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Decomposing China's bilateral export growth: A firm-regional-transactions structural gravity approach ☆

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ABSTRACT

This paper undertakes a decomposition of China's firm-transaction-level exports with an emphasis on aggregates thereof at the prefectural level. Chinese prefectures are large and, relative to some smaller countries, the larger ones are visible players in the world market. We decompose China's prefecture-product-level bilateral exports to foreign countries into their main components. These are factor costs, market potential (including trade frictions and foreign expenditure) as well as quality and productivity. We consider the latter two as to be drawn from a bivariate Pareto distribution that is specific to prefectures, products, and countries. This strategy enables retrieving fixed market access costs and permits conducting counterfactual experiments with a focus on the distribution across Chinese prefectures.

1. Introduction

The single-most remarkable change in the international economic landscape in the past three decades was China's gradual emergence as a major player in international trade. The root of this change must be seen in the country's declaration to open up as early as 1978 in the Third Session of the Eleventh Central Committee of the Communist Party of China (CPC). Fig. 1 depicts China's relative importance in world trade in percent since that time. Clearly, when a market that accounts for roughly one-quarter of the world's resources (at least, in terms of labor, but China is also large in terms of land mass and some natural resource endowments)

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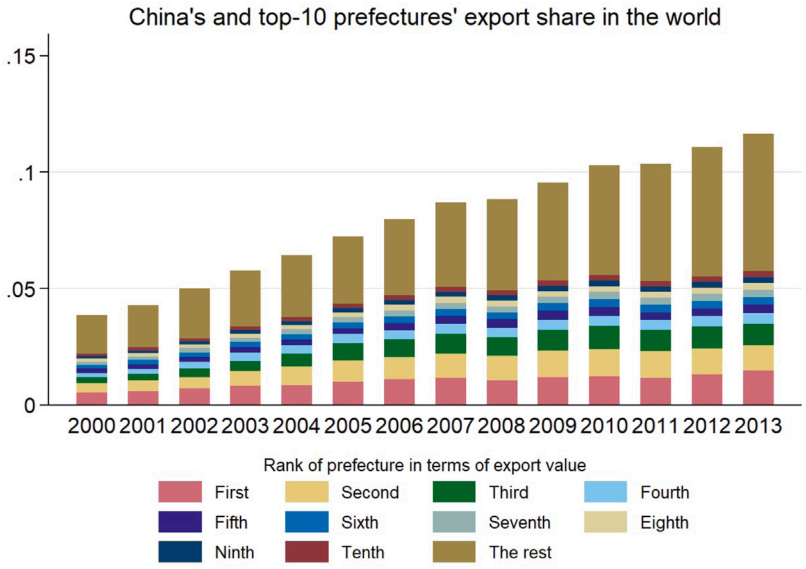

Fig. 1. China's and top-10 prefectures' export share in the world from 2000–2013.

and operated almost in isolation before is gradually integrated into the world market, this has fundamental global consequences: for transaction volumes, market structure, factor supply and demand, etc. A recent body of work focuses on implications of China's opening up for foreign labor markets (see Autor et al., 2013, 2016; Dauth et al., 2014; Costa et al., 2016), for firms and market shares outside China (Iacovone et al., 2013), for industry dynamics and productivity (see Auer et al., 2013; Bloom et al., 2016), and for global stock markets (see Egger and Zhu, 2020).

For many purposes, where some analysis of the "China shock" is in the limelight, measures of exogenous drivers behind China's growth of trade are key to have. For this but also out of general interest in understanding the phenomenon, a measurement and analysis of the drivers behind China's export growth are mandatory. Clearly, a major source of the changes in China and elsewhere which were associated with China's global market participation had been political in nature: as of the year 2000 China was a member of 50 intergovernmental organizations and 1275 international nongovernmental organizations (see Kent, 2002), and in 2001 it became a member of the World Trade Organization. In fact, one might be tempted to forget that, apart from global market potential, fundamental changes happened within China as well. China is a very large economy not only in terms of its land mass, population, GDP, and trade.[1]

Because of its large geographical size, its heterogeneous geography, and also its institutional heterogeneity, treating China as a point rather than a composite of a large number of meso-regional units may not be desirable. Politically, China is organized in 34 province-level and 332 prefecture-level administrative regions as of the year 2013. In that year, China's population amounted to more than bn. 1.3. Both its provinces as well as its prefectures vary substantially in population size. One would expect that the same is true for their exports. However, the larger ones of China's many prefectures dominate many of the smaller countries on the globe in terms of their exports because of their size and location. This can be documented based on the country's transaction-level data which permit geo-referencing the country's exporters. Fig. 1 provides a portrait of China's as well as its prefectures' share in world exports according to the mentioned data over the period 2000–2013.[2] The figure contains bars, the additive height of which represent China altogether, and whose components pertain to the ten most important prefecture-level regions and the remaining regions together.[3] The figure indicates that China altogether tripled its share in world exports within the considered time window, and, by the end of the period, the ten most important regions together accounted for one-half of that share, and the three most important ones each accounted for around one percent of the world's exports.

In this paper, we shed light on the heterogeneity of China's prefecture-level regions in terms of their fundamental characteristics from a trade-economists perspective: the quality of products produced and the productivity of firms operating there, the prevailing local factor costs, and the market potential of firms which is a composite of foreign demand and trade frictions. We illustrate to which

[1] In 2013, China accounted for 7% of the world's land mass, 19% of the world's population, 12% of world GDP, and 12.4% of world exports.

[2] Note that these data sum up to the country's official trade statistics as they are available from, e.g., the International Monetary Fund or the United Nations Conference on Trade and Development.

[3] We do not name the top-10 regions in the figure, as their composition and ranking changes over time. However, the top-10 prefectures are in every covered year drawn from the following alphabetically ordered list: Beijing, Chongqing, Dalian, Dongguan, Guangzhou, Hangzhou, Ningbo, Qingdao, Shanghai, Shenzhen, Suzhou, Tianjin, Wuxi, and Xiamen. Shenzhen and Shanghai always rank first and second, respectively, in the figure.

extent the heterogeneity in fundamental factors contributes to the inequality in export participation across Chinese prefectures.[4] In doing so, we focus on the period 2000–2013, as this is the longest time span we have trustworthy data for, and where we can track the subnational, prefecture-level origin and the destination (country) of product-level export shipments for China. We build particularly on theoretical frameworks of gravity models which feature heterogeneous firms and selection of those firms (due to fixed market-entry costs; see Melitz, 2003). Such models had been further developed, e.g., by Chaney (2008), Arkolakis (2010), and Bernard et al. (2011). We follow Bernard et al. (2011) in the sense of distinguishing between production-process (productivity) and product (here, quality) attributes. However, we consider both to be specific to products for specific markets and assume them to be bivariate Pareto distributed in the quantitative model.

We document a skewed distribution in the endogenous components, the fundamental drivers, and the export outcome across Chinese prefectures. Specifically, when comparing export levels in 2013 as well as their changes between 2000 and 2013 in terms of their distribution across Chinese prefectures, we see the following average pattern. First of all, exports are particularly high along the coast line and the prefectures not too far inwards from it. However, exports grew somewhat more strongly somewhat westwards of than along the coast. This is consistent with efforts of China to build infrastructure which connects regions off the coast to ones on the coastline. We see that the latter is aligned with patterns of changes of export components in a favorable way for exports. In particular, when aggregating to the level of prefectures (i.e., when abstracting from individual products and destination countries), we see that market potential (including trade costs), the potential number of producers, quality-augmented productivity, and even factor costs (which consist not only of wages but also of imported input prices) have changed in a way between 2000 and 2013, which would stimulate exports.

With this agenda of decomposing China's overall and its regional export growth, the proposed analysis has two particular potential merits. First, when focusing on changes in export volume and structure across spatial units within China, we can associate changes in exports with observable product and prefecture characteristics capturing aspects of changing technology and quality together with fixed-cost, factor-cost, and foreign-market potential changes. The latter may help improving our understanding to which extent unilateral change in China's regions was instrumental for the country's export success. Second, a regional focus helps grasping the importance of contributions by extensive-versus intensive-margin changes to the aggregate growth of China's exports.[5]

As indicated above, for the purposes of this paper we make use of China's transaction-type export data which provide information not only on the value as well as the physical quantity of exports, the product code and the destination country, but also information of the exporter – mostly but not only companies – including their geographical base. We consider firm-level exports as to be determined by four structural components: foreign market potential (including trade costs), factor costs, and productivity as well as quality. The latter two are drawn from a bivariate Pareto distribution of the first type. Given the shape parameter of that distribution, the productivity and quality cutoff levels are determined by aggregate exports. These (endogenous) cutoff levels reveal the fixed market-access costs for each prefecture, product and foreign market. Hence, given the Pareto shape parameter, fixed market-access costs as well as foreign market potential and factor costs are the fundamental drivers of a prefecture's exports. Factor costs consist of wage costs and imported input prices, the former of which are endogenously treated and the latter are exogenously treated here. With those components at hand, we set each exogenous component counterfactually to its level of 2000 all else equal as of 2013 to see what its "marginal" contribution is to the level and heterogeneity of exports across Chinese prefectures.

Our research primarily relates to three strands of earlier work. The first one focuses on micro-level (firm and trade) data and highlights specific effects in reduced-form empirical analyses (see, e.g., Yang and Temple, 2012; Ding and Niu, 2019; Koster et al., 2019). The second line of work also adopts a micro-level perspective but in a structural approach as is usually found in industrial organization (see, e.g., Fan et al., 2018). The third strand of work invokes structural spatial models applied to China (see, e.g., Baum-Snow et al., 2017; Cai et al., 2023; Egger et al., 2023). However, none of that research aimed at decomposing the growth of China's trade, neither altogether nor at a regional level. The advantage of such a decomposition is that it is exact (i.e., it is without residual), and the disadvantage is that it is not causal, because the components are jointly determined by deep parameters (such as trade costs, fixed market-access costs, factor endowments, etc.). However, a counterfactual analysis is capable, given a set of assumptions regarding the deep parameters and some model structure, of identifying the overall consequences of changes in exogenous drivers of trade for trade and other factors.

Regarding general equilibrium effects, we find that the changes in market potential and fixed costs each are found to have had a major impact on regional exports. The latter result is owed to the variation of the changes in these attributes across prefectures as well as their correlation with other regional attributes. Had these factors not changed in the way they did, our results suggest that the levels of export-market participation across Chinese regions would have been much more unequal in 2013 than they actually were.

Earlier work points to the role of the rise of market potential as well as technological upgrading on China's part as major drivers behind China's overall export growth (see Lin, 2010). The gain in market potential is credited with resting on three important pillars for China. First, China's joining the World Trade Organization resulted in a reduction in de-facto policy costs associated with importing Chinese products by WTO members (see Fan et al., 2015, 2018, 2019; Handley and Limão, 2017). Second, China's infrastructure investments in ports as well as the transport network connecting Chinese regions with those ports reduced market-access costs related to internal cost factors (see Egger et al., 2023). Finally, the participation of China in global value chains skewed

[4] China's political and fiscal decentralization causes fierce competition among provincial economies, and the fiscal decentralization generates strong incentives to economic development of local governments. The latter is credited to contribute to China's economic miracle (Cai and Treisman, 2006).

[5] Aggregating to the level of China altogether might mask the role of adjustments at extensive margins and lead to downward-biased quantifications of the role of fixed market-access costs for China's export growth.

the demand towards Chinese products due to China's comparative advantage in producing manufactures at comparatively low costs (Ceglowski and Golub, 2007; Xing, 2021).

Technological upgrading has been measured for China. While much of the earlier work on this aspect focuses on a detection of as well as macroeconomic reasons behind technology growth either within firms or in the aggregate in general (see Song et al., 2011), what the present paper focuses on is the growth of the mass of potential producers together with firm selection. Some other work discerned productivity (through costs and prices) and quality. E.g., Shi (2011) decomposed China's trade growth from 1995 to 2007 into three margins (the extensive product-country margin and two intensive margins: price and quantity) and found that the export growth of China was mainly driven by quantity growth rather than productivity (cost) or quality improvements. Using somewhat more recent data than Shi (2011), Gao et al. (2014) found that the role of productivity (costs) and quality became more important in more recent times.

However, most of the work on China's export growth (or miracle) considers aggregate, product-level, or firm-level aspects without much of a regional focus. We believe that the adopted focus on regions, products and destination markets is relevant in the present context. First of all, China is one of the largest economies on the globe, and treating it as a point does not do justice to the large degree of regional heterogeneity. The latter is particularly relevant, when thinking of a selection of firms into exporting, where regional factors are likely important. Second, there is a large degree of heterogeneity in the production of different products across China's regions. Notably, some earlier work pointed to two potential biases resulting from aggregation of micro data. One of those strands addresses a sectoral aggregation bias. Associated work states that key model parameters such as factor costs, trade costs or productivity are indexed with and a function of parameters that are sector- or product-specific (e.g., the so-called trade elasticity is one of those parameters). Ignoring the distinction of products (or sectors) leads to an aggregation bias, as gravity and quantitative trade models are multiplicative at the micro (the firm-product) level while the aggregation is additive (see Hillberry, 2002; Yotov et al., 2016; French, 2017; Redding and Weinstein, 2019; Breinlich et al., 2022). Another strand of work suggests that spatial aggregation may be a further source of bias. The reason is that factor costs, productivity, and remoteness may vary starkly across the regions within a country. Again, the structural form of modern gravity and quantitative trade models at the micro level is multiplicative (log-additive) but aggregation is level-additive which leads to similar problems as an aggregation at the sector level (see Jara-Díaz and Donoso, 1989; Coughlin and Novy, 2021). Either type of bias rises with the heterogeneity in the parameters across the aggregated units. One would argue that for an economy such as China, which dominates the world market in some products and where some regions are larger than countries, either type of aggregation and potential associated bias should be expected to be potentially large.

Adopting a regional focus, Wang et al. (2010) focused on drivers of regional export sophistication within China. They used city-product-level data and found that the accumulation of human capital and the establishment of high-tech zones contributed to the evolution of China's export structure. Processing trade and the presence of foreign firms (one might say, the participation in global value chains) contributed to raising prices of products. However, that work focused on explaining export sophistication rather than regional export growth. Jarreau and Poncet (2012) found that Chinese provinces specializing in more sophisticated products grew faster between 1997 and 2009. While the latter attends to the question of regional export growth, it still focused largely on export sophistication rather than providing a decomposition of exports. Moreover, the aforementioned work did not aim at exact decompositions of region-product-market exports of China into their components nor on an analysis of counterfactual changes of fundamental drivers in a general equilibrium context that builds on modern quantitative work of gravity models with firm selection into markets.

The remainder of the paper is organized as follows. The subsequent section builds on a theoretical framework of firm-product-market export data to establish an exact decomposition of region-country-product export changes. Moreover, it pinpoints relevant exogenous drivers behind the endogenous components of exports. A counterfactual analysis can be based on the proposed model structure to quantify changes in exports, treating firm selection into products and markets as well as average productivity and wage costs as jointly endogenous. Section 3 introduces data from China which the decomposition and counterfactual procedures employ. Section 4 summarizes the results from the decomposition and counterfactual analyses, using 332 prefectures for aggregation of the fundamentals, and presents estimates of China's regional export drivers for the period 2000 to 2013. The last section concludes with a short summary.

2. Structural decomposition of export levels and growth

2.1. From firm- to prefecture-product exports in China

This section has two purposes. First, it outlines a model of annual firm-level data on exports per product, country of destination, and year. Second, it proposes an aggregation of these data across firms and a decomposition of the aggregate to various levels, region-product-country or region per year. The latter serves as the basis of a quantification of changes in China's prefecture-level exports over a time horizon of 14 years between 2000 and 2013.

Let f, h, r, c, t refer to the firm, product, Chinese region of origin, foreign (consumer-) country, and year in which exports are measured. We will proceed follow the convention of referring to the set and numbers of these entities by calligraphic capital letters $\mathfrak{F}, \mathfrak{H}, \mathfrak{R}, \mathfrak{C}, \mathfrak{T}$ and roman capital letters F, H, R, C, T, respectively. Whenever the latter carry an index themselves, they will pertain to the indexed entities, as will become clear later. It will turn out useful to further use $\mathfrak{M} = \mathfrak{R} \cup \mathfrak{C}$ for the joint set of Chinese regions and foreign countries, index their elements by m, and refer to their number as M.

Following Khandelwal et al. (2013), we assume that the utility function of consumers in country c at time t exhibits a Cobb–Douglas and constant-elasticity-of-substitution (CES) nested form of

$$U_{ct} = \prod_{h\in\mathfrak{H}} U_{cht}^{\alpha_h} \quad , U_{cht} = \left(\int_{m\in\mathfrak{M}} \int_{f\in\mathfrak{F}_{mcht}} (\lambda_{fmcht} q_{fmcht})^{\frac{(\sigma_h-1)}{\sigma_h}} \, df\, dm \right)^{\frac{\sigma_h}{(\sigma_h-1)}}, \tag{1}$$

where $\alpha_h \in (0,1)$ are expenditure shares which have the property of summing up to one, $\sum_{h\in\mathfrak{H}} \alpha_h = 1$, $\sigma_h > 1$ is an elasticity-of-substitution parameter among horizontal varieties of a product, and $\mathfrak{F}_{mcht}$ is the set of firms in market m and product h country c is purchasing from in year t. The number of these firms is $F_{mcht} \geq 0$. The terms λ_{mcfht} and q_{mcfht} are a preference (quality) parameter and quantity pertaining to a particular transaction. Under monopolistic competition, firms charge a constant markup of $\mu_h = \sigma_h/(\sigma_h - 1)$.

We use ω_{rht} to denote the factor costs per efficiency unit of the factor bundle available to producers in $\{mht\}$, and assume that it is composed of local labor costs at prices of ω^L_{mht} and imported-intermediate prices of ω^I_{mht}, which are combined in a Cobb–Douglas fashion with labor-share parameter γ^L_{mh} and intermediate-share parameter $\gamma^I_{mh} = 1 - \gamma^L_{mh}$. Then, $\omega_{mht} = (\frac{\omega^L_{mht}}{\gamma^L_{mh}})^{\gamma^L_{mh}} (\frac{\omega^I_{mht}}{\gamma^I_{mh}})^{\gamma^I_{mh}}$ measures the total factor costs per efficiency unit. Using ϕ_{fmch} to refer to the productivity of firm f in the production of (customized) output in product h and market c, $\tau_{mcht} \geq 1$ for iceberg trade costs in h when shipped from m to c at time t, Y_{cht} for aggregate expenditure on h in c at t, and P_{ct} for the aggregate ideal price index consumers face in c at t on everything they consume,[6] we can, when focusing on Chinese regions as the subset $\mathfrak{R} \subseteq \mathfrak{M}$, write the production quantity (q) and sales (export) value of firm f anchored in Chinese region r in product h to country c at t as

$$q_{frcht} = \phi_{frcht} (I_{frcht})^{\gamma^I_{rh}} (L_{frcht})^{\gamma^L_{rh}}, \tag{2}$$

$$x_{frcht} = \lambda^{\sigma_h-1}_{frcht} (\phi^{-1}_{frcht} \mu_h \omega_{rht} \tau_{rcht})^{1-\sigma_h} \frac{Y_{cht}}{P^{1-\sigma_h}_{ct}}. \tag{3}$$

Let us use tilde to denote $(\sigma_h - 1)$- or $(1 - \sigma_h)$-exponentiated terms in Eq. (3). Specifically, use $\tilde{\lambda}_{frcht} = \lambda^{\sigma_h-1}_{frcht}$ for quality, $\tilde{\phi}_{frcht} = \phi^{\sigma_h-1}_{frcht}$ for productivity, $\tilde{\omega}_{rht} = \omega^{1-\sigma_h}_{rht}$ for factor-bundle prices per efficiency unit, and let us subsume all remaining terms in Eq. (3) into $b_{rcht} = \tau^{1-\sigma_h}_{rcht} \mu^{1-\sigma_h}_h \frac{Y_{cht}}{P^{1-\sigma_h}_{ct}}$. Then, Eq. (3) can be compactly re-written as

$$x_{frcht} = \tilde{\lambda}_{frcht} \tilde{\phi}_{frcht} \tilde{\omega}_{rht} b_{rcht}. \tag{4}$$

In what follows, we will be interested in aggregate exports and their components

$$X_{rcht} = \int_{f\in\mathfrak{F}_{rcht}} x_{frcht} df = \left(\int_{f\in\mathfrak{F}_{rcht}} \tilde{\lambda}_{frcht} \tilde{\phi}_{frcht} df \right) \tilde{\omega}_{rht} b_{rcht}. \tag{5}$$

What will matter for aggregate trade from r in h to c at t are two things from the above integral, both endogenous to entry: the actual number of producers serving c from r in h, say, F_{rcht}, and the average value of the quality-augmented productivity term $\tilde{\lambda}_{frcht}\tilde{\phi}_{frcht}$ across all F_{rcht} actual producers. It is customary in the quantitative literature in international economics to assume that at least productivity is stochastic (see Eaton and Kortum, 2002; Melitz, 2003; Chaney, 2008; Arkolakis, 2010), following some tractable parametric form. It is qualitatively supported that productivity (and, in turn, export sales) are distributed following an extreme-value distribution. While Eaton and Kortum (2002) had proposed using an untruncated Fréchet distribution for this purpose with perfectly competitive producers, work allowing for constant positive price-cost margins and endogenous firm entry and exit tends to rely on a Pareto distribution (see Chaney, 2008; Arkolakis, 2010). We build on and extend the latter notion by assuming that both firm-level product quality and productivity are stochastic but not independently so. Specifically, we consider $(\tilde{\lambda}_{frcht}, \tilde{\phi}_{frcht})$ to be distributed bivariate Pareto of the so-called *first type* (see Mardia, 1962). Let $\tilde{\lambda}^0_{rcht}$ and $\tilde{\phi}^0_{rcht}$ denote the exogenous floor parameters of $\tilde{\lambda}$ and $\tilde{\phi}$ of the untruncated bivariate Pareto distribution pertaining to $\{rcht\}$. Furthermore, let a_{rch} denote the respective bivariate Pareto shape parameter.[7] Then, for all $v \in \{\tilde{\lambda}, \tilde{\phi}\}$, the bivariate cumulative distribution function about $(\tilde{\lambda}_{frcht}, \tilde{\phi}_{frcht})$ is

$$G_{rcht}(\tilde{\lambda}, \tilde{\phi}) = 1 - (\sum_{v\in\{\tilde{\lambda},\tilde{\phi}\}} v/v^0_{rcht})^{-a_{rch}} + (\sum_{v\in\{\tilde{\lambda},\tilde{\phi}\}} v/v^0_{rcht} - 1)^{-a_{rch}}, \tag{6}$$

with $v > v^0_{rcht} > 0$ and $a_{rch} > 2$. This bivariate Pareto distribution exhibits the convenient property that the marginal distributions of $\tilde{\lambda}$ and $\tilde{\phi}$ are of the univariate Pareto Type 1 form. Using $\tilde{\lambda}^*_{rcht} \geq \tilde{\lambda}^0_{rcht}$ and $\tilde{\phi}^*_{rcht} \geq \tilde{\phi}^0_{rcht}$ to denote the (upon entry) endogenous cutoff parameters, potentially truncating the left tail of the distribution of $\tilde{\lambda}_{frcht}$ and $\tilde{\phi}_{frcht}$, we can obtain the integral $G^*_{rcht} = G_{rcht}(\tilde{\lambda}^*_{rcht}, \tilde{\phi}^*_{rcht}) \in [0,1]$. When using F_{rht} to denote the number of potential entrant firms serving any customer market from r with

[6] Consider the price index P_{cht} to be defined as $P_{cht} = \left(\int_{m\in\mathfrak{M}} \int_{f\in\mathfrak{F}_{mch}} \bar{p}^{-(\sigma_h-1)}_{fmcht} df\, dm \right)^{-1/(\sigma_h-1)}$, where $\bar{p}_{fmcht} = p_{fmcht}\tau_{fmcht}$, using p_{fmcht} for the mill price and $\tau_{mcht} \geq 1$ for the iceberg-trade-cost parameter. The price index for all expenditures is then $P_{ct} \propto \prod_{h\in\mathfrak{H}} P^{\alpha_h}_{cht}$.

[7] Note that the shape parameter can be inferred from the correlation coefficient

$$Corr(\tilde{\lambda}_{rchft}, \tilde{\phi}_{rchft}) = \frac{1}{a_{rch}}, \quad a_{rch} > 2.$$

product h at time t, the actual number of producers serving market c are $F_{rcht} = F_{rht}(1-G^*_{rcht})$. Moreover, with the assumed bivariate Pareto form, the average quality-augmented productivity level, say, $\tilde{\psi}_{rcht}$, is defined as.[8]

$$\tilde{\psi}_{rcht} = \int_{\tilde{\lambda}^*_{rcht}}^{\infty} \int_{\tilde{\phi}^*_{rcht}}^{\infty} \tilde{\lambda}\tilde{\phi} dG_{rcht} = \frac{a^2_{rch} - a_{rch} - 1}{(a_{rch}-2)(a_{rch}-1)} \tilde{\lambda}^*_{rcht}\tilde{\phi}^*_{rcht}. \tag{7}$$

As a result, we may write aggregate bilateral exports per Chinese region, destination country, and product at time t as

$$X_{rcht} = F_{rht}(1-G^*_{rcht})\tilde{\psi}_{rcht}\tilde{\omega}_{rht}b_{rcht}. \tag{8}$$

We will utilize the latter (as well as region-product and region aggregates thereof) for two purposes: (i) decompose the observed changes in X_{rcht} into its components to see how much they contributed to the overall change; (ii) conducting some counterfactual analyses regarding fundamental exogenous components to shed light on some of the likely roots of the observed changes. The latter will require some additional assumptions and further structure on an underlying model.

2.2. Decomposition of region-country-product export changes

We are interested in decomposing the change in X_{rcht}, the aggregate level of export revenues in product h to country c from region r between periods $s < t$ and t, choosing $s = 2000$ and $t = 2013$ for reasons of data coverage. Using $\Delta V_t = V_t - V_s$ for any variable V, note that we can write the change in exports as

$$\Delta X_{rcht} = \Delta\left(F_{rht}(1-G^*_{rcht})\tilde{\psi}_{rcht}\tilde{\omega}_{rht}b_{rcht} \right). \tag{9}$$

In Appendix B, we derive the latter as

$$\Delta X_{rcht} = \Delta F_{rht}\chi_{F,rcht} + \Delta(1-G^*_{rcht})\chi_{(1-G^*),rchts} + \Delta\tilde{\psi}_{rcht}\chi_{\tilde{\psi},rchts} + \Delta\tilde{\omega}_{rht}\chi_{\tilde{\omega},rchts} + \Delta b_{rcht}\chi_{b,rchs}, \tag{10}$$

where the parameters $\chi_{V,rchts}$ for $V \in \{F, (1-G^*), \tilde{\psi}, \tilde{\omega}, b\}$ are importance weights implied by Eq. (9). We can normalize the latter as $\bar{\chi}_{V,rchts} = \chi_{V,rchts}/\Delta X_{rcht}$ so that the individual components sum up to unity. Unlike a log transformation, the decomposition

$$1 = \Delta F_{rht}\bar{\chi}_{F,rcht} + \Delta(1-G^*_{rcht})\bar{\chi}_{(1-G^*),rchts} + \Delta\tilde{\psi}_{rcht}\bar{\chi}_{\tilde{\psi},rchts} + \Delta\tilde{\omega}_{rht}\bar{\chi}_{\tilde{\omega},rchts} + \Delta b_{rcht}\bar{\chi}_{b,rchs} \tag{11}$$

is well defined for components as long as either $X_{rcht} \neq 0$ or $X_{rchs} \neq 0$. However, with an untransformed ΔX_{rcht}, the individual components, even when summing up to unity, may be numerically very large. Therefore, we will report on rank distributions rather than absolute numbers thereof across regions and products.

A further advantage of the changes in Eq. (9) is that they can be simply aggregated by summation across products h and countries c to obtain an absolute composition of aggregate regional export changes $\Delta X_{rt} = \sum_{c\in\mathfrak{C}_{rt}} \sum_{h\in\mathfrak{H}_{rt}} \Delta X_{rcht}$. Again, we can normalize the individual components behind this change by ΔX_{rt}, and we can, upon investigating the distribution of X_{rt} and its (weighted) components at time t, consider the observed change in that distribution, e.g., in terms of Gini coefficients.

2.3. Counterfactual changes

The above decomposition relies on the components in Eq. (8). In a general-equilibrium model in the spirit of Melitz (2003), all of those would be endogenous, as they rely on the input and output prices across all H products and M markets. It should be noted that, with the data at hand, it is not possible to estimate the parameters required to treat $H(M-1)$-many wages ω^L_{mht} and imported intermediate prices ω^I_{mht} jointly endogenous at time t. Key reasons for the latter are two. First, we do not observe domestic sales per market m and product h at time t. Second, we do not observe markets for goods and factors at the required detail for the C countries beyond China's R regions. Therefore, we have to resort to a hybrid model which treats certain model aspects exogenous to be able to consider endogenous responses of domestic wages ω^L_{rht} to changes in some fundamentals. For this purpose, we assume the exogenous factors to consist of $\{F_{rht}, L_{rht}, \bar{\zeta}_{rcht}, a_{rch}, \omega^I_{rht}, \gamma^I_{rh}, \sigma_h, b_{rcht}\}$, where L_{rht} is region-product-specific labor supply (see Appendix C for an exact definition), and $\bar{\zeta}_{rcht}$ is a market-access-cost parameter (see Section 3.2.4 for a definition). Hence, in contrast to a global general equilibrium model, we treat foreign market potential b_{rcht} to be fixed, and we do the same for the prices of imported intermediates, ω^I_{rht}. Both b_{rcht} and ω^I_{rht} are a function of foreign wages, consumer price indices, etc., all of which have to be treated as fixed for the aforementioned reasons of data availability. Finally, we abstract from domestic sales in China, as these are measured neither at the product level nor bilaterally for region pairs. Accordingly, we only consider endogenous changes in response to exporting.

We outline the building blocks of a model which treats the number of active firms, F_{rcht} through the support $(1-G^*_{rcht})$ as well as the average quality-adjusted (or -augmented) productivity parameter $\tilde{\psi}_{rcht}$ and region-product wages ω^L_{rht} as endogenous and a function of the aforementioned fundamentals. Then, we use the change in $\{\bar{\zeta}_{rcht}, \omega^I_{rht}, b_{rcht}\}$ to see how much of a change this triggers in predicted exports X_{rcht}. We provide details on the analytical approach in Appendix A.

[8] Details on the derivations can be found in Appendix A.

3. Data and measurement of exports and their components

The present paper contributes to a literature which invokes Melitz-type models in an otherwise macroeconomic approach towards international trade (see, e.g., Arkolakis, 2010; Eaton et al., 2011; Corcos et al., 2012; and others). Such models incorporate two types of ingredients: first, aggregate (here, region-product-market) data on bilateral trade flows among the cross-sectional (macro-level) units and, second, small sets of data moments on the distribution of firms which are used to calibrate parameters that macro data on bilateral trade alone would not permit. Specifically, the firm data are utilized to calibrate measures of dispersion of firm productivity, in our case, also the quality of products sold. We utilize the following data to this end.

3.1. Data

3.1.1. Trade data

For the purpose of this paper, we use trade data from two sources. First, we use transaction-level trade data from Chinese Customs. These data are used for two purposes. On the one hand, they are aggregated up to the annual level for each reporting exporting and importing firm by source/destination country and Harmonized System (HS) 6-digit product. In particular, this obtains bilateral export data, which are indexed by firm f, prefecture-level region r,[9] HS 6-digit product h, market c and year t, say, x_{frcht}. The latter, is composed multiplicatively of quantity, q_{frcht}, and average price per unit p_{frcht}. Price and quantity will be used to estimate features of the distribution of firms regarding quality and productivity. The firm-level metric of export value x_{frcht} will further be used to obtain aggregate exports of each region r, to a country c in product h in year t, X_{rcht}, which is just the integral of x_{frcht}. It should be noted that x_{frcht} sums up across regions r to China's aggregate exports to any country c in product h as reported in UNCTAD's Comtrade database.

Moreover, we use annual data on bilateral (country-pair) trade at the level of HS 6-digit products from the Centre d'Etudes Prospectives et d'Informations Internationales' (CEPII's) BACI database.[10] The coverage of years in our data is from 2000 to 2013.

A comparison of Chinese prefectures' exports with those of foreign countries suggests that the top-5 prefectures together export as much to the world as the 137 smallest countries on the globe do in 2013. The top-5 exporting prefectures in China rank 21 (Shenzhen), 24 (Shanghai), 28 (Suzhou), 41 (Dongguan), 52 (Beijing), when being considered as and put together with foreign countries in that year.

3.1.2. Other data used to decompose exports

The exact decomposition of export flows proposed in this paper requires decomposing the "supply-potential" component of aggregate region-country-product-year exports into the factor-cost, productivity, and quality components. Note that this requirement is specific to Melitz-type models, where firms select into markets. In the class of models described and covered by Arkolakis et al. (2012), such micro-foundations are not necessary.[11]

We employ firm-level data on wage costs per employee from China's Annual Survey of Industrial Firms (CASIF). The respective wage costs will, upon matching the CASIF data with ones from China Customs on firm-product-country-level trade, serve to obtain an estimate of wage costs per prefecture, product, and year. We also use firm-level imported-intermediate costs from matched Customs and CASIF data to predict the material costs per unit for each prefecture, product, and year. Section 3.2.1 will outline the details of the respective estimation.

Besides, we use estimates of σ_h from Broda and Weinstein (2006) at the HS 10-digit-level and match the HS 6-digit averages thereof to China's Customs data. See Section 3.2.1 also for some more details on this.

It should be noted that, for the sake of counterfactual analysis and for obtaining predictions of aggregate changes in response to shocks, we need to abstract from the variation in the data at the level of the firm with regard to wage costs, intermediate costs, as well as markups as related to σ_h. Note that in all macro approaches as well as in micro-to-macro approaches (see Eaton et al., 2013), such an abstraction is elemental, because otherwise (i) measuring firm level productivity, (ii) characterizing the distribution of firm prices as a function of few parameters, and (iii) characterizing aggregate trade flows in a parsimonious way as a composite of firm-level trade flows is infeasible. For this reason, we abstract from the variation of wage and intermediate costs (and, as a consequence, also

[9] Chinese Customs provides information on the four-digit prefecture code for each exporter and importer in China through the firm identifier. However, this identifier does not permit uniquely identifying the prefecture (or address) a firm belongs to (see Egger et al., 2021). We obtain the prefecture location of the exporters and importers in China as follows. First, we assign the prefecture name to an exporter and importer wherever the firm name and address permit doing so. This is the case for 677,429 exporters and importers in the data. Second, for another 3178 exporters and importers we extract information on the prefecture from the zip-code data, wherever this is uniquely possible (only for 128 exporters and importers). For the remaining 3050 exporters and importers for which no name and address but only the firm identifier is available, we use the first four digits of the identifier to assign the prefecture to be the one which is most frequently associated with the respective four-digit identifier in the data. Overall we distinguish between 332 prefectures that the universe of Chinese trade transactions in the data is associated with.

[10] We use the conversion table from the UN Comtrade to convert different versions of HS codes into the HS 1992 codes.

[11] These models cover the cases of Armington endowment models of the Eaton and Kortum (2002) type, the Anderson and Van Wincoop (2003, 2004) type, the Dixit–Stiglitz–Krugman type as used in Bergstrand et al. (2016), and even the Melitz type, as long as firm distributions are not truncated across markets due to market-specific fixed costs as in Helpman et al. (2008). The reason is that in all these models, mill prices of the firms are a function of the representative factor-cost bundle and otherwise exogenous parameters that do not change in counterfactual equilibrium. However, in Melitz-type models with selection, the average productivity (and in the present paper also the average quality) changes in counterfactual equilibrium. This has two consequences: the region-country-product component of exports cannot be attributed to variable trade frictions alone, and changes in the region-product component are not due to changes in the price of the composite factor bundle alone but also due to changing productivity (and, eventually, quality) due to firm entry or exit.

of the respective cost-share parameters) across firms and "load" the heterogeneity in prices entirely on productivity, as had been done in Arkolakis (2010), Corcos et al. (2012), and as it is assumed throughout in quantitative work in international trade of the more macro type (see Arkolakis, Costinot, and Rodríguez-Clare, 2012).

3.2. Measurement of components

The purpose of this section is to deliver a quantification of the components of China's region-country-product exports X_{rcht} in Eq. (8) — these are $\{F_{rht}, (1-G^*_{rcht}), \tilde{\psi}_{rcht}, \tilde{\omega}_{rht}, b_{rcht}\}$ as well as the corresponding changes of ΔX_{rcht} in Eq. (9). We will proceed in steps in the calibration and measurement of these components.

3.2.1. Measurement of trade-elasticity parameter σ_h as well as the unit-factor-bundle costs ω_{rht}

First of all, σ_h is needed to convert the unit-factor-bundle costs ω_{rht} into the metric $\tilde{\omega}_{rht} = \omega_{rht}^{1-\sigma_h}$. Second, it is an elemental measure to compute counterfactual changes of endogenous outcomes to shocks in general equilibrium (see Arkolakis, Costinot, and Rodríguez-Clare, 2012). we employ estimates of σ_h from Broda and Weinstein (2006) at the HS 10-digit-level. We adjust extreme value of σ_h in Broda and Weinstein (2006) to not exceed the values suggested by the ratio of operating revenues to operating profits within a 2-digit-sector (denoted by s) and year in the CASIF dataset covering accounting data for Chinese firms. Doing so, we restrict σ_h to not exceed a value of 12. Then, we use the resulting estimates of σ_h and match them as simple averages to the 6-digit HS product level.

Second, the unit-factor-bundle costs ω_{rht} are not directly observable, but they are an elemental component of the prices charged by firms. We put structure on ω_{rht} to enable its measurement as follows. First, we assume that output is produced with a region-product-specific Cobb–Douglas technology, using labor and imported intermediate goods. Let us denote the region-product cost Cobb–Douglas shares by $\{\gamma^L_{rh}, \gamma^I_{rh}\} = (0,1)$ with $\gamma^L_{rh} + \gamma^I_{rh} = 1$. Specifically, we consider

$$\ln\omega_{rht} = \gamma^L_{rh}\ln\omega^L_{rht} + \gamma^I_{rh}\ln\omega^I_{rht}. \tag{12}$$

We measure γ^L_{rh} as the average (across firms and years) predicted cost share pertaining to labor costs relative to labor plus imported intermediates using CASIF and Customs data, and we obtain $\gamma^I_{rh} = 1 - \gamma^L_{rh}$.

In order to compute ω_{rht}, we also need ω^L_{rht} and ω^I_{rht}. The latter two need to be imputed and are not directly observable in the data. What is observable are ω^L_{rft} and ω^I_{rft} as the wage costs per employee, firm, and year as well as the unit values of intermediate goods imported by each firm in a year. However, firms are nested in products h, and products h are nested in 2-digit sectors of the CASIF classification. Using $V \in \{L, I\}$ we predict region-product-time unit-factor costs ω^V_{rht} as region-2-digit-sector-time unit-factor costs from fixed-effects regressions of the type

$$\begin{aligned} \ln\omega^V_{rft} &= \text{FE}^V_{rt} + \text{FE}^V_{st} + \epsilon^V_{ft} \quad \forall \text{V} \in \{L, I\}, \\ \hat{\omega}^V_{rht} &= \exp(\hat{\text{FE}}^V_{rt} + \hat{\text{FE}}^V_{st}) \quad \forall \text{h} \in s. \end{aligned} \tag{13}$$

Using the latter estimates in Eq. (12) obtains estimates of ω_{rht} and, in conjunction with σ_h of $\tilde{\omega}_{rht}$.

3.2.2. Measurement of the average quality-adjusted productivity parameter $\tilde{\psi}_{rcht}$

The parameter $\tilde{\psi}_{rcht}$ in Eq. (8) is not directly observable. It is informed by scaled quality ($\tilde{\lambda}$) as well as inverse productivity ($\tilde{\phi}$). However, quality and productivity vary across firms, and their distribution in a particular product h and country c in a year t is truncated due to firm selection. In order to quantify the region-country-product-year average $\tilde{\psi}_{rcht}$, we start with firm-level data. Specifically, we use data on export quantities q_{frcht}, free-on-board unit values p_{frcht}, as well as cost-insurance-freight-including consumer prices $\bar{p}_{frcht}$.

We consider firms to draw the quality parameter $\tilde{\lambda}_{frcht}$ and the productivity parameter $\tilde{\phi}_{frcht}$ from a bivariate Pareto distribution. Let us emphasize that this is different from common practice (see, e.g., Arkolakis, 2010, or Corcos et al., 2012) in that these parameters vary across destination markets as well as time. This is done so as to acknowledge the variation of these parameters in all dimensions of the data.

We follow Khandelwal et al. (2013) to determine quality based on the following equation

$$\ln q_{frcht} + \sigma_h \ln\bar{p}_{frcht} = \alpha_{cht} + \epsilon_{frcht}, \tag{14}$$

where α_{cht} is a cht-fixed effect, and ϵ_{frcht} is a residual.

Using firm-transaction-level data on log export quantities $\ln q_{frcht}$ and (cost-insurance-freight-inclusive) consumer prices $\ln\bar{p}_{frcht}$ in conjunction with the aforementioned estimates or σ_h, one can proceed as follows. First, within-cht-transform $\ln q_{frcht}$ and $\sigma_h\ln\bar{p}_{frcht}$ so as to eliminate any variation in cht-space. This transformation eliminates the term α_{cht} from Eq. (14). Then, given σ_h, one can compute a measure of export-product quality as

$$\ln\lambda_{frcht} = \frac{\hat{\epsilon}_{frcht}}{\sigma_h - 1}. \tag{15}$$

Note that the mill price of firm f from Chinese region r regarding product h to country c at time t is determined as

$$p_{frcht} = \frac{\mu_h\omega_{rht}}{\phi_{frcht}}. \tag{16}$$

Table 1
R^2 of the cumulative quantiles of the nonparametric distribution and the bivariate-Pareto-predicted counterparts about firm-level quality and productivity.

Percentiles	$\ln \tilde{\lambda}_{Q,rcht}$	$\ln \tilde{\phi}_{Q,rcht}$
1	0.923	0.884
5	0.948	0.933
10	0.962	0.952
25	0.982	0.974
50	0.995	0.991
75	0.999	0.998
90	1	0.999
95	1	1
99	1	1
Min	0.859	0.715
Max	1	1

Hence, a given mill price p_{frcht}, markup $\mu_h = \sigma_h/(\sigma_h - 1)$, and factor-cost parameter ω_{rht} pin down total factor productivity.

It must be noted at this point that the obtained estimates of λ_{frcht} and ϕ_{frcht} are inherently nonparametric. The advantage of considering a nonparametric distribution about $\{\lambda_{frcht}, \phi_{frcht}\}$ or the scaled counterparts $\{\tilde{\lambda}_{frcht}, \tilde{\phi}_{frcht}\}$ would be that any gap between the micro, $rchft$-level, and the macro, $rcht$-level, data would be closed. However, the consideration of nonparametric distributions poses a fundamental problem for counterfactual analysis: when conducting experiments which on net lead to an entry of latent firms into a market (a product and country), we need to know the unobserved parameters $\{\lambda_{frcht}, \phi_{frcht}\}$ for these entrants, and a nonparametric distribution does not permit imputing those. Therefore, it is customary in international economics to work with parametric distributions (see Chaney, 2008; Arkolakis, 2010; Bernard et al., 2011; Eaton et al., 2011; Corcos et al., 2012).

In this regard, the following trade-off can be stated. While considering nonparametric firm distributions permits targeting the aggregate $rcht$-level exports, X_{rcht}, as well as the truncation of the firm distribution (i.e., the cutoff levels $\{\tilde{\lambda}^*_{frcht}, \tilde{\phi}^*_{frcht}\}$) and, in turn, cutoff-firm exports (x^*_{frcht}) simultaneously, it does not in a straightforward way support a counterfactual analysis involving firm entry, as the density of the latent part of the firm distribution is unknown. On the contrary, imposing (low-)parametric assumptions on the firm distribution, as is customary, does not permit targeting aggregate trade flows, X_{rcht}, simultaneously with $\{\tilde{\lambda}^*_{frcht}, \tilde{\phi}^*_{frcht}\}$ or x^*_{frcht}. However, a parametric distribution with global parameters (i.e., ones that apply also for the latent exporters) permits conducting counterfactual analyses with firm entry. We follow the customary, second approach and will report on how the untargeted levels of $\{\tilde{\lambda}^*_{frcht}, \tilde{\phi}^*_{frcht}\}$ based on the micro data compare with the imputed counterparts assuming a bivariate Pareto distribution. Specifically, we utilize the micro data on $\{\tilde{\lambda}_{frcht}, \tilde{\phi}_{frcht}\}$ to estimate the shape parameter of a bivariate Pareto distribution of the first type (see Footnote 7), following Mardia (1962). The cutoff values of the parameters of the distribution are specific to each region-product-country tuple in year t, $\{\tilde{\lambda}^*_{rcht}, \tilde{\phi}^*_{rcht}\}$. The aggregate value of exports from region r in product h to country c in year t, X_{rcht}, reveals the product of the latter exponentiated by $1 - \sigma_h$, $\tilde{\psi}_{rcht} = \frac{a^2_{rch} - a_{rch} - 1}{(a_{rch}-2)(a_{rch}-1)} \tilde{\lambda}^*_{rcht} \tilde{\phi}^*_{rcht}$. We use the firm-level data to determine the ratio of the cutoff parameters $\tilde{\lambda}^*_{rcht}/\tilde{\phi}^*_{rcht}$ for the marginal firm. This ratio will be kept fixed in the counterfactual analysis. Combining the above two equations associated with $\tilde{\lambda}^*_{rcht}\tilde{\phi}^*_{rcht}$, we can solve for $\tilde{\lambda}^*_{rcht}$ and $\tilde{\phi}^*_{rcht}$, separately. Calibrating $\tilde{\lambda}^*_{rcht}$ and $\tilde{\phi}^*_{rcht}$ separately helps matching aggregate export quantities apart from export values.

One issue with a macro-type approach towards firm productivity (and quality, here) is that the nonparametric distribution of firms will typically deviate to a certain degree from any parametric form. However, a parametric assumption about firm heterogeneity is customary to be able to quantify the (net) entry of firms after shocks. In quantitative models which only rely on aggregated data, it is not feasible to address the question of the relative fit of the nonparametric firm distribution by the assumed parameterized distribution. However, we can assess this fit here, as we observe the firm level data. Specifically, we do so by following the approach in Arkolakis (2010) and others to compute cumulative quantiles of the nonparametric distribution about the firm-level quality and productivity, $\{\ln \tilde{\lambda}_{Q,rcht}, \ln \tilde{\phi}_{Q,rcht}\}$, and the bivariate-Pareto-predicted counterparts, $\{\ln \hat{\tilde{\lambda}}_{Q,rcht}, \ln \hat{\tilde{\phi}}_{Q,rcht}\}$. Regarding the latter, we note that the marginal distributions of the bivariate Pareto of the first type are univariate Pareto Type I distributions (see Mardia, 1962). The values $\{\ln \tilde{\lambda}_{Q,rcht}, \ln \tilde{\phi}_{Q,rcht}\}$ correspond to the log of the average values of $\{\ln \tilde{\lambda}_{frcht}, \ln \tilde{\phi}_{frcht}\}$ in any percentile of Q or higher, and $\{\ln \hat{\tilde{\lambda}}_{Q,rcht}, \ln \hat{\tilde{\phi}}_{Q,rcht}\}$ correspond to the predicted values based on a bivariate Pareto distribution of the first type. We then correlate the elements in $\{\ln \tilde{\lambda}_{Q,rcht}, \ln \tilde{\phi}_{Q,rcht}\}$ with their counterparts in $\{\ln \hat{\tilde{\lambda}}_{Q,rcht}, \ln \hat{\tilde{\phi}}_{Q,rcht}\}$ across all quantiles for each region-country-product tuple $\{rch\}$. We do so by regressing one on another, loop over all $\{rch\}$, and report the results on the distribution of the R^2 values in Table 1.

Table 1 provides details on the respective parametric distribution across $\{rch\}$, using 2013 data. The table indicates that the minimum R^2 value for $\ln \hat{\tilde{\lambda}}_{Q,rcht}$ amounts to 0.859, while that for $\ln \hat{\tilde{\phi}}_{Q,rcht}$ amounts to 0.715. The corresponding median values are 0.995 and 0.991, respectively. Overall, we deem this parametric fit not perfect but acceptable, recalling that permitting a net entry of firms in a region, country, and product requires some parametric assumption.

3.2.3. Measurement of b_{rcht}

According to Eq. (4), we can use export data x_{frcht} together with the obtained components $\tilde{\lambda}_{frcht}$, $\tilde{\phi}_{frcht}$ and $\tilde{\omega}_{rht}$ to determine b_{rcht} as a residual:

$$b_{rcht} = \frac{x_{frcht}}{\tilde{\lambda}_{frcht}\tilde{\phi}_{frcht}\tilde{\omega}_{rht}}. \tag{17}$$

Recall that the latter inter alia accounts for variable trade costs apart from product-country expenditures.

3.2.4. Measurement of the firm-truncation measure $1-G^*_{rcht}$, the number of latent exporters F_{rht}, and of fixed market-access cost parameter $\bar{\zeta}_{rcht}$

As outlined in Section 2.1, the number of firms in region r which actually sell product h to country c in year t is determined as $F_{rcht} = F_{rht}(1 - G^*_{rcht})$. Note that F_{rcht} can be measured from the data as the count of sellers from r of h in c at t. However, neither the number of latent firms F_{rht} nor the truncation measure $(1 - G^*_{rcht}) \in [0, 1]$ is directly observed.

However, we can measure $(1 - G^*_{rcht})$, when integrating Eq. (6) using the estimate of the bivariate shape parameter a_{rch} as estimated above. For this, we need to make an assumption about the floor parameters of the latent bivariate Pareto distribution, which is determined by the smallest $\tilde{\lambda}_{frcht}$ and $\tilde{\phi}_{frcht}$ for each $\{rht\}$ across countries. Hence, we assume that the latent distribution has full theoretical support. Moreover, we consider the estimated cutoff parameters $(\tilde{\lambda}^*_{rcht}, \tilde{\phi}^*_{rcht})$ in the integration of Eq. (6) to obtain $G^0_{rcht} = G_{rcht}(\tilde{\lambda}^0_{rcht}, \tilde{\phi}^0_{rcht}) = 0$ and $G^*_{rcht} = G_{rcht}(\tilde{\lambda}^*_{rcht}, \tilde{\phi}^*_{rcht})$. The former is the cumulative density outside the theoretical support of quality-productivity space and the latter one is the cumulative density outside the truncated quality-productivity space, but assuming a bivariate Pareto function of the first type with known and otherwise estimated parameters. Once estimates of the unobservable truncation variable $(1 - G^*_{rcht})$ are derived for all regions, countries, products, and years, the mass of latent firms can be computed by dividing the measured number of exporters, F_{rcht}, by $(1 - G^*_{rcht}) = [0, 1]$.

The firm-level parameters $\tilde{\lambda}_{frcht}$ and $\tilde{\phi}_{frcht}$ are drawn from a distribution and are exogenous by assumption. Their counterparts pertaining to the marginal, least-selling firm from r in country c, product h, and year t, $\tilde{\lambda}^*_{rcht}$ and $\tilde{\phi}^*_{rcht}$, are endogenous. The latter is immaterial for their measurement given data on export flows, but it is relevant when considering counterfactual experiments, as then $\tilde{\lambda}^*_{rcht}$ and $\tilde{\phi}^*_{rcht}$ will adjust.

With a bivariate Pareto distribution of the first type about $\tilde{\lambda}^*_{rcht}$ and $\tilde{\phi}^*_{rcht}$ with joint density $g(\tilde{\lambda}_{frcht}, \tilde{\phi}_{frcht})$ and shape parameter a_{rch}, expected exports from r to c in h at t are determined as

$$E[x_{frcht}] = \underbrace{\frac{a^2_{rch} - a_{rch} - 1}{(a_{rch} - 2)(a_{rch} - 1)} \tilde{\lambda}^*_{rcht} \tilde{\phi}^*_{rcht}}_{=\tilde{\psi}_{rcht}} \tilde{\omega}_{rht} b_{rcht}. \tag{18}$$

The latter pins down $\tilde{\psi}_{rcht}$[12] and permits determining the cutoff firm's export level as[13]:

$$x^*_{rcht} = \tilde{\lambda}^*_{rcht} \tilde{\phi}^*_{rcht} \tilde{\omega}_{rht} b_{rcht}. \tag{19}$$

At this point, it is important to re-iterate on measurement issues with micro as well as macro data on trade flows at hand. As mentioned above, something has to give with a macro approach towards trade: we cannot target aggregate exports, X_{rcht}, as well as the marginal firm's exports, x^*_{frcht} simultaneously when assuming a parametric distribution function (such as a bivariate Pareto distribution) whose parameters are estimated from the micro data. Such an approach would only be successful, if the micro data would exactly follow the assumed parametric distribution. To the extent that this is not the case, we have to sacrifice something, namely here either the Pareto shape parameter or the estimated cutoff levels of $\tilde{\psi}^*_{rcht}$ or $(\tilde{\lambda}^*_{rcht}, \tilde{\phi}^*_{rcht})$ and, in turn, x^*_{rcht}. We documented above that this strategy leads to some gap between the micro data and the model predictions, which we deemed tolerable in the light that the chosen approach permits conducting counterfactual experiments in general equilibrium.

In Melitz-type models the truncation parameters (here, $\tilde{\lambda}^*_{rcht}$ and $\tilde{\phi}^*_{rcht}$; usually, only $\tilde{\phi}^*_{rcht}$) and, in turn, $(1 - G^*_{rcht})$ depend on the (region-country-product-time) fixed market-access costs. Let us denote the latter by ζ_{rcht}. The model predictions of $(\tilde{\lambda}^*_{rcht}, \tilde{\phi}^*_{rcht})$ imply a certain level of fixed costs. Specifically, in the chosen model, the marginal exports reveal the implicit fixed market-access costs of firms in r to sell product h at t to country c as

$$\zeta_{rcht} = \frac{x^*_{rcht}}{\sigma_h} = \frac{\tilde{\lambda}^*_{rcht} \tilde{\phi}^*_{rcht} \tilde{\omega}_{rht} b_{rcht}}{\sigma_h}. \tag{20}$$

Ultimately, at a given markup parameter σ_h and a joint bivariate Pareto density function $g(\tilde{\lambda}_{frcht}, \tilde{\phi}_{frcht})$ with shape parameter a_{rch}, the fixed costs ζ_{rcht} – conditional on $\tilde{\omega}_{rht} b_{rcht}$ and σ_h – determine the mass of firms present as well as the export volume relative to some benchmark situation.

We assume that

$$\zeta_{rcht} = \bar{\zeta}_{rcht} (\omega^L_{rht})^{\gamma^L_{rh}}. \tag{21}$$

Hence, a given ζ_{rcht}, ω^L_{rht}, and γ^L_{rh} pins down $\bar{\zeta}_{rcht}$.

Overall, with the chosen approach the fixed-cost parameter $\bar{\zeta}_{rcht}$ is selected such that aggregate prefecture level exports X_{rcht} are predicted without residual.

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12 Details on the derivation procedure can be found in Appendix A.

13 While we can retrieve values of the firm-level parameters $\tilde{\lambda}_{frcht}$ and $\tilde{\phi}_{frcht}$ from the actual exporters in the data, the above insights permit computing the cutoff level $\tilde{\lambda}^*_{rcht} \tilde{\phi}^*_{rcht}$ not only for the observed benchmark situation but also for some counterfactual situation. The same is true for the marginal firm's export value, x^*_{rcht}.

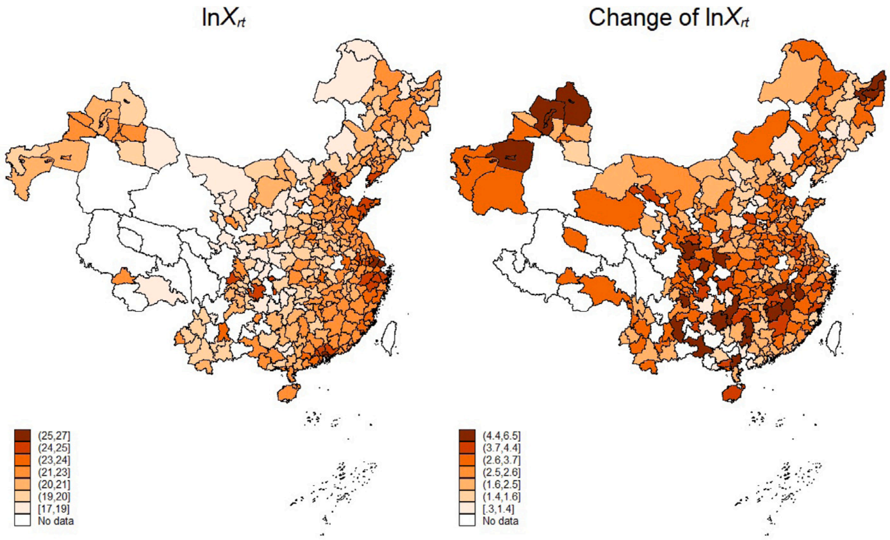

Fig. 2. Distribution of $\ln X_{rt}$ and changes of $\ln X_{rt}$ for Chinese prefectures in 2013 and from 2000 to 2013, respectively.

4. Results

4.1. Descriptive analysis of region-level export components

In this section, we document the findings regarding the (partly endogenous) components and the (exogenous) fundamentals behind prefecture-level exports in 2013 and their change from 2000 to 2013.

Fig. 2 is devoted to displaying the geographical distribution of the level in 2013 and the change between 2000 and 2013 of total regional exports across Chinese prefectures. For this, we compute $X_{rt} = \sum_c \sum_h X_{rcht}$ and its log-transformed counterpart, $\ln X_{rt}$ as well as $\Delta \ln X_{rt}$, where the latter subtracts the value of 2000 from the one of 2013.

The left panel of Fig. 2 clearly suggests that regional exports are particularly large in prefectures in the vicinity of the Chinese coast in 2013. However, the right panel of the same figure suggests that the change was on average bigger in prefectures that were somewhat located westwards of the coastline. The latter documents China's success in letting off-coastal regions benefit of its export-market participation in more recent periods.

In Tables 2–3, we report on the distribution of the components of region-country-product exports as in Eqs. (8) and (9)–(11) for levels and changes, respectively. Moreover, in Figs. 3–4, we report on some pairwise correlations between these components. In a nutshell, the corresponding results can be summarized as follows.

An inspection of Table 2 suggests that the truncation variable $(1 - G^*)$ displays the relatively largest dispersion (measured by the standard deviation normalized by the mean), followed by the number of entrant firms (F), quality-augmented productivity $(\tilde{\psi})$, inverse scaled factor costs $(\tilde{\omega})$, and foreign market potential (b).

Table 3 summarizes the changes of the same variables in logs between the years 2000 and 2013. According to this table, the quality-augmented productivity $(\tilde{\psi})$ increased at the median, and it displayed the largest coefficient of variation among all considered variables. The truncation variable $(1-G^*)$ declined at the median, and its change displayed the second-largest coefficient of variation among the considered factors. The number of entrant firms (F) and foreign market potential (b) increased, and inverse factor costs declined at the median, and all these changes had a relatively minor variation among the cross-sectional units.

In Figs. 3–4 we report on the correlations in levels of 2013 and changes from 2000 to 2013 between some of the important determinants of trade. We do so at the same level of aggregation as they vary in the aggregate data, namely $rcht$ for quality-augmented productivity $(\tilde{\psi})$, the truncation variable, $1 - G^*$, and market potential, b, and at the rht level for latent firm numbers, F, and inverse scaled factor costs, $\tilde{\omega}$.

An inspection of these figures suggests the following. First, the upper left panels in the two figures indicate that quality-augmented productivity $(\tilde{\psi})$ and the number of latent firms tend to be positively correlated. Hence, the more potential entrants there are in a prefecture, the higher is on average the quality-augmented productivity of the average firm in that prefecture, after selection, which serves a destination market with a product. This is true for levels as well as changes. The quality-augmented average productivity $(\tilde{\psi})$ and the truncation parameter $(1 - G^*)$ are negatively correlated. Note that the latter is generic to a degree. If the Pareto shape parameter and the floor parameters of the latent quality-augmented productivity distribution were the same across products and regions in China, one would expect a negative correlation between $\tilde{\psi}$ (the quality-augmented productivity level) and the fraction of potential firms which actually serve a market, $(1-G^*)$. The latter can be seen from the two upper right panels in Figs. 3–4. A higher

Table 2
Descriptive statistics for the export components at region-country-product level in years 2000 and 2013.

Percentiles	$\ln F_{rht}$	$\ln(1-G^*_{rcht})$	$\ln\tilde{\psi}_{rcht}$	$\ln\tilde{\omega}_{rht}$	$\ln b_{rcht}$
1	0.69	−35.13	1.49	−99.14	3.42
5	0.69	−27.65	3.90	−83.44	7.16
10	0.69	−21.30	5.53	−62.66	8.12
25	2.41	−12.91	9.80	−36.46	9.56
50	6.55	−5.13	17.94	−20.62	11.73
75	14.37	−1.26	30.73	−10.90	15.52
90	22.79	0	53.45	−5.89	21.95
95	29.16	0	71.00	−4.09	27.71
99	36.58	0	86.85	−2.58	47.98
Mean	9.53	−8.22	23.95	−27.81	13.92
Std. Dev.	8.95	8.78	19.97	23.14	8.34

Table 3
Descriptive statistics for the change of ln export components at region-country-product level from 2000 to 2013.

Percentiles	$\Delta\ln F_{rht}$	$\Delta\ln(1-G^*_{rcht})$	$\Delta\ln\tilde{\psi}_{rcht}$	$\Delta\ln\tilde{\omega}_{rht}$	$\Delta\ln b_{rcht}$
1	−23.54	−27.33	−10.49	−10.33	−2.38
5	−13.46	−17.02	−5.57	−7.12	−0.47
10	−7.80	−11.76	−3.69	−5.41	0.11
25	−1.58	−4.24	−1.65	−3.28	1.06
50	1.13	−0.09	0.01	−1.74	2.42
75	5.08	2.12	1.51	−0.85	4.50
90	12.56	8.38	3.09	−0.42	8.08
95	17.81	14.06	4.33	−0.29	10.93
99	28.19	24.15	8.09	−0.15	19.71
Mean	1.76	−1.05	−0.19	−2.44	3.39
Std. Dev.	8.95	8.86	3.29	2.24	3.94

Table 4
Rank of export components for the 15 biggest exporting prefectures in 2013.

Prefecture	F_{rt}	$1-G^*_{rt}$	$\tilde{\psi}_{rt}$	$\tilde{\omega}_{rt}$	b_{rt}	x_{rt}
Shenzhen	2	244	83	49	34	1
Shanghai	12	271	29	48	2	2
Suzhou	16	231	65	45	20	3
Dongguan	11	267	146	54	28	4
Ningbo	18	261	41	58	63	5
Guangzhou	22	252	70	59	11	6
Beijing	42	255	10	172	5	7
Xiamen	10	264	18	87	46	8
Chongqing	75	219	19	31	13	9
Tianjin	26	265	78	47	1	10
Hangzhou	24	266	48	78	12	11
Foshan	64	206	49	96	15	12
Wuxi	41	257	47	111	8	13
Qingdao	14	263	58	147	23	14
Huizhou	7	258	171	83	107	15

quality-augmented productivity is associated with higher factor costs paid in levels,[14] but the opposite is true for changes. And quality-augmented productivity tends to be higher in markets with a larger sales potential but the opposite is true when considering changes. The latter two sets of insights can be gained from the lower two panels in Figs. 3–4.

In Table 4, we report on the rank of the top-15 prefectures regarding their overall exports as of 2013 in the last column. In the second to fifth columns we report on the rank of each structural component underlying the export value among all prefectures, according to Eq. (8).[15] The table suggests the following insights. First, high export ranks of the top-ranking prefectures are mainly earned from high ranks in three factors: their size (as measured by the number of potential entrants, F), their market potential (one might say, location; b), and their average quality-augmented productivity ($\tilde{\psi}$). Obviously, increased competition at factor markets makes the same prefectures rank less favorably in unit factor costs ($\tilde{\omega}$), and the same prefectures tend to be particularly selective in terms of firm entry ($1-G^*$). The latter shows in relatively lower ranks in those variables among the top-ranking prefectures.

Besides, the changes of components from 2000 to 2013 also display a large degree of regional heterogeneity. Specifically, 46 regions experienced negative changes in quality-augmented productivity ($\tilde{\psi}$) and 9 regions experienced a reduction in market

14 Recall that factor costs ω are inversely related to $\tilde{\omega}$.

15 We use export-share weights to aggregate the five components from the country-product-region level to the region for each year.

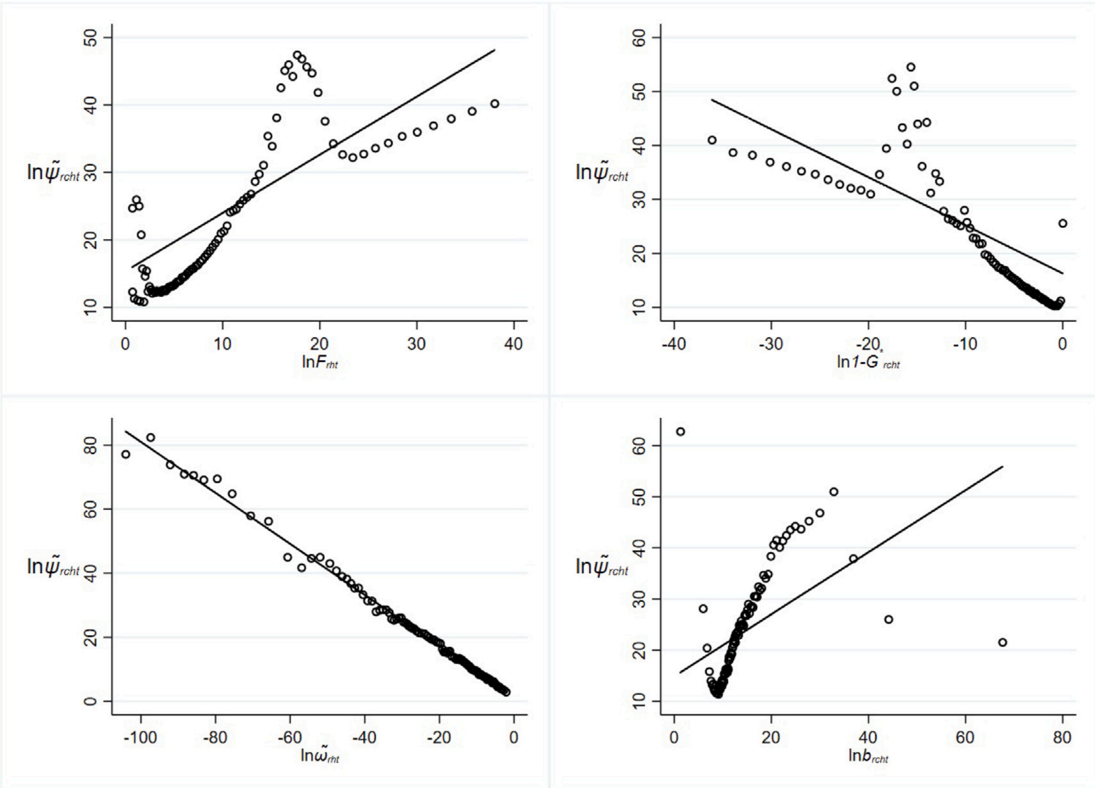

Fig. 3. Ln$\tilde{\psi}_{rcht}$ against lnF_{rht}, ln$(1 - G^{*}_{rcht})$, $\tilde{\omega}_{rht}$, and lnb_{rcht} in year 2013.

potential (b), 101 regions experienced higher fixed market-access cost ($\bar{\zeta}$), and 159 regions experienced higher intermediate input cost (ω^{I}) at the end of the sample period relative to the beginning.

In Tables 5 and 6 we report on the results regarding the exact decomposition of the change in exports per region, country, and product from 2000 to 2013 into its (partly endogenous) components. Table 5 presents the figures regarding the contribution shares of the five considered components to overall export growth from 2000 to 2013. Note that the results there are based on Eq. (11). Hence, the shares sum up to unity for every region, country, and product, $\{rch\}$. They are then summed across countries and products $\{ch\}$ and re-normalized to again sum up to unity. In Table 5, we report the median contributions of the respective five components regarding the change from 2000 to 2013. The numbers should be interpreted as to indicate how much of the change when going backwards from 2013 to 2000 (associated with a decline in exports) accrues at the median to a component. The numbers suggest that much of the change was due to changes in the number of potential entrants (F), followed by the change in market access (b) and quality-augmented productivity (ψ). Changes in firm selection and factor costs appear to have counteracted the (negative, when going backwards) stimuli of potential entrants, market access, and quality-augmented productivity.

Table 6 shows for how big a fraction the same individual components of prefecture-level exports as in Table 5 were the most (or second, or third, etc.) important factors among the five across all prefectures. Specifically, the first column indicates that the most important factor on average was the change in truncation variable which translates potential suppliers into actual ones and which tunes average quality-adjusted productivity $(1 - G^{*})$, followed by the number of potential entrants (F). The table attests to a significant variation in the relative importance of the considered factors across prefectures.

In the light of the changes in overall regional exports and ones associated with the components in Tables 5 and 6, two questions are interesting to ask. First, did the distribution of exports become more or less equalized over time? And, second, did the five components contribute to a greater equality or inequality among regions in their export-market participation? Table 7 addresses this question. The table footnote suggests that the Gini coefficient about prefecture-level exports amounted to 0.860 in the year 2000, whereas it amounted to 0.829 in 2013. Hence, Chinese prefectures became more equal in exporting when comparing year-2013 with year-2000 data. The year-2000 minus year-2013 Gini coefficient amounts to 0.031. It turns out that each one of the five considered components changed the Gini coefficient in the direction of the data on exports altogether. In other words, rolling an individual component back to its year-2000 data point all else equal would have raised the inequality in prefecture-level exports ceteris paribus.

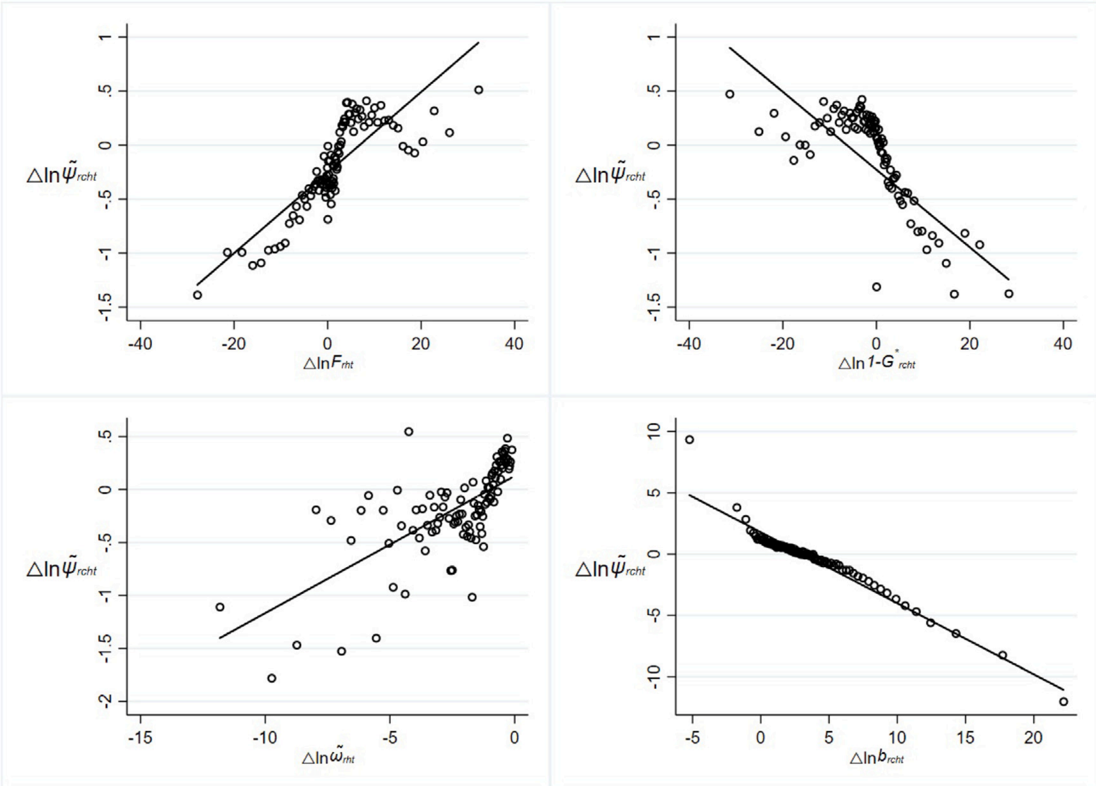

Fig. 4. Changes of $\ln\tilde{\psi}_{rcht}$ against changes of $\ln F_{rht}$, $\ln(1-G^{*}_{rcht})$, $\tilde{\omega}_{rht}$, and $\ln b_{rcht}$ from 2000 to 2013.

Table 5
Median of weighted share of generic multiplicative components of the change in exports at the region-country-product level from 2000 to 2013.

	Median
$\Delta F_{rht}\bar{\chi}_{F,rcht}$	0.839
$\Delta(1-G^{*}_{rcht})\bar{\chi}_{(1-G^{*}),rchts}$	−0.017
$\Delta\tilde{\psi}_{rcht}\bar{\chi}_{\tilde{\psi},rchts}$	0.166
$\Delta\tilde{\omega}_{rht}\bar{\chi}_{\tilde{\omega},rchts}$	−0.397
$\Delta b_{rcht}\bar{\chi}_{b,rchs}$	0.537

Table notes: Components $\Delta V_{rcht}\bar{\chi}_{V,rchts}$ measure the relative contribution of component V to the overall change in x_{rcht} between periods t and s, $V \in \{F, 1-G^{*}, \tilde{\lambda}^{*}, \tilde{\phi}^{*}, \tilde{\omega}, b\}$.

Table 6
Ranking of each weighted share of generic multiplicative component of the change in exports across regions as a fraction of unity in rows and columns.

Components	Rank 1	Rank 2	Rank 3	Rank 4	Rank 5
$\sum_{ch}\Delta F_{rht}\bar{\chi}_{F,rcht}$	0.275	0.143	0.087	0.088	0.407
$\sum_{ch}\Delta(1-G^{*}_{rcht})\bar{\chi}_{(1-G^{*}),rchts}$	0.412	0.071	0.099	0.143	0.275
$\sum_{ch}\Delta\tilde{\psi}_{rcht}\bar{\chi}_{\tilde{\psi},rchts}$	0.011	0.121	0.780	0.088	0
$\sum_{ch}\Delta\tilde{\omega}_{rht}\bar{\chi}_{\tilde{\omega},rchts}$	0.126	0.214	0.006	0.462	0.192
$\sum_{ch}\Delta b_{rcht}\bar{\chi}_{b,rchs}$	0.176	0.451	0.028	0.219	0.126

Table notes: Components $\Delta V_{rcht}\bar{\chi}_{V,rchts}$ measure the relative contribution of component V to the overall change in x_{rcht} between periods t and s, $V \in \{F, 1-G^{*}, \tilde{\lambda}^{*}, \tilde{\phi}^{*}, \tilde{\omega}, b\}$.

The corresponding effects are biggest for the contributions of quality-adjusted productivity ($\Delta\tilde{\psi}_{rcht}$) and market potential ($\Delta b_{rcht}$), followed by the firm-selection effect ($\Delta(1-G^{*}_{rcht})$), the factor costs ($\tilde{\omega}_{rht}$), and the potential number of firm entrants (ΔF_{rht}).[16]

[16] It is worth noting that the partial effects of the five components individually sum up to more than the total change. But the changes in all components together sum up to the total change in regional exports due to the exact-decomposition property for both ΔX_{rcht} and ΔX_{rt}. Hence, there are offsetting effects of changing all the components jointly.

Table 7
Gini changes of prefecture-level exports in 2000 and counterfactual experiments of generic multiplicative components as a deviation from 2013 data.

Panel A: Gini in 2000 minus benchmark year of 2013					
Gini change	0.031				
Panel B: Gini change in the counterfactual experiments of generic multiplicative components of export value in deviation to 2013					
	F_{rht}	$(1-G^*_{rcht})$	$\tilde{\psi}_{rcht}$	$\tilde{\omega}_{rht}$	b_{rcht}
Gini change	0.078	0.102	0.149	0.089	0.125

Table notes: The Gini coefficient in the export data of 2000 and 2013 is 0.860 and 0.829, respectively.

Table 8
Descriptive statistics for the exogenous parameters at region-country-product-level in years 2000 and 2013.

Percentiles	$\ln F_{rht}$	$\ln \bar{\zeta}_{rcht}$	$\ln \omega^I_{rht}$	$\ln b_{rcht}$	$\ln a_{rch}$
1	0.69	−6.18	0.03	3.42	0.72
5	0.69	−4.54	0.83	7.16	0.78
10	0.69	−3.78	1.27	8.12	0.86
25	2.41	−2.56	1.86	9.56	0.99
50	6.55	−1.25	2.51	11.73	1.25
75	14.37	0.01	3.31	15.52	1.65
90	22.79	1.23	3.91	21.95	2.14
95	29.16	2.05	4.36	27.71	2.31
99	36.58	3.77	5.29	47.98	2.49
Mean	9.53	−1.26	2.57	13.92	1.37
Std. Dev.	8.95	2.02	1.09	8.34	0.51

4.2. Exogenous fundamentals and the distribution of region-level exports

While the analysis above permits an exact decomposition of China's prefecture-level exports, it does not support any causal interpretations. The reason is that the decomposition, even though theoretically consistent, involves factors of which most are endogenous from a theoretical viewpoint. In this subsection, we utilize the above results on the bivariate Pareto distribution of the first type about $\tilde{\lambda}_{frcht}$ and $\tilde{\phi}_{frcht}$ to conduct some counterfactual analyses with regard to changes in fixed market-access costs ($\bar{\zeta}_{rcht}$), imported-input costs (ω^I_{rht}), and market potential (b_{rcht}). In Chaney-Melitz-type models the market-access-cost parameter $\bar{\zeta}_{rcht}$ would be treated as exogenous. Also trade costs behind market potential b_{rcht} would be treated as exogenous. But wage costs ω^L_{rht}, imported-input prices ω^I_{rht}, and income-related expenditure in b_{rcht} would be endogenous. However, we can only perform a conditional equilibrium analysis here, as the data needed to calibrate a model with endogenous foreign prices and incomes at the detail as for China's regions are beyond reach. Still, an associated conditional equilibrium analysis can inform us about the conditional responses of key outcome variables at the level of Chinese prefectures, and those are three: firm selection through responses in $(1-G^*_{rcht})$ (or the number of actual relative to potential suppliers), quality-augmented average productivity $\tilde{\psi}_{rcht}$, and prefecture-level wages in ω^L_{rht}.

4.2.1. Descriptive statistics for exogenous fundamentals at the region-country-product level

In Table 8, we provide details on the distribution of the key parameters treated as exogenous here $\{F_{rht}, \bar{\zeta}_{rcht}, \omega^I_{rht}, b_{rcht}\}$ in terms of deciles across prefectures in the years 2000 and 2013. Moreover, we report the same statistics for the Pareto shape parameter a_{rch}. We do the latter, as this parameter is vital for governing entry and exit responses in the number of active firms ($F_{rcht} \leq F_{rht}$) through the truncation variable $(1-G^*_{rcht})$ as well as adjustments in the endogenous average quality-adjusted productivity parameter $\tilde{\psi}_{rcht}$.[17] When inspecting the mean and standard deviations just below the percentile values, we see that the relative dispersion (the standard deviation normalized by the mean) is absolutely largest for the fixed-cost parameter $\bar{\zeta}_{rcht}$ in Table 8. The relative dispersion is smaller for potential entrants, market potential, imported input prices, and the Pareto shape parameter, mentioned in declining order. From this, we would argue that at least the impulse (shock) from changing the dispersion in some of these parameters is larger when doing so for fixed costs versus imported input prices versus market potential.[18]

Table 9 shows the descriptive statistics about the changes of the variables in Table 8 from 2000 to 2013. There, fixed costs dominate in terms of the absolute dispersion as well. Regarding the other parameters, the dispersion is higher for the changes in the number of potential entrants than for market potential and imported input costs, in declining order.

[17] The data suggest that for 95% of the region-product-country units the shape parameters a_{rch} is larger than 2, as required, even without any constraint imposed. Note that the admissible parameter range for the shape parameter excludes values that are smaller than unity. For 5% of the region-product-country units, the Pareto parameter is not larger than 2. We adjust the respective shape parameters to exceed 2 for all those observations by simply adding unity to the smallest value. This is done to make sure that the total exports are still complete (add up to the aggregate export volume) after this adjustment.

[18] However, note also that the product level (when considering prefecture, country, and time as additional dimensions of variation) dominates the other dimensions of variance in the data on potential entrants, the shape parameter, and market potential. Only for imported input prices the prefecture-level variance component dominates the other ones. We suppress a detailed account of an analysis of variance here for the sake of brevity.

Table 9
Descriptive statistics for the change of ln exogenous parameters at region-country-product-level from 2000 to 2013.

Percentiles	$\Delta \ln F_{rht}$	$\Delta \ln \bar{\zeta}_{rcht}$	$\Delta \ln \omega^I_{rht}$	$\Delta \ln b_{rcht}$
1	−23.539	−4.461	−0.726	−2.382
5	−13.456	−2.884	−0.093	−0.469
10	−7.803	−2.160	0.137	0.109
25	−1.577	−1.101	0.427	1.055
50	1.127	−0.001	0.847	2.421
75	5.081	1.136	1.196	4.500
90	12.558	2.281	1.624	8.076
95	17.809	3.071	1.747	10.926
99	28.194	4.792	2.281	19.710
Mean	1.756	0.036	0.837	3.393
Std. Dev.	8.951	1.831	0.600	3.941

Table 10
Growth rate of bilateral region-country-product exports (X_{rcht}) in data between 2000 and 2013 and due to changes in $\{\bar{\zeta}_{rcht}, \omega^I_{rht}, b_{rcht}\}$ over the same period in counterfactual conditional general equilibrium.

	(1) Benchmark	(2) $\bar{\zeta}_{rcht}$	(3) ω^I_{rht}	(4) b_{rcht}
5	−0.994	−0.998	−0.846	−1
10	−0.986	−0.984	−0.748	−1
25	−0.943	−0.892	−0.483	−1
50	−0.764	−0.600	−0.059	−0.995
75	−0.048	−0.015	0.374	−0.918
90	2.537	3.173	1.961	−0.608
95	7.313	25.710	8.177	0

4.3. Export responses to ceteris-paribus changes of exogenous export components in conditional general equilibrium

As indicated above, the exact decomposition of the change in exports from 2000 to 2013 into its components was possible only when considering components that were not strictly exogenous to the analysis. All endogenous variables are jointly determined by a set of deep parameters motivated in the context of a structural model. In the quantitative model we consider, deep parameters are labor endowments, the fundamental parameters of the bivariate Pareto distribution about firm quality and productivity, fixed market-entry costs and, for reasons of data availability which precludes considering them as endogenous, also the number of potential firm entrants per region and product, foreign market potential, and the unit costs of imported intermediate goods.[19]

Here, we focus on changes in three of those parameters – fixed market-entry costs, imported input costs, and foreign market potential – in assessing their role for region-level exports when considering the market entry of firms as well as their average productivity and quality of output and local wage costs to be endogenous. Based on these assumptions, we consider rolling back fixed market-access costs, market potential, and imported input costs in 2013 ceteris paribus to their level in 2000. This leads to endogenous adjustments in region-product-level wage costs, firm entry, average quality and productivity, and, ultimately exports, one at a time. Then, we compute the corresponding export level for each region, country, product, and year based on Eq. (8). Using the latter, we can compare the benchmark distribution of exports per region with the one under the three counterfactual distributions, one pertaining to each fundamental. We summarize the results from this analysis in two ways.

First, we present changes in the data and component-specific counterfactual changes attributed to the three considered exogenous components regarding wages and region-country-product-level exports in Table 10. In the first column of the table, we report on the distribution of observed export changes when going backwards from 2013 to 2000. Those changes are negative at the median, because the average region product and market saw smaller levels of exports in 2000 than in 2013. However, some cross-sectional units (primarily smaller region-product-country units) did export more in 2000 than in 2013. The table suggests that market potential accounted for a large share of the change, more so than fixed market-access costs and imported-input prices in declining order. It should be noted that also market potential was lower in 2000 than in 2013 on average (see Table 9), and it is not surprising that its reduction is associated with a decline in exports. Fixed market-access costs were higher in 2000 than in 2013 at the median (see Table 9), and their increase also contributes to a reduction in exports. Finally, though intermediate goods prices decreased at the median, exports would have been lower had intermediates assumed their price of 2000 rather than of 2013 in the latter year. Clearly, the individual contributions do not exactly add up to the overall change in exports due to the nonlinear model structure.

Second, we report Gini coefficients in Table 11 for exports to assess to which extent the data and the counterfactual changes feature an increase versus a decline in cross-regional inequality in the respective measures when moving backwards from 2013

[19] We do not observe all countries' fundamentals at the required detailed level to consider a multi-country endogenous determination of wage income per worker. For that reason, market potential needs to be treated as exogenous. Moreover, as is the case for the vast majority of countries, detailed product-level sales in the domestic market (neither altogether nor across regions) are available. Hence, we have to entirely abstract from domestic product-level sales in China and keep them implicitly constant to counterfactual changes.

Table 11
Gini changes of prefecture-level exports in 2000 and the counterfactual experiments of deep exogenous parameters relative to benchmark of 2013.

Panel A: Gini change in 2000 relative to benchmark of 2013			
Gini change	0.031		
Panel B: Gini change in the counterfactual situations of deep exogenous parameters relative to benchmark of 2013			
	$\bar{\zeta}_{rcht}$	ω^{I}_{rht}	b_{rcht}
Gini change	0.136	0.128	0.127

Table notes: The gini coefficient of exports in the benchmark of 2000 and 2013 is 0.860 and 0.829, respectively.

to 2000 in all or specific dimensions of the data. The results in Table 11 indicate that the distribution of exports across the cross-sectional units was more unequal in 2000 than in 2013. This is reflected in the change in the Gini coefficient being positive when moving backwards from 2013 to 2000. According to the table, the change in fixed market access costs followed by imported intermediate goods prices and market size were the biggest drivers behind the change in the inequality of export-market participation.

It should be noted that market potential (b_{rcht}) is the only factor which overlaps between the exact decomposition and the counterfactual analysis. (Even that is the case only, because we have to treat it as fixed in the latter for reasons of data availability.) It can be seen from a comparison of Tables 7 and 11 that the range of contributions to the dispersion of exports across regions is of a comparable magnitude for the endogenous and the exogenous components. Market potential is less important in Table 7, where it does not impact other factors, than in Table 11, where its change leads to endogenous responses of factor costs and selection.

5. Conclusions

This paper decomposes China's firm-transaction exports into four fundamental components: quality and market potential as two demand-side components, and productivity and factor costs as two supply-side components. This is done in order to shed light on China's export-market participation at the regional level of prefectures, many of which correspond to cities of which more than 300 can be distinguished. Such a regional perspective is interesting, as China's larger prefectures are significantly larger than the world's smaller countries.

More precisely, the paper's agenda is organized in four steps: decompose region-product-country-level export flows and export changes exactly into their components in a way that is consistent with theoretical micro-level gravity and quantitative trade models; shed light on their relative variation and contribution to the regional heterogeneity in export success across Chinese prefectures and cities; analyze the change in the components in terms of region-level characteristics; (iv) assess the role of exogenous factors behind the components for region-level exports in a counterfactual analysis using a conditional general-equilibrium framework. Of this analysis, three insights stand out.

The variation in the change of the number of potential entrants is a key factor for the growth or regional exports in China. The change in market access and quality-augmented productivity are also but somewhat less important. However, changes in imported input prices, market potential, and fixed costs promoted a greated equality of regional export success in China. Overall, the proposed analysis can help improving our understanding of the roots of China's export success. Moreover, it helps viewing one of the largest countries on the globe as a composite of regions, which differ quite strongly in terms of market potential, wage costs, and characteristics of the firm distributions (including the heterogeneity of productivity and quality draws as well as fixed market-access costs).

Data availability

Data can be made available to license holders.

China Customs Data (Reference data) (Mendeley Data)

.

Appendix A. Means for the multivariate Pareto distribution of export product quality and productivity

Let $A = a_{rch}(a_{rch}+1)(\tilde{\lambda}^{*}_{rcht}\tilde{\phi}^{*}_{rcht})^{a_{rch}+1}$, $B = \tilde{\phi}^{*}_{rcht}\tilde{\lambda}_{frcht} - \tilde{\lambda}^{*}_{rcht}\tilde{\phi}^{*}_{rcht}$, the joint density function of $\tilde{\lambda}_{frcht}$ and $\tilde{\phi}_{frcht}$ is

$$g(\tilde{\lambda}_{frcht}, \tilde{\phi}_{frcht}) = A(B + \tilde{\lambda}^{*}_{rcht}\tilde{\phi}_{frcht})^{-(a_{rch}+2)}. \tag{A.1}$$

The means of $\tilde{\lambda}_{frcht}\tilde{\phi}_{frcht}$, say, $\tilde{\psi}_{rcht}$ are given by

$$\begin{aligned}
\tilde{\psi}_{rcht} &= \int_{\tilde{\lambda}^*_{rcht}}^{\infty}\int_{\tilde{\phi}^*_{rcht}}^{\infty}\tilde{\lambda}\tilde{\phi}dG_{rcht} \\
&= \int_{\tilde{\lambda}^*_{rcht}}^{\infty}\int_{\tilde{\phi}^*_{rcht}}^{\infty}\tilde{\lambda}_{frcht}\tilde{\phi}_{frcht}g(\tilde{\lambda}_{frcht},\tilde{\phi}_{frcht})d\tilde{\phi}_{frcht}d\tilde{\lambda}_{frcht} \\
&= \int_{\tilde{\lambda}^*_{rcht}}^{\infty}\tilde{\lambda}_{frcht}\int_{\tilde{\phi}^*_{rcht}}^{\infty}A(B+\tilde{\lambda}^*_{rcht}\tilde{\phi}_{frcht})^{-(a_{rch}+2)}\tilde{\phi}_{frcht}d\tilde{\phi}_{frcht}d\tilde{\lambda}_{frcht} \\
&= \frac{A}{\tilde{\lambda}^*_{rcht}}\int_{\tilde{\lambda}^*_{rcht}}^{\infty}\tilde{\lambda}_{frcht}\int_{\tilde{\phi}^*_{rcht}}^{\infty}(B+\tilde{\lambda}^*_{rcht}\tilde{\phi}_{frcht})^{-(a_{rch}+2)}(B+\tilde{\lambda}^*_{rcht}\tilde{\phi}_{frcht}-B)d\tilde{\phi}_{frcht}d\tilde{\lambda}_{frcht} \\
&= \frac{A}{\tilde{\lambda}^*_{rcht}}\int_{\tilde{\lambda}^*_{rcht}}^{\infty}\tilde{\lambda}_{frcht}\int_{\tilde{\phi}^*_{rcht}}^{\infty}\left[(B+\tilde{\lambda}^*_{rcht}\tilde{\phi}_{frcht})^{-(a_{rch}+1)}-B(B+\tilde{\lambda}^*_{rcht}\tilde{\phi}_{frcht})^{-(a_{rch}+2)}\right]d\tilde{\phi}_{frcht}d\tilde{\lambda}_{frcht} \\
&= \frac{A}{\tilde{\lambda}^*_{rcht}}\int_{\tilde{\lambda}^*_{rcht}}^{\infty}\tilde{\lambda}_{frcht}\left[\frac{(B+\tilde{\lambda}^*_{rcht}\tilde{\phi}_{frcht})^{-a_{rch}}}{-a_{rch}\tilde{\lambda}^*_{rcht}}\Bigg|_{\tilde{\phi}^*_{rcht}}^{\infty}-\frac{B(B+\tilde{\lambda}^*_{rcht}\tilde{\phi}_{frcht})^{-(a_{rch}+1)}}{-(a_{rch}+1)\tilde{\lambda}^*_{rcht}}\Bigg|_{\tilde{\phi}^*_{rcht}}^{\infty}\right]d\tilde{\lambda}_{frcht} \\
&= \frac{A}{\tilde{\lambda}^*_{rcht}}\int_{\tilde{\lambda}^*_{rcht}}^{\infty}\tilde{\lambda}_{frcht}\left[\frac{(\tilde{\phi}^*_{rcht}\tilde{\lambda}_{frcht})^{-a_{rch}}}{a_{rch}\tilde{\lambda}^*_{rcht}}-\frac{B(\tilde{\phi}^*_{rcht}\tilde{\lambda}_{frcht})^{-(a_{rch}+1)}}{(a_{rch}+1)\tilde{\lambda}^*_{rcht}}\right]d\tilde{\lambda}_{frcht} \\
&= \frac{A}{\tilde{\lambda}^*_{rcht}}\int_{\tilde{\lambda}^*_{rcht}}^{\infty}\tilde{\lambda}_{frcht}\left[\frac{(\tilde{\phi}^*_{rcht}\tilde{\lambda}_{frcht})^{-a_{rch}}}{a_{rch}\tilde{\lambda}^*_{rcht}}-\frac{(\tilde{\phi}^*_{rcht}\tilde{\lambda}_{frcht}-\tilde{\lambda}^*_{rcht}\tilde{\phi}^*_{rcht})(\tilde{\phi}^*_{rcht}\tilde{\lambda}_{frcht})^{-(a_{rch}+1)}}{(a_{rch}+1)\tilde{\lambda}^*_{rcht}}\right]d\tilde{\lambda}_{frcht} \\
&= \frac{A\tilde{\phi}^{*-a_{rch}}_{rcht}}{\tilde{\lambda}^*_{rcht}}\int_{\tilde{\lambda}^*_{rcht}}^{\infty}\left[\frac{\tilde{\lambda}^{(1-a_{rch})}_{frcht}}{a_{rch}\tilde{\lambda}^*_{rcht}}-\frac{\tilde{\lambda}^{(1-a_{rch})}_{frcht}}{(a_{rch}+1)\tilde{\lambda}^*_{rcht}}+\frac{\tilde{\lambda}^{-a_{rch}}_{frcht}}{(a_{rch}+1)}\right]d\tilde{\lambda}_{frcht} \\
&= \frac{A\tilde{\phi}^{*-a_{rch}}_{rcht}}{\tilde{\lambda}^*_{rcht}}\left[\frac{\tilde{\lambda}^{(2-a_{rch})}_{frcht}}{a_{rch}(2-a_{rch})\tilde{\lambda}^*_{rcht}}\Bigg|_{\tilde{\lambda}^*_{rcht}}^{\infty}-\frac{\tilde{\lambda}^{(2-a_{rch})}_{frcht}}{(a_{rch}+1)(2-a_{rch})\tilde{\lambda}^*_{rcht}}\Bigg|_{\tilde{\lambda}^*_{rcht}}^{\infty}+\frac{\tilde{\lambda}^{(1-a_{rch})}_{frcht}}{(a_{rch}+1)(1-a_{rch})}\Bigg|_{\tilde{\lambda}^*_{rcht}}^{\infty}\right] \\
&= \frac{A\tilde{\phi}^{*-a_{rch}}_{rcht}}{\tilde{\lambda}^*_{rcht}}\left[-\frac{\tilde{\lambda}^{*(1-a_{rch})}_{rcht}}{a_{rch}(2-a_{rch})}+\frac{\tilde{\lambda}^{*(1-a_{rch})}_{rcht}}{(a_{rch}+1)(2-a_{rch})}-\frac{\tilde{\lambda}^{*(1-a_{rch})}_{rcht}}{(a_{rch}+1)(1-a_{rch})}\right] \\
&= A(\tilde{\lambda}^*_{rcht}\tilde{\phi}^*_{rcht})^{-a_{rch}}\left[\frac{1}{a_{rch}(a_{rch}-2)}-\frac{1}{(a_{rch}+1)(a_{rch}-2)}+\frac{1}{(a_{rch}+1)(a_{rch}-1)}\right] \\
&= \frac{a^2_{rch}-a_{rch}-1}{(a_{rch}-2)(a_{rch}-1)}\tilde{\lambda}^*_{rcht}\tilde{\phi}^*_{rcht}.
\end{aligned} \tag{A.2}$$

The means of export value per Chinese region, destination country, and product at time t are

$$\begin{aligned}
E[x_{frcht}(\tilde{\lambda},\tilde{\phi})] &= \int_{\tilde{\lambda}^*_{rcht}}^{\infty}\int_{\tilde{\phi}^*_{rcht}}^{\infty}x_{frcht}(\tilde{\lambda}_{frcht},\tilde{\phi}_{frcht})g(\tilde{\lambda}_{frcht},\tilde{\phi}_{frcht})d\tilde{\phi}_{frcht}d\tilde{\lambda}_{frcht} \\
&= \int_{\tilde{\lambda}^*_{rcht}}^{\infty}\int_{\tilde{\phi}^*_{rcht}}^{\infty}\tilde{\lambda}_{rcht}\tilde{\phi}_{frcht}\tilde{\omega}_{rht}b_{rcht}g(\tilde{\lambda}_{frcht},\tilde{\phi}_{frcht})d\tilde{\phi}_{frcht}d\tilde{\lambda}_{frcht} \\
&= \tilde{\omega}_{rht}b_{rcht}\int_{\tilde{\lambda}^*_{rcht}}^{\infty}\int_{\tilde{\phi}^*_{rcht}}^{\infty}\tilde{\lambda}_{rcht}\tilde{\phi}_{frcht}g(\tilde{\lambda}_{frcht},\tilde{\phi}_{frcht})d\tilde{\phi}_{frcht}d\tilde{\lambda}_{frcht} \\
&= \frac{a^2_{rch}-a_{rch}-1}{(a_{rch}-2)(a_{rch}-1)}\tilde{\lambda}^*_{rcht}\tilde{\phi}^*_{rcht}\tilde{\omega}_{rht}b_{rcht} \\
&= \tilde{\psi}_{rcht}\tilde{\omega}_{rht}b_{rcht}.
\end{aligned} \tag{A.3}$$

And the aggregate bilateral exports per Chinese region, destination country, and product at time t are

$$X_{rcht} = F_{rcht}E[x_{frcht}(\tilde{\lambda},\tilde{\phi})] = F_{rht}(1-G^*_{rcht})\tilde{\psi}_{rcht}\tilde{\omega}_{rht}b_{rcht}. \tag{A.4}$$

Appendix B. Decomposing region-product-country export changes

For decomposing the change in aggregate export revenues at the region-country-product level, let us use the following convention for export value in two periods t and $s < t$ and a generic cross-sectional region-country-product unit, $\{x_{rcht}, x_{rchs}\}$. First of all, suppose that x_{rcht} is multiplicatively composed of, e.g., five components, $\{A_{1,rht}, A_{2,rcht}, A_{3,rcht}, A_{4,rht}, A_{5,rcht}\}$, and the similarly for x_{rchs}. Specifically, $A_{1,rht} = F_{rht}$, $A_{2,rcht} = (1 - G^*_{rcht})$, $A_{3,rcht} = \tilde{\psi}_{rcht}$, $A_{4,rht} = \tilde{\omega}_{rht}$, and $A_{5,rcht} = b_{rcht}$. Eq. (8) can be transformed into

$$X_{rcht} = \prod_{d=1}^{5} A_{d,rcht}. \tag{B.1}$$

Using Δ to denote changes as period-t-minus-s values, we have for any variable $V \in \{X, A\}$, $\Delta V_{rcht} = V_{rcht} - V_{rchs}$. Then,

$$\begin{aligned}\Delta X_{rcht} &= \Delta(\prod_{d=1}^{5} A_{d,rcht}) \\ &= A_{1,rht}A_{2,rcht}A_{3,rcht}A_{4,rht}A_{5,rcht} - A_{1,rhs}A_{2,rchs}A_{3,rchs}A_{4,rhs}A_{5,rchs}.\end{aligned} \tag{B.2}$$

Let $B_{rcht} = A_{2,rcht}C_{rcht}$, where $C_{rcht} = A_{3,rcht}D_{rcht}$, and $D_{rcht} = A_{4,rht}A_{5,rcht}$. Note that

$$\Delta X_{rcht} = A_{1,rht}B_{rcht} - A_{1,rhs}B_{rchs} = \Delta A_{1,rht}B_{rcht} + A_{1,rhs}\Delta B_{rcht}, \tag{B.3}$$

$$\Delta B_{rcht} = A_{2,rcht}C_{rcht} - A_{2,rchs}C_{rchs} = \Delta A_{2,rcht}C_{rcht} + A_{2,rchs}\Delta C_{rcht}, \tag{B.4}$$

$$\Delta C_{rcht} = A_{3,rcht}D_{rcht} - A_{3,rchs}D_{rchs} = \Delta A_{3,rcht}D_{rcht} + A_{3,rchs}\Delta D_{rcht}, \tag{B.5}$$

$$\Delta D_{rcht} = A_{4,rht}A_{5,rcht} - A_{4,rhs}A_{5,rchs} = \Delta A_{4,rht}A_{5,rcht} + A_{4,rhs}\Delta A_{5,rcht}. \tag{B.6}$$

Hence,

$$\begin{aligned}\Delta X_{rcht} &= \Delta A_{1,rht}A_{2,rcht}A_{3,rcht}A_{4,rht}A_{5,rcht} \\ &+ \Delta A_{2,rcht}A_{1,rhs}A_{3,rcht}A_{4,rht}A_{5,rcht} \\ &+ \Delta A_{3,rcht}A_{1,rhs}A_{2,rchs}A_{4,rht}A_{5,rcht} \\ &+ \Delta A_{4,rht}A_{1,rhs}A_{2,rchs}A_{3,rchs}A_{5,rcht} \\ &+ \Delta A_{5,rcht}A_{1,rhs}A_{2,rchs}A_{3,rchs}A_{4,rhs}.\end{aligned} \tag{B.7}$$

Let us use $\chi_{A1,rcht} = A_{2,rcht}A_{3,rcht}A_{4,rht}A_{5,rcht}$, $\chi_{A2,rchts} = A_{1,rhs}A_{3,rcht}A_{4,rht}A_{5,rcht}$, $\chi_{A3,rchts} = A_{1,rhs}A_{2,rchs}A_{4,rht}A_{5,rcht}$, $\chi_{A4,rchts} = A_{1,rhs}A_{2,rchs}A_{3,rchs}A_{5,rcht}$, and $\chi_{A5,rchs} = A_{1,rhs}A_{2,rchs}A_{3,rchs}A_{4,rhs}$ and think of them as weights to the changes in the indexed variables. Then, we may write the latter equation as

$$\begin{aligned}\Delta X_{rcht} &= \Delta A_{1,rht}\chi_{A1,rcht} + \Delta A_{2,rcht}\chi_{A2,rchts} + \Delta A_{3,rcht}\chi_{A3,rchts} \\ &+ \Delta A_{4,rht}\chi_{A4,rchts} + \Delta A_{5,rcht}\chi_{A5,rchs}.\end{aligned} \tag{B.8}$$

Since $A_{1,rht} = F_{rht}$, $A_{2,rcht} = (1 - G^*_{rcht})$, $A_{3,rcht} = \tilde{\psi}_{rcht}$, $A_{4,rht} = \tilde{\omega}_{rht}$, and $A_{5,rcht} = b_{rcht}$, we can write the form of ΔX_{rcht} to be

$$\Delta X_{rcht} = \Delta F_{rht}\chi_{F,rcht} + \Delta(1 - G^*_{rcht})\chi_{(1-G^*),rchts} + \Delta\tilde{\psi}_{rcht}\chi_{\tilde{\psi},rchts} + \Delta\tilde{\omega}_{rht}\chi_{\tilde{\omega},rchts} + \Delta b_{rcht}\chi_{b,rchs}. \tag{B.9}$$

Appendix C. A constrained general equilibrium model to consider endogenous firm entry and endogenous wages across Chinese regions

As labor in region r is specific to product h at time t, we consider it as fixed at L_{rht}. We consider it to consist of three components: labor used in production for export markets ($L^{\text{production}}_{rht}$), labor used for export-market entry (L^{access}_{rht}), and labor used otherwise (L^{rest}_{rht}). Hence, we have

$$L_{rht} = L^{\text{production}}_{rht} + L^{\text{access}}_{rht} + L^{\text{rest}}_{rht}. \tag{C.1}$$

Two remarks are key here towards specifying and making use of these components. First, as is the case with most countries, how much firms, regions or even China altogether sell domestically of product h is unknown. Second, the detail at which we observe China's sales to foreign countries is not available for those. Hence, any analysis which considers a response of wage costs per rht to some shocks can at best be approximative and needs to abstract from changes abroad and even domestically in China. We will consider such shocks in what follows in this spirit.

(1) Determination of $L^{\text{production}}_{rht}$

Consider the mill price for output of firm f in $rcht$ to be $p_{frcht} = \frac{\mu_h \omega_{rht}}{\phi_{frcht}}$. The conditional factor demand for labor in production consistent with the assumed technology is:

$$L^{\text{production}}_{frcht} = \left(\frac{\gamma^L_{rh}}{\gamma^I_{rh}}\right)^{\gamma^I_{rh}} \left(\frac{\omega^L_{rht}}{\omega^I_{rht}}\right)^{-\gamma^I_{rh}} \frac{q_{frcht}}{\phi_{frcht}}. \tag{C.2}$$

For given ω^I_{rht}, which we assume to be the case, let $\kappa_{rht} = \left(\frac{\gamma^L_{rh}}{\gamma^I_{rh}}\right)^{\gamma^I_{rh}} (\omega^I_{rht})^{\gamma^I_{rh}}$, so that we have

$$L^{\text{production}}_{frcht} = \kappa_{rht}(\omega^L_{rht})^{-\gamma^I_{rh}} \frac{q_{frcht}}{\phi_{frcht}}, \tag{C.3}$$

where

$$\begin{aligned}\frac{q_{frcht}}{\phi_{frcht}} &= \frac{x_{frcht}}{p_{frcht}\phi_{frcht}}\\ &= \frac{\tilde{\lambda}_{frcht}\tilde{\Phi}_{frcht}\tilde{\omega}_{rht}b_{rcht}}{\mu_h\omega_{rht}}\\ &= \frac{\tilde{\lambda}_{frcht}\tilde{\Phi}_{frcht}\omega_{rht}^{-\sigma_h}b_{rcht}}{\mu_h}.\end{aligned} \tag{C.4}$$

Since $\omega_{rht} = \frac{\kappa_{rht}}{\gamma^L_{rh}}(\omega^L_{rht})^{\gamma^L_{rh}}$, together with Eq. (C.4), we can transform Eq. (C.3) into

$$\begin{aligned}L^{\text{production}}_{frcht} &= \kappa_{rht}(\omega^L_{rht})^{-\gamma^I_{rh}}\frac{\tilde{\lambda}_{frcht}\tilde{\Phi}_{frcht}\left[\frac{\kappa_{rht}}{\gamma^L_{rh}}(\omega^L_{rht})^{\gamma^L_{rh}}\right]^{-\sigma_h}b_{rcht}}{\mu_h}\\ &= \frac{\kappa^{1-\sigma_h}_{rht}(\gamma^L_{rh})^{\sigma_h}}{\mu_h}\tilde{\lambda}_{frcht}\tilde{\Phi}_{frcht}(\omega^L_{rht})^{\sigma_h\gamma^I_{rh}-\sigma_h-\gamma^I_{rh}}b_{rcht}.\end{aligned} \tag{C.5}$$

Then we can aggregate $L^{\text{production}}_{frcht}$ to the region-product level as

$$L^{\text{production}}_{rht} = \frac{\kappa^{1-\sigma_h}_{rht}(\gamma^L_{rh})^{\sigma_h}}{\mu_h}(\omega^L_{rht})^{\sigma_h\gamma^I_{rh}-\sigma_h-\gamma^I_{rh}}\sum_c b_{rcht}\int_{f\in\mathfrak{F}_{rcht}}\tilde{\lambda}_{frcht}\tilde{\Phi}_{frcht}df, \tag{C.6}$$

Since the means of $\tilde{\lambda}_{frcht}\tilde{\Phi}_{frcht}$ are given by

$$E[\tilde{\lambda}_{frcht}\tilde{\Phi}_{frcht}] = \frac{a^2_{rch}-a_{rch}-1}{(a_{rch}-2)(a_{rch}-1)}\tilde{\lambda}^*_{rcht}\tilde{\Phi}^*_{rcht}, \tag{C.7}$$

we obtain

$$\int_{f\in\mathfrak{F}_{rcht}}\tilde{\lambda}_{frcht}\tilde{\Phi}_{frcht}df = \frac{a^2_{rch}-a_{rch}-1}{(a_{rch}-2)(a_{rch}-1)}F_{rcht}\tilde{\lambda}^*_{rcht}\tilde{\Phi}^*_{rcht}. \tag{C.8}$$

Eq. (C.6) can be further transformed into

$$L^{\text{production}}_{rht} = \frac{\kappa^{1-\sigma_h}_{rht}(\gamma^L_{rh})^{\sigma_h}}{\mu_h}(\omega^L_{rht})^{\sigma_h\gamma_{rh}-\sigma_h-\gamma_{rh}}\sum_c\frac{a^2_{rch}-a_{rch}-1}{(a_{rch}-2)(a_{rch}-1)}F_{rcht}\tilde{\lambda}^*_{rcht}\tilde{\Phi}^*_{rcht}b_{rcht}. \tag{C.9}$$

Note that the implicit fixed market-access costs of firms in r to sell product h at t to country c are given by Eq. (20). Since $\zeta_{rcht} = \bar{\zeta}_{rcht}(\omega^L_{rht})^{\gamma^L_{rh}}$, given that $\tilde{\omega}_{rht} = \omega^{1-\sigma_h}_{rht} = (\frac{\kappa_{rht}}{\gamma^L_{rh}})^{1-\sigma_h}(\omega^L_{rht})^{\gamma^L_{rh}(1-\sigma_h)}$, we have

$$\begin{aligned}\tilde{\lambda}^*_{rcht}\tilde{\Phi}^*_{rcht} &= \frac{\zeta_{rcht}\sigma_h}{\tilde{\omega}_{rht}b_{rcht}}\\ &= \frac{\bar{\zeta}_{rcht}(\omega^L_{rht})^{\gamma^L_{rh}}\sigma_h}{(\frac{\kappa_{rht}}{\gamma^L_{rh}})^{1-\sigma_h}(\omega^L_{rht})^{\gamma^L_{rh}(1-\sigma_h)}b_{rcht}}\\ &= \frac{\bar{\zeta}_{rcht}\sigma_h}{(\frac{\kappa_{rht}}{\gamma^L_{rh}})^{1-\sigma_h}b_{rcht}}(\omega^L_{rht})^{\sigma_h\gamma^L_{rh}}.\end{aligned} \tag{C.10}$$

Note that F_{rcht} denotes the number of firms whose $\tilde{\lambda}_{frcht}\tilde{\Phi}_{frcht}$ is not smaller than $\tilde{\lambda}^*_{rcht}\tilde{\Phi}^*_{rcht}$, which we can obtain from the data, and $F_{rcht} = F_{rht}(1-G^*_{rcht})$, we have

$$\begin{aligned}L^{\text{production}}_{rht} &= \frac{\kappa^{1-\sigma_h}_{rht}(\gamma^L_{rh})^{\sigma_h}}{\mu_h}(\omega^L_{rht})^{\sigma_h\gamma^I_{rh}-\sigma_h-\gamma^I_{rh}}\\ &\quad\times\sum_c\frac{a^2_{rch}-a_{rch}-1}{(a_{rch}-2)(a_{rch}-1)}F_{rht}(1-G^*_{rcht})\frac{\bar{\zeta}_{rcht}\sigma_h}{(\frac{\kappa_{rht}}{\gamma^L_{rh}})^{1-\sigma_h}b_{rcht}}(\omega^L_{rht})^{\sigma_h\gamma^L_{rh}}b_{rcht}\\ &= (\omega^L_{rht})^{-\gamma^I_{rh}}\gamma^L_{rh}(\sigma_h-1)F_{rht}\sum_c\frac{a^2_{rch}-a_{rch}-1}{(a_{rch}-2)(a_{rch}-1)}\bar{\zeta}_{rcht}(1-G^*_{rcht}).\end{aligned} \tag{C.11}$$

Let $\Psi_{rht} = \gamma^L_{rh}(\sigma_h-1)F_{rht}\sum_c\frac{a^2_{rch}-a_{rch}-1}{(a_{rch}-2)(a_{rch}-1)}\bar{\zeta}_{rcht}(1-G^*_{rcht})$, Eq. (C.11) can be simplified to

$$L^{\text{production}}_{rht} = (\omega^L_{rht})^{-\gamma^I_{rh}}\Psi_{rht}. \tag{C.12}$$

(2) Determination of L^{access}_{rht}

The fixed labor use of region r in product h and market d at year t for each firm (Λ_{rcht}) is determined by the fixed market access cost ζ_{rcht}, i.e., $\gamma^L_{rh}\zeta_{rcht} = \omega^L_{rht}\Lambda_{rcht}$. Since $\bar{\zeta}_{rcht} = \frac{\zeta_{rcht}}{(\omega^L_{rht})^{\gamma^L_{rh}}}$, we have

$$\Lambda_{rcht} = \frac{\gamma^L_{rh}\zeta_{rcht}}{\omega^L_{rht}} = (\omega^L_{rht})^{-\gamma^I_{rh}}(\gamma^L_{rh})\bar{\zeta}_{rcht}. \tag{C.13}$$

Then the fixed labor use of region r in each product, market, and year is

$$L^{\text{access}}_{rcht} = F_{rcht}\Lambda_{rcht} = (\omega^L_{rht})^{-\gamma^I_{rh}}\gamma^L_{rh}F_{rht}(1-G^*_{rcht})\bar{\zeta}_{rcht}. \tag{C.14}$$

Let $\Gamma_{rcht} = \gamma^L_{rh}F_{rht}(1-G^*_{rcht})\bar{\zeta}_{rcht}$, Eq. (C.14) can be transformed into

$$L^{\text{access}}_{rcht} = (\omega^L_{rht})^{-\gamma^I_{rh}}\Gamma_{rcht}. \tag{C.15}$$

We can aggregate L^{access}_{rcht} to the region-product-level, which is

$$L^{\text{access}}_{rht} = \sum_c L^{\text{access}}_{rcht}. \tag{C.16}$$

(3) Determination of L^{rest}_{rht}

From Eq. (C.1), we have that

$$L^{\text{rest}}_{rht} = L_{rht} - L^{\text{production}}_{rht} - L^{\text{access}}_{rht}, \tag{C.17}$$

where $L_{rht} = \rho_{rht}L_{rt}$, $\rho_{rht} = \frac{L^{\text{production}}_{rht}+L^{\text{access}}_{rht}}{L^{\text{production}}_{rt}+L^{\text{access}}_{rt}}$.

We assume that L^{rest}_{rht} satisfies

$$L^{\text{rest}}_{rht} = (\omega^L_{rht})^{-\gamma^I_{rh}}\bar{L}^{\text{rest}}_{rht}. \tag{C.18}$$

(4) Approximating changes in ω^L_{rht}

We have to and will keep the region-product-specific labor supply, L_{rht}, as well as input costs ω^I_{rht}, ideal consumer price indices, and foreign market demand fixed to any shocks we consider. As a consequence, what will change in labor demand is exclusively related to exports. Due to this consideration, we obtain an explicit relationship between region-product wage costs, the cutoff levels for quality and productivity in each region-product-market tuple, and region-product labor supply.

Since $L^{\text{production}}_{rht} = (\omega^L_{rht})^{-\gamma^I_{rh}}\Psi_{rht}$, $L^{\text{access}}_{rcht} = (\omega^L_{rht})^{-\gamma^I_{rh}}\Gamma_{rcht}$, $L^{\text{rest}}_{rht} = (\omega^L_{rht})^{-\gamma^I_{rh}}\bar{L}^{\text{rest}}_{rht}$, bring them into Eq. (C.1) we can obtain

$$(\omega^L_{rht})^{-\gamma^I_{rh}}(\Psi_{rht} + \sum_c \Gamma_{rcht} + \bar{L}^{\text{rest}}_{rht}) = L_{rht}, \tag{C.19}$$

which can be further transformed into

$$\omega^L_{rht} = \left(\frac{\Psi_{rht} + \sum_c \Gamma_{rcht} + \bar{L}^{\text{rest}}_{rht}}{L_{rht}}\right)^{\frac{1}{\gamma^I_{rh}}}. \tag{C.20}$$

(5) Calculation of $1 - G^*_{rcht}$

Let $\vartheta_{rcht} = \frac{\bar{\zeta}_{rcht}\sigma_h}{(\frac{\kappa_{rht}}{\gamma^L_{rh}})^{1-\sigma_h}b_{rcht}}$, Eq. (C.10) can be written as

$$\tilde{\lambda}^*_{rcht}\tilde{\phi}^*_{rcht} = \vartheta_{rcht}(\omega^L_{rht})^{\sigma_h\gamma^L_{rh}}. \tag{C.21}$$

Since $\frac{\tilde{\lambda}^*_{rcht}}{\tilde{\phi}^*_{rcht}} = \xi_{rcht}$, which we can calculate from the firm-level data, then we have

$$\begin{aligned}\tilde{\lambda}^*_{rcht} &= \sqrt{\xi_{rcht}\vartheta_{rcht}}(\omega^L_{rht})^{\frac{\sigma_h\gamma^L_{rh}}{2}},\\ \tilde{\phi}^*_{rcht} &= \sqrt{\frac{\vartheta_{rcht}}{\xi_{rcht}}}(\omega^L_{rht})^{\frac{\sigma_h\gamma^L_{rh}}{2}}.\end{aligned} \tag{C.22}$$

Plugging Eq. (C.22) into Eq. (6), we can obtain

$$
\begin{aligned}
1-G^*_{rcht} &= \left(\frac{\tilde{\lambda}^*_{rcht}}{\tilde{\lambda}^0_{rcht}}\right)^{-a_{rch}} + \left(\frac{\tilde{\phi}^*_{rcht}}{\tilde{\phi}^0_{rcht}}\right)^{-a_{rch}} - \left(\frac{\tilde{\lambda}^*_{rcht}}{\tilde{\lambda}^0_{rcht}} + \frac{\tilde{\phi}^*_{rcht}}{\tilde{\phi}^0_{rcht}} - 1\right)^{-a_{rch}} \\
&= \left(\frac{\sqrt{\xi_{rcht}\vartheta_{rcht}}}{\tilde{\lambda}^0_{rcht}}\right)^{-a_{rch}} (\omega^L_{rht})^{\frac{-a_{rch}\sigma_h\gamma^L_{rh}}{2}} + \left(\frac{\sqrt{\frac{\vartheta_{rcht}}{\xi_{rcht}}}}{\tilde{\phi}^0_{rcht}}\right)^{-a_{rch}} (\omega^L_{rht})^{\frac{-a_{rch}\sigma_h\gamma^L_{rh}}{2}} \\
&\quad - \left[\left(\frac{\sqrt{\xi_{rcht}\vartheta_{rcht}}}{\tilde{\lambda}^0_{rcht}} + \frac{\sqrt{\frac{\vartheta_{rcht}}{\xi_{rcht}}}}{\tilde{\phi}^0_{rcht}}\right)(\omega^L_{rht})^{\frac{\sigma_h\gamma^L_{rh}}{2}} - 1\right]^{-a_{rch}} \\
&= \left[\left(\frac{\sqrt{\xi_{rcht}\vartheta_{rcht}}}{\tilde{\lambda}^0_{rcht}}\right)^{-a_{rch}} + \left(\frac{\sqrt{\frac{\vartheta_{rcht}}{\xi_{rcht}}}}{\tilde{\phi}^0_{rcht}}\right)^{-a_{rch}}\right](\omega^L_{rht})^{\frac{-a_{rch}\sigma_h\gamma^L_{rh}}{2}} \\
&\quad - \left[\left(\frac{\sqrt{\xi_{rcht}\vartheta_{rcht}}}{\tilde{\lambda}^0_{rcht}} + \frac{\sqrt{\frac{\vartheta_{rcht}}{\xi_{rcht}}}}{\tilde{\phi}^0_{rcht}}\right)(\omega^L_{rht})^{\frac{\sigma_h\gamma^L_{rh}}{2}} - 1\right]^{-a_{rch}}.
\end{aligned}
\tag{C.23}
$$

Let $\varsigma_{rcht} = \left(\frac{\sqrt{\xi_{rcht}\vartheta_{rcht}}}{\tilde{\lambda}^0_{rcht}}\right)^{-a_{rch}} + \left(\frac{\sqrt{\frac{\vartheta_{rcht}}{\xi_{rcht}}}}{\tilde{\phi}^0_{rcht}}\right)^{-a_{rch}}$, $\eta_{rcht} = \left(\frac{\sqrt{\xi_{rcht}\vartheta_{rcht}}}{\tilde{\lambda}^0_{rcht}} + \frac{\sqrt{\frac{\vartheta_{rcht}}{\xi_{rcht}}}}{\tilde{\phi}^0_{rcht}}\right)$, Eq. (C.23) can be written as

$$
1-G^*_{rcht} = \varsigma_{rcht}(\omega^L_{rht})^{\frac{-a_{rch}\sigma_h\gamma^L_{rh}}{2}} - (\eta_{rcht}(\omega^L_{rht})^{\frac{\sigma_h\gamma^L_{rh}}{2}} - 1)^{-a_{rch}}. \tag{C.24}
$$

Appendix D. Supplementary data

Supplementary material related to this article can be found online at https://doi.org/10.1016/j.euroecorev.2024.104718.

References

Anderson, J.E., Van Wincoop, E., 2003. Gravity with gravitas: a solution to the border puzzle. Am. Econ. Rev. 93 (1), 170–192.
Anderson, J.E., Van Wincoop, E., 2004. Trade costs. J. Econ. Lit. 42 (3), 691–751.
Arkolakis, C., 2010. Market penetration costs and the new consumers margin in international trade. J. Polit. Econ. 118 (6), 1151–1199.
Arkolakis, C., Costinot, A., Rodríguez-Clare, A., 2012. New trade models, same old gains?. Am. Econ. Rev. 102 (1), 94–130.
Auer, R.A., Degen, K., Fischer, A.M., 2013. Low-wage import competition, inflationary pressure, and industry dynamics in Europe. Eur. Econ. Rev. 59, 141–166.
Autor, D.H., Dorn, D., Hanson, G.H., 2013. The China syndrome: Local labor market effects of import competition in the United States. Am. Econ. Rev. 103 (6), 2121–2168.
Autor, D.H., Dorn, D., Hanson, G.H., 2016. The China shock: Learning from labor-market adjustment to large changes in trade. Annu. Rev. Econ. 8, 205–240.
Baum-Snow, N., Brandt, L., Henderson, J.V., Turner, M.A., Zhang, Q., 2017. Roads, railroads, and decentralization of Chinese cities. Rev. Econ. Stat. 99 (3), 435–448.
Bergstrand, J.H., Egger, P., Larch, M., 2016. Economic determinants of the timing of preferential trade agreement formations and enlargements. Econ. Inquiry 54 (1), 315–341.
Bernard, A.B., Redding, S.J., Schott, P.K., 2011. Multiproduct firms and trade liberalization. Q. J. Econ. 126 (3), 1271–1318.
Bloom, N., Draca, M., Van Reenen, J., 2016. Trade induced technical change? The impact of Chinese imports on innovation, IT and productivity. Rev. Econom. Stud. 83 (1), 87–117.
Breinlich, H., Novy, D., Santos Silva, J.M.C., 2022. Trade, gravity and aggregation. Rev. Econ. Stat. 1–29.
Broda, C., Weinstein, D.E., 2006. Globalization and the gains from variety. Q. J. Econ. 121 (2), 541–585.
Cai, S., Caliendo, L., Parro, F., Xiang, W., 2023. Mechanics of Spatial Growth. Working Paper.
Cai, H., Treisman, D., 2006. Did government decentralization cause China's economic miracle? World Politics 58 (4), 505–535.
Ceglowski, J., Golub, S., 2007. Just how low are China's labour costs? World Econ. 30 (4), 597–617.
Chaney, T., 2008. Distorted gravity: heterogeneous firms, market structure, and the geography of international trade. Amer. Econ. Rev. 98 (4), 1707–1721.
Corcos, G., Del Gatto, M., Mion, G., Ottaviano, G.I.P., 2012. Productivity and firm selection: quantifying the 'new' gains from trade. Econom. J. 122 (561), 754–798.
Costa, F., Garred, J., Pessoa, J.P., 2016. Winners and losers from a commodities-for-manufactures trade boom. J. Int. Econ. 102, 50–69.
Coughlin, C.C., Novy, D., 2021. Estimating border effects: The impact of spatial aggregation. Internat. Econom. Rev. 62 (4), 1453–1487.
Dauth, W., Findeisen, S., Suedekum, J., 2014. The rise of the east and the far east: German labor markets and trade integration. J. Eur. Econom. Assoc. 12 (6), 1643–1675.
Ding, C., Niu, Y., 2019. Market size, competition, and firm productivity for manufacturing in China. Reg. Sci. Urban Econ. 74, 81–98.
Eaton, J., Kortum, S., 2002. Technology, geography, and trade. Econometrica 70 (5), 1741–1779.
Eaton, J., Kortum, S., Kramarz, F., 2011. An anatomy of international trade: evidence from french firms. Econometrica 79 (5), 1453–1498.
Eaton, J., Kortum, S., Sotelo, S., 2013. International trade: linking micro and macro. In: Advances in Economics and Econometrics: Tenth World Congress. In: Applied Economics, vol. II, pp. 329–370.

Egger, P.H., Loumeau, G., Loumeau, N., 2023. China's dazzling transport-infrastructure growth: Measurement and effects. J. Int. Econ. 142, 103734.
Egger, P., Rao, S.X., Papini, S., 2021. A new algorithm for matching Chinese NBS firm-level with customs data. China Econ. J. 14 (3), 311–335.
Egger, P.H., Zhu, J., 2020. The US–Chinese trade war: an event study of stock-market responses. Econ. Policy 35 (103), 519–559.
Fan, H., Li, Y.A., Yeaple, S.R., 2015. Trade liberalization, quality, and export prices. Rev. Econ. Stat. 97 (5), 1033–1051.
Fan, H., Li, Y.A., Yeaple, S.R., 2018. On the relationship between quality and productivity: Evidence from China's accession to the WTO. J. Int. Econ. 110, 28–49.
Fan, H., Li, Y.A., Yeaple, S.R., 2019. Trade liberalization and firms' export performance in China: Theory and evidence. J. Comp. Econ. 47 (3), 640–668.
French, S., 2017. Comparative Advantage and Biased Gravity. UNSW Business School Research Paper, (2017-03).
Gao, Y., Whalley, J., Ren, Y., 2014. Decomposing China's export growth into extensive margin, export quality and quantity effects. China Econ. Rev. 29 (1), 19–26.
Handley, K., Limão, N., 2017. Policy uncertainty, trade, and welfare: Theory and evidence for China and the United States. Amer. Econ. Rev. 107 (9), 2731–2783.
Helpman, E., Melitz, M., Rubinstein, Y., 2008. Estimating trade flows: trading partners and trading volumes. Q. J. Econ. 123 (2), 441–487.
Hillberry, R.H., 2002. Aggregation bias, compositional change, and the border effect. Can. J. Econ./Rev. Can. Econ. 35 (3), 517–530.
Iacovone, L., Rauch, F., Winters, L.A., 2013. Trade as an engine of creative destruction: Mexican experience with Chinese competition. J. Int. Econ. 89 (2), 379–392.
Jara-Díaz, S.R., Donoso, P.P., 1989. On the bias caused by spatial aggregation of flows on the estimation of the degree of scale economies. Transp. Sci. 23 (3), 151–158.
Jarreau, J., Poncet, S., 2012. Export sophistication and economic growth: Evidence from China. J. Dev. Econ. 97 (2), 281–292.
Kent, A., 2002. China's international socialization: The role of international organizations. Glob. Gov. 8 (343).
Khandelwal, A.K., Schott, P.K., Wei, S.J., 2013. Trade liberalization and embedded institutional reform: Evidence from Chinese exporters. Amer. Econ. Rev. 103 (6), 2169–2195.
Koster, H.R., Cheng, F.F., Gerritse, M., van Oort, F.G., 2019. Place-based policies, firm productivity, and displacement effects: Evidence from Shenzhen, China. J. Reg. Sci. 59 (2), 187–213.
Lin, J., 2010. The China miracle demystified. In: Econometric Society World Congress.
Mardia, K.V., 1962. Multivariate pareto distributions. Ann. Math. Stat. 1008–1015.
Melitz, M.J., 2003. The impact of trade on intra-industry reallocations and aggregate industry productivity. Econometrica 71 (6), 1695–1725.
Redding, S.J., Weinstein, D.E., 2019. Aggregation and the gravity equation. AEA Pap. Proc. 109, 450–455.
Shi, B., 2011. Extensive margin, quantity and price in China's export growth. China Econ. Rev. 22 (2), 233–243.
Song, Z., Storesletten, K., Zilibotti, F., 2011. Growing like china. Amer. Econ. Rev. 101 (1), 196–233.
Wang, Z., Wei, S.J., Hale, G., 2010. What Accounts for the Rising Sophistication of China's Exports? University of Chicago Press.
Xing, Y., 2021. Decoding China's export miracle: A global value chain analysis.
Yang, Q.G., Temple, P., 2012. Reform and competitive selection in China: An analysis of firm exits. Struct. Change Econ. Dyn. 23 (3), 286–299.
Yotov, Y.V., Piermartini, R., Larch, M., 2016. An Advanced Guide to Trade Policy Analysis: The Structural Gravity Model. WTO iLibrary.