{\rho,Rail}} = \frac{\partial R_{ij}}{\partial \lambda_{ij}} \cdot \frac{\partial \lambda_{ij}}{\partial d} \cdot \frac{\partial d}{\partial \tau_{\rho,Rail}} < 0, \forall i \neq j, \forall \rho, \tag{C.25}$$

where $\frac{\partial \lambda_{ij}}{\partial d} < 0$ is directly implied by equation (C.16). The aggregate revenue increases. The rising exports and intensifying rail choice improve the volume of rail transportation.

The declining trade cost lowers the entry quality cutoff, since

$$R_{ij} = Jb^{\kappa} (\bar{z}_{ij})^{-\kappa} \bar{r}_{ij} = Jb^{\kappa} (\bar{z}_{ij})^{-\kappa} \frac{\sigma \kappa w f}{\kappa - \sigma + 1}, \tag{C.26}$$

we have $\frac{\partial \bar{z}_{ij}}{\partial \tau_{\rho,Rail}} > 0$ as $\frac{\partial R_{ij}}{\partial \tau_{\rho,Rail}} < 0$. Note that the number of exporters to destination j is given by $N_{ij} = Jb^{\kappa} (\bar{z}_{ij})^{-\kappa}$ and the incumbent's revenue and profit is given by equation (C.11) and (C.10). As the cutoff decreases when the cost goes down, we obtain $\frac{\partial N_{ij}}{\partial \tau_{\rho,Rail}} < 0$, $\frac{\partial \pi_{ij}}{\partial \tau_{\rho,Rail}} < 0$ and $\frac{\partial r_{ij}}{\partial \tau_{\rho,Rail}} < 0, \forall i \neq j, \forall \rho$ by chain rule. The connection of CRE increases both intensive and extensive margins of exports.

Proof of Proposition 2

The export by different transport mode is given by the export revenue multiplied by the fraction of the transportation:

$$R_{ij,t} = R_{ij} \cdot \mu_t \tag{C.27}$$

For non-rail transportation t, $\frac{\partial R_{ij,t}}{\partial \tau_{\rho,Rail}}$ depends on the parameters κ and ϑ:

$$\begin{aligned} R_{ij,t} = R_{ij} \cdot \mu_t &= \lambda_{ij} L \cdot \mu_t \\ &= \frac{d^{-\kappa}}{1 + (N+1)d^{-\kappa}} L \cdot \frac{d_t}{\sum_{t'} (d_{t'})^{-\vartheta}} \\ &= \frac{d^{-\kappa}}{1 + (N+1)d^{-\kappa}} L \cdot \frac{d_t}{(\frac{d}{\xi})^{-\vartheta}} \\ &= \frac{d^{\vartheta - \kappa}}{1 + (N+1)d^{-\kappa}} \frac{d_t}{\xi^{\vartheta}} L \\ &= \frac{1}{d^{\kappa - \vartheta} + (N+1)d^{-\vartheta}} \frac{d_t}{\xi^{\vartheta}} L \end{aligned} \tag{C.28}$$

where we plug in $d = \xi (\sum_{t'} (d_{t'})^{-\vartheta})^{-\frac{1}{\vartheta}}$.

C.6 Welfare (Hat Algebra)

To express the welfare with λ, J and w, we combine the following equations:

$$R^s_{jj} = J^s_j \left(b_j\right)^{\kappa} \left(\bar{z}^s_{jj}\right)^{-\kappa} \bar{r}^s_{jj} = \lambda^s_{jj} \alpha^s w_j L_j, \tag{C.29}$$

$$\bar{r}^s_{jj} = \frac{\sigma^s \kappa w_j f_j}{\kappa - \sigma^s + 1}, \tag{C.30}$$

$$\bar{z}^s_{jj} = \left(\frac{\left(\sigma^s\right)^{\sigma^s} \left(Q^s_j\right)^{\sigma^s - 1}}{L_j (\sigma^s - 1)^{\sigma^s - 1} (\alpha^s w_j)^{\sigma^s}} \right)^{\frac{1}{\sigma^s - 1}} c_j w_j d^s_{ij} \left(w_j f_j\right)^{\frac{1}{\sigma^s - 1}}, \tag{C.31}$$

Finally, we derive the welfare as:

$$\begin{aligned} U_j &= \prod_{s=1}^{S} \left(Q^s_j\right)^{\alpha^s}, \\ Q^s_j &= \left(\frac{\sigma^s \kappa w_j J^s_j \left(b_j\right)^{\kappa}}{(\kappa - \sigma^s + 1) \alpha^s w_j L_j} \right)^{\frac{1}{\kappa}} \frac{(\sigma^s - 1) \left(L_j (\alpha^s w_j)^{\sigma^s}\right)^{\frac{1}{\sigma^s - 1}}}{\left(\sigma^s\right)^{\frac{\sigma^s}{\sigma^s - 1}} c_j w_j d_{jj} \left(w_j\right)^{\frac{1}{\sigma^s - 1}}} \left(f_j\right)^{-\frac{\kappa - \sigma^s + 1}{\kappa}} \left(\lambda^s_{jj}\right)^{-\frac{1}{\kappa}}. \end{aligned} \tag{C.32}$$

Applying the hat algebra technique on the welfare expression (C.32) and the equilibrium system (14), (15) and (16), we obtain:

$$\hat{U}_j = \prod_{s=1}^{S} \left(\hat{Q}^s_j\right)^{\alpha^s} \tag{C.33}$$

$$\hat{Q}^s_j = \left(\hat{J}^s_j\right)^{\frac{1}{\kappa}} \left(\hat{\lambda}^s_{jj}\right)^{-\frac{1}{\kappa}} \tag{C.34}$$

$$\hat{\lambda}^s_{ij} = \frac{\hat{J}^s_i (\hat{d^s_{ij}} \hat{w}_i)^{-\kappa}}{\sum_v \lambda^s_{vj} \hat{J}^s_v (\hat{d^s_{vj}} \hat{w}_v)^{-\kappa}} \tag{C.35}$$

$$\hat{J}^s_i \hat{w}_i = \frac{\sum_j \lambda^s_{ij} \hat{\lambda}^s_{ij} \hat{w}_j w_j L_j}{\sum_j \lambda^s_{ij} w_j L_j} \tag{C.36}$$

$$\hat{w}_i = \frac{\sum_s \sum_j \alpha^s \lambda^s_{ij} w_j L_j \hat{\lambda}^s_{ij} \hat{w}_j}{\sum_s \sum_j \alpha^s \lambda^s_{ij} w_j L_j} \tag{C.37}$$

We calibrate the initial wage w_j under the equilibrium, using the equation (16). We feed in the consumption share α^s, trade flow share λ^s_{ij}, and population L_j. Consider a change in trade cost d^s_{ij} [45], we solve out the "hat" by the following steps. Relative to the baseline model, in which the entry cost of a firm in city i and sector s is constant in the number of entrants, we allow entry costs to be convex in the number of entrants within each city-sector, reflecting limited local entrepreneurial resources. The free-entry condition of our model then

[45] We impose a floor of 0.6 on the trade cost change; values of d^s_{ij} below 0.6 are set to 0.6.

implies $\hat{J}_i^s = \hat{\chi}_i \big(\hat{J}_i^{s*}\big)^{\nu}$ with an entry elasticity $\nu < 1$, where $\hat{J}_i^{s*}$ denotes the raw free-entry target obtained from (C.36) and $\hat{\chi}_i$ is an entry cost shifter common to all sectors within a city. The shifter is pinned down by the city-level aggregate entry condition, $\sum_s q_i^s \hat{J}_i^s = 1$, so that the adjusted entry target is

$$\tilde{J}_i^s = \frac{\big(\hat{J}_i^{s*}\big)^{\nu}}{\sum_{s'} q_i^{s'} \big(\hat{J}_i^{s'*}\big)^{\nu}}, \qquad q_i^s \equiv \frac{B_i^s \alpha^s}{\sum_{s'} B_i^{s'} \alpha^{s'}}, \qquad B_i^s \equiv \sum_j \lambda_{ij}^s w_j L_j, \tag{C.38}$$

where B_i^s is the baseline revenue of city-sector (i, s). Each city's total entry scale is thus pinned down by the aggregate entry condition, while the sectoral composition of entrants responds to relative free-entry gaps with elasticity ν. We set $\nu = 0.75$; the baseline model corresponds to $\nu = 1$.

- Step 1: Guess a vector of wages $\hat{\mathbf{w}} = (\hat{w}_1, \ldots, \hat{w}_{N+2})$ and a $N \times S$ matrix of entrants $\hat{\mathbf{J}}$.
- Step 2: Use equilibrium (C.35) to solve for expenditure shares $\hat{\lambda}_{ij}^s(\hat{\mathbf{w}}, \hat{\mathbf{J}})$.
- Step 3: Compute the raw free-entry target $\hat{J}_i^{s*}$ from (C.36), adjust it to $\tilde{J}_i^s$ according to (C.38), and update $\hat{\mathbf{J}}$ towards $\tilde{\mathbf{J}}$.
- Step 4: Given $\hat{\mathbf{J}}$, substitute $\hat{\mathbf{J}}$ and $\hat{\lambda}_{ij}^s$ into the market clearing condition (C.37) and update $\hat{\mathbf{w}}$.
- Step 5: Iterate steps 2–4 with damped log-linear updates until the free-entry condition, the market clearing condition, and the aggregate entry condition all hold with a maximal residual of 10^{-4}.

We can also solve out the change of export revenue and decompose it into change of entrants and change of average revenue, applying the hat algebra technique on the equations (C.12) and (C.15).

$$\hat{R}_{ij}^s = \hat{N}_{ij}^s \times \hat{\bar{r}}_{ij}^s \tag{C.39}$$

where

$$\hat{N}_{ij}^s = \hat{J}_i^s (\hat{\tilde{z}}_{ij}^s)^{-\kappa} = \hat{J}_i^s \left(\hat{w}_i \frac{\hat{Q}_j^s}{\hat{w}_j} \hat{d}_{ij}^s \right)^{-\kappa} \tag{C.40}$$

$$\hat{\bar{r}}_{ij}^s = \hat{w}_j \tag{C.41}$$

Monetary Equivalent. The welfare expressed in equivalent income is derived from the following equation:

$$U_j = \prod_{s=1}^{S} \big(Q_j^s\big)^{\alpha^s} = \underbrace{w_j L_j}_{X_j} \prod_{s=1}^{S} \big(\frac{\alpha^s}{\mathbb{P}_j^s}\big)^{\alpha^s} \tag{C.42}$$

where the sub-utility is given by the following:

$$Q_j^s = \frac{X_j^s}{\mathbb{P}_j^s} = \frac{\alpha^s w_j L_j}{\mathbb{P}_j^s} \tag{C.43}$$

and the price index is:

$$\mathbb{P}_j^s = \left[\sum_i \int_{\omega \in \Omega_{ij}^s} z(\omega)^{\sigma^s - 1} p_{ij}(\omega)^{1-\sigma^s} d\omega \right]^{\frac{1}{1-\sigma^s}} \tag{C.44}$$

To maintain the initial situation (constant prices), the equivalent variation, that is, the counterfactual income X_j^* that raises welfare to U_j', satisfies the following condition:

$$U_j' = X_j^* \prod_{s=1}^{S} (\frac{\alpha^s}{\mathbb{P}_j^s})^{\alpha^s}. \tag{C.45}$$

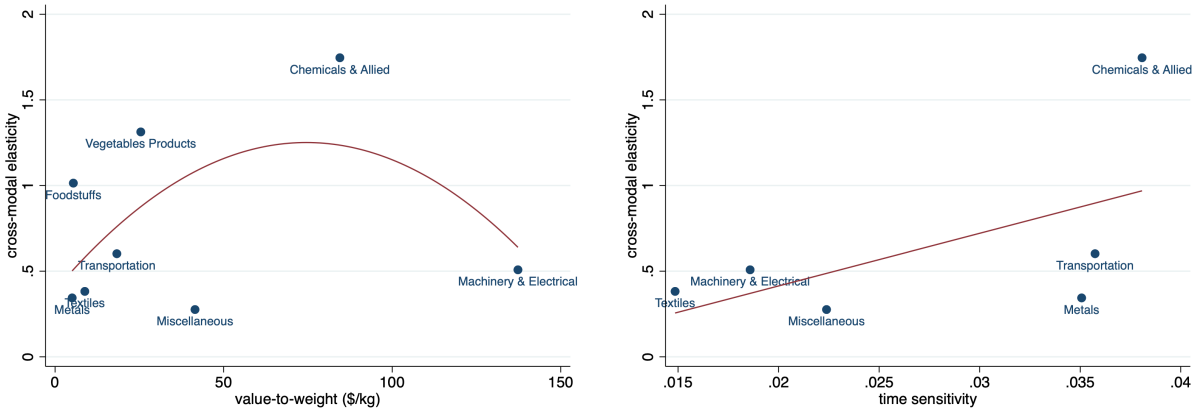
Thus, under homothetic preferences, the equivalent variation in monetary income directly reflects the change in welfare.

$$\frac{X_j^*}{X_j} = \frac{U_j'}{U_j} = \hat{U}_j \tag{C.46}$$

D Additional Quantitative Results

D.1 Elasticities

Figure D.1: Heterogeneity of elasticities



(a) Unit value

(b) Time sensitivity

Note: Each point represents a category from Table 3. Both figures plot cross-modal elasticity on the y-axis. Panel (a) shows value-to-weight ratio and panel (b) shows time sensitivity on the x-axis. We calculate average value-to-weight ratio for products within each category, weighted by total exports at HS 8-digit level from 2010 to 2018. Value-to-weight ratio equals total value divided by total quantity for each product. Time sensitivity averages are calculated at HS 2-digit level within each category, weighted by total exports from 2010 to 2018. Data for time sensitivity is missing for vegetable products and foodstuffs in panel (b). Red lines show fitted values: quadratic in panel (a) and linear in panel (b).

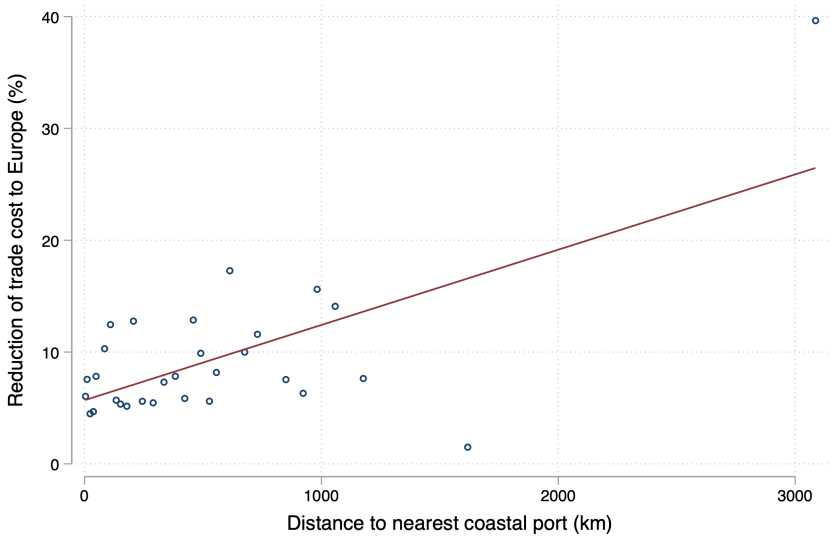
D.2 Welfare Analysis

Table D.1: Harmonization of sectors provided by the Customs Database, the MRIO table and Taobao

Customs Database	MRIO	Taobao
Vegetable Products	Agricultural, Forestry, Animal Husbandry & Fishery Products & Services	
Foodstuffs	Food & Tobacco	Food, Tobacco & Alcohol
Chemical & Allied	Chemical Products	Healthcare
Textiles	Textiles	Clothing
	Textile Clothing, Shoes, Hats, Leather, Down & Related Products	
Metals	Metal Smelting & Rolling Processing Products	
	Metal Products	
Machinery & Electrical	Specialized Equipment	Household Goods & Services
	Electrical Machinery & Equipment	
	Communication Equipment, Computers & Other Electronic Devices	
	General Equipment	
Transportation	Transportation Equipment	Transportation & Communication
Miscellaneous	Instruments & Meters	Education, Culture & Entertainment
	Other Manufactured Products	Other Goods & Services
	Wood Products & Furniture	
	Paper Printing, Culture, Education & Sports Goods	

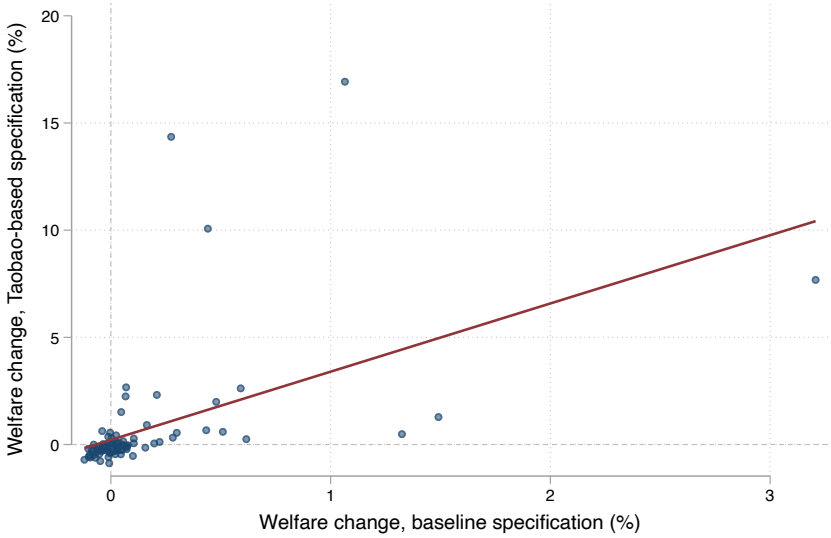
Note: MRIO industries and *Taobao* categories that cannot be matched to one of the customs categories are dropped. For the MRIO table, these are mainly services as well as mining, energy, and utility products (26 of 42 industries); for *Taobao*, this is the housing category.

Figure D.2: Simulated reductions in trade costs and cities' distance from sea ports



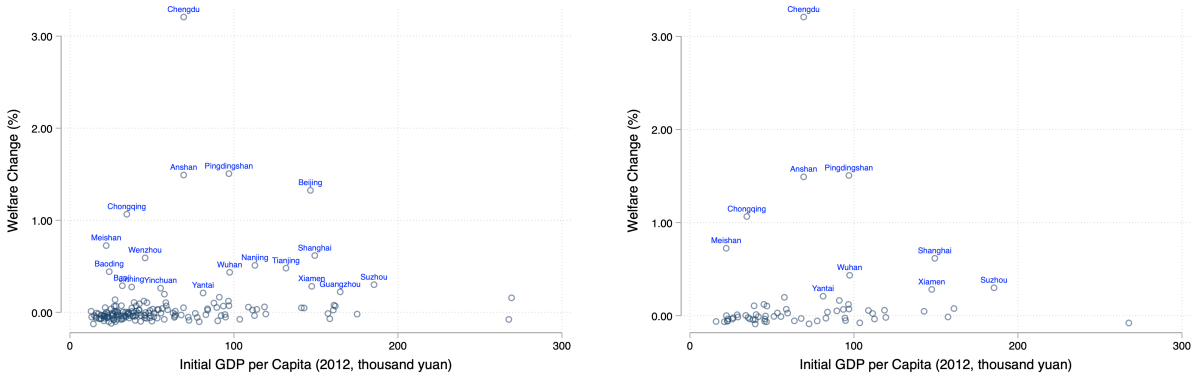
Note: Figure shows simulated reductions in trade cost to Europe against distance to the nearest coastal port following CRE connections. Each point represents a bin of cities with comparable distance to seaports and indicates the mean trade-cost reduction within the bin.

Figure D.3: CRE effects on city-level welfare: baseline vs. *Taobao*-based domestic trade shares



Note: Figure compares city-level welfare changes in our baseline specification (domestic trade shares from the MRIO table) with the *Taobao*-based robustness specification. Each dot represents one of the 87 cities covered by both specifications. The line shows the linear fit.

Figure D.4: Welfare gains and initial GDP per capita

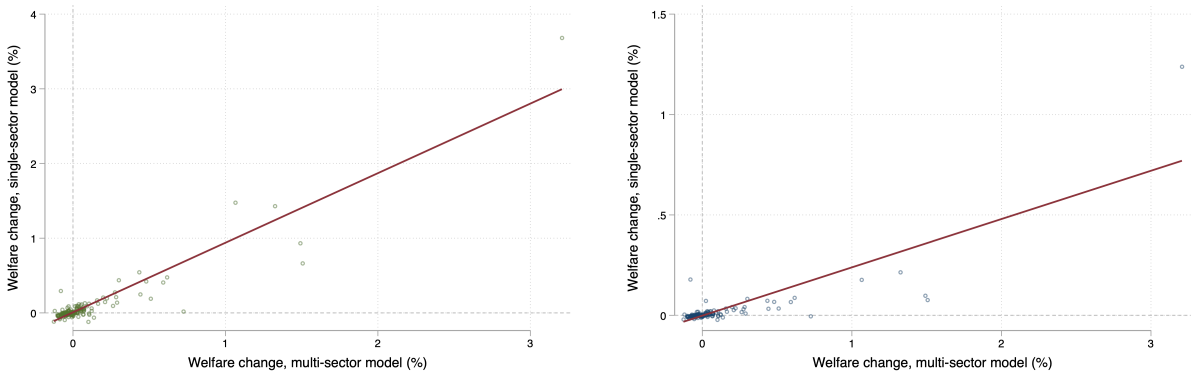


(a) All cities

(b) Cities within 200 km of a CRE terminal

Note: Each dot represents a Chinese city in our sample. The figures relate simulated welfare changes to cities' initial GDP per capita in 2012 (in thousand yuan). Panel (b) restricts the sample to the 64 cities within 200 kilometers of a CRE terminal.

Figure D.5: CRE effects on city-level welfare in single- vs. multi-sector model



(a) Single-sector model with $\sigma = 1.826$

(b) Single-sector model with $\sigma = 5$

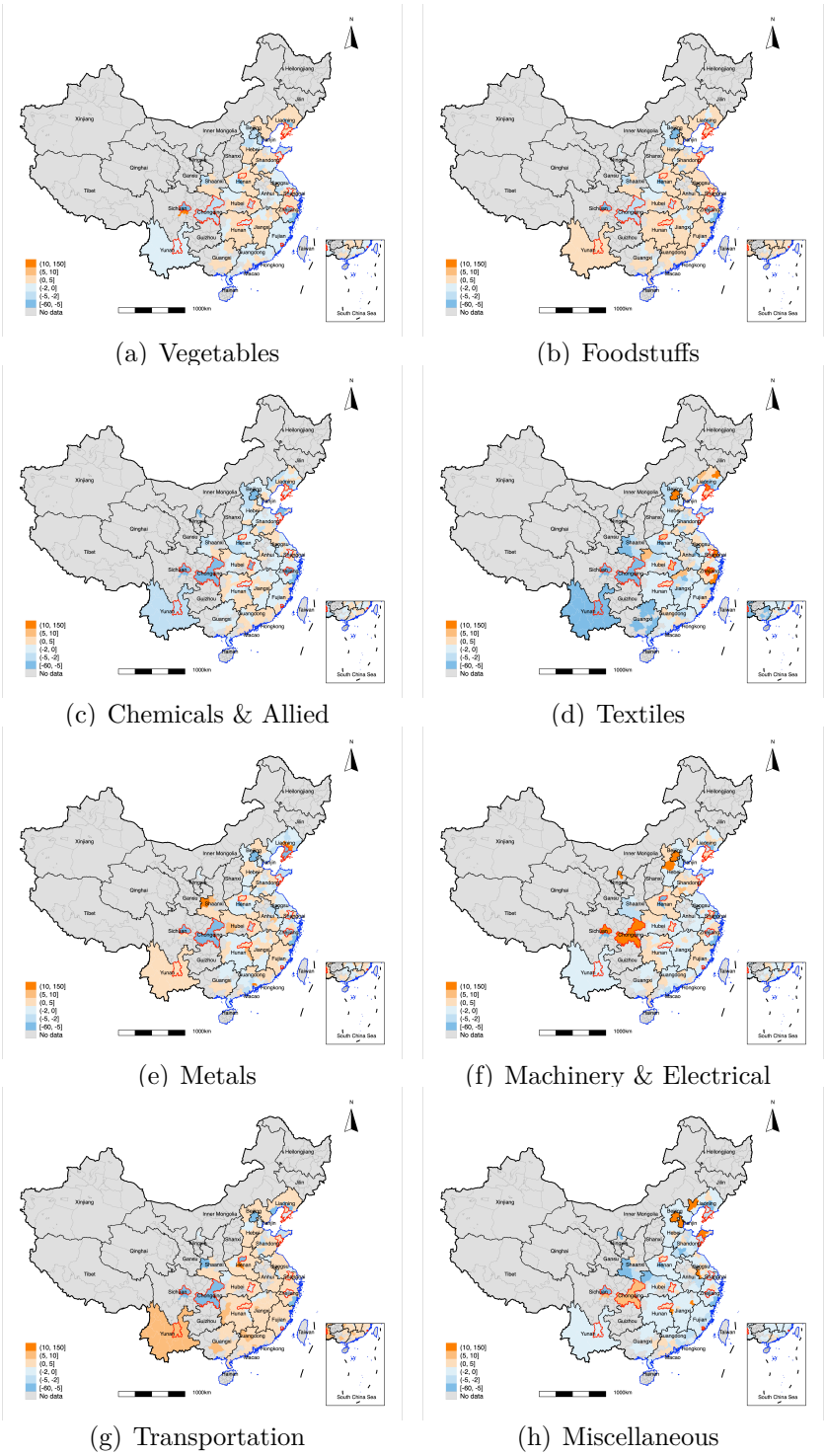
Note: Each dot represents a Chinese city in our sample. The figures compare simulated welfare changes under the multi-sector model (x-axis) with the single-sector model using $\sigma = 1.826$ in panel (a) and $\sigma = 5$ in panel (b); lines show linear fits.

Table D.2: Welfare effects of CRE connections in multi- vs. single-sector model

Welfare gains (%)	Multi-sector	Single-sector ($\sigma = 1.826$)	Single-sector ($\sigma = 5$)
Simple average	0.076	0.079	0.017
GDP-weighted average	0.248	0.265	0.054
Standard deviation	0.346	0.346	0.100
Minimum	−0.126	−0.118	−0.022
10th percentile	−0.076	−0.036	−0.007
Median	−0.012	−0.000	−0.000
90th percentile	0.262	0.191	0.035
Maximum	3.207	3.683	1.238

Note: The table summarizes city-level welfare changes across the 167 Chinese cities in our sample. The multi-sector model employs the sector-specific trade elasticities σ^s from Macedoni and Xu (2022). The single-sector models employ a common trade elasticity of $\sigma = 1.826$ following Macedoni and Xu (2022) and $\sigma = 5$ following Bonadio (2024), respectively. See Appendix C.6 for detailed calculations.

Figure D.6: Change in firm entry by sector (%)



(a) Vegetables (b) Foodstuffs

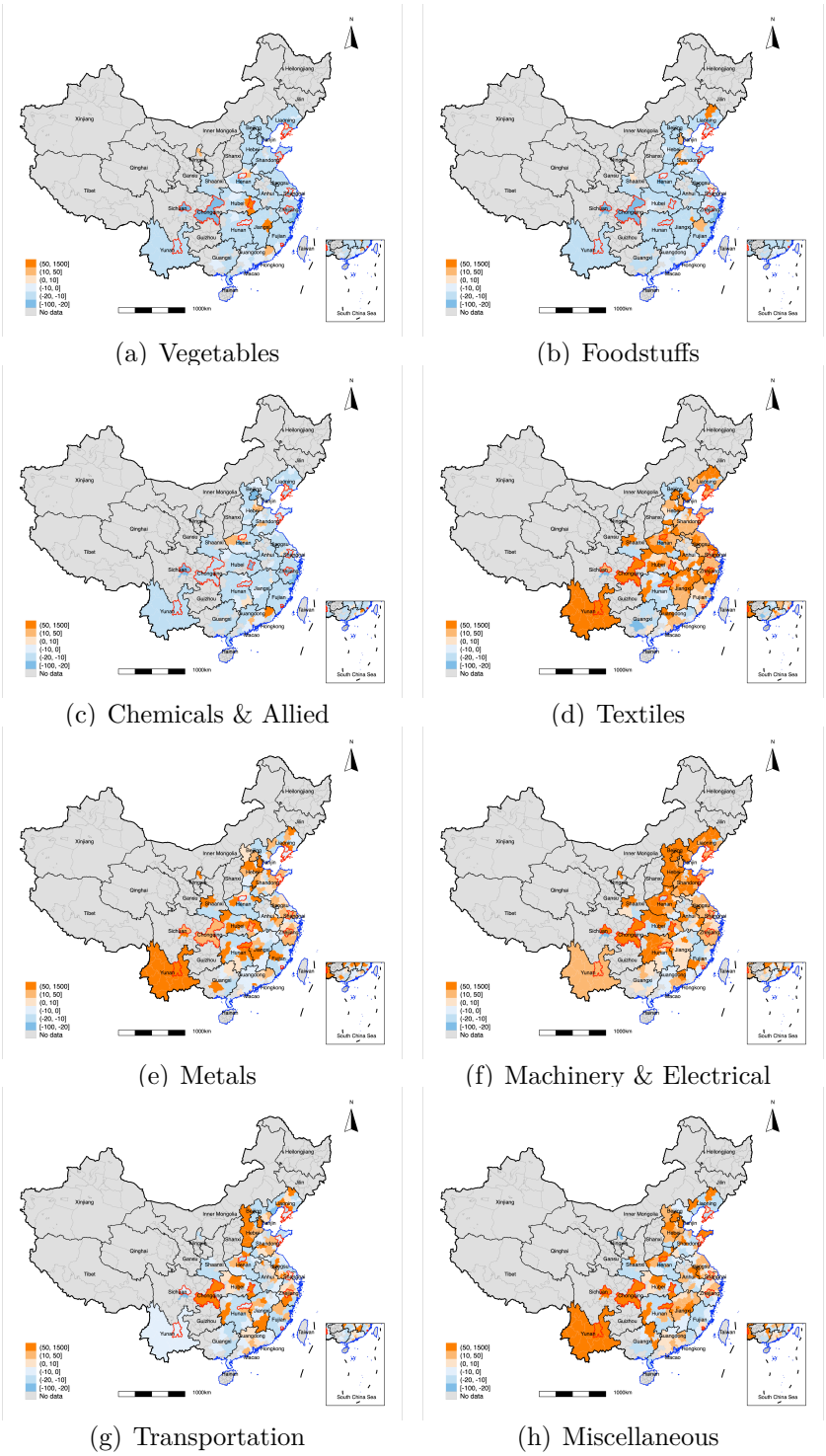
(c) Chemicals & Allied (d) Textiles

(e) Metals (f) Machinery & Electrical

(g) Transportation (h) Miscellaneous

Note: The figure shows the geographical distribution of firm entry changes for each sector, computed by solving the model in relative changes. Values are $(\hat{J} - 1) \times 100$, so that positive values correspond to an expansion of entry. Regions outside the estimation sample are shown in gray.

Figure D.7: Change in the number of exporters into the European market (%)



(a) Vegetables (b) Foodstuffs

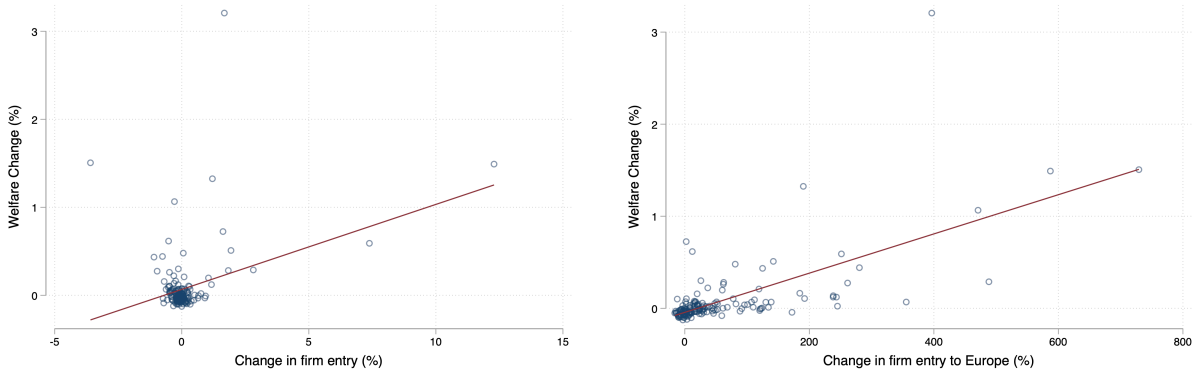
(c) Chemicals & Allied (d) Textiles

(e) Metals (f) Machinery & Electrical

(g) Transportation (h) Miscellaneous

Note: The figure shows the geographical distribution of changes in the number of exporters serving the European market for each sector, computed by solving the model with the exact hat algebra. Values are $(\hat{N} - 1) \times 100$, so that positive values correspond to an increase in the number of EU exporters. Regions outside the estimation sample are shown in gray.

Figure D.8: Firm entry and welfare changes across cities



(a) Firm entry and welfare

(b) Entry into the European market and welfare

Note: Each dot represents a Chinese city in our sample. Panel (a) plots cities' welfare changes against changes in aggregate firm entry, weighted by export flows across sectors; panel (b) plots welfare changes against changes in the number of exporters serving the European market, weighted by exports to Europe. Lines show linear fits.