Accounting for Chinese Exports*

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Abstract

While much attention has been devoted to the consequences of Chinese export growth, we instead focus in this paper on uncovering the *causes* of Chinese trade. To do so, we study detailed data on Chinese exporting from 2000 to 2013, and first show that there have been important changes in the structure of Chinese trade, most notably a rapid increase in exporting and entry by private Chinese firms from 2000 to 2008, and a slowdown in exporting and entry by both foreign and private Chinese firms after 2008. To explain these patterns, we construct a structural model of Chinese trade with heterogeneous firms, endogenous entry, multiple internal production locations, and input-output linkages between sectors. We use the model to develop a structural decomposition of Chinese exports into various factors: export demand, foreign competition, entry costs, marketing costs, employment, investment shocks, imported input prices, product quality, and factor productivities. We then simulate counterfactuals within the model to quantify the contribution of each factor to changes in aggregate Chinese exports. Our findings suggest that high rates of firm entry, growth in foreign import demand, labor productivity growth, and rapid increases in productivity of private Chinese firm capital were the key drivers of Chinese export growth from 2000 to 2007. From 2008 onward, stagnation in these key drivers of export growth were also central to the relative slowdown in Chinese exporting from 2008 to 2013.

1 Introduction

China's participation in the world market for goods and services has been one of the most important developments for the global economy in recent decades. Between 2000 and 2016, the annual value of Chinese exports grew by a staggering 742%, compared with overall world export growth of 107% and OECD export growth of 86% over the same time period. In the process, the share of world exports accounted for by exports from China grew from 3.5% to 14.3%. At the same time, there have been important changes in the dynamics of Chinese trade. The most notable of these has been the slowdown in exports: China witnessed an average annual export growth rate of 24.7% between 2000 to 2008 compared with a much more meager average annual growth rate of 5.2% from 2009 to 2016.[1]

The rapid growth in Chinese trade volumes has unsurprisingly been accompanied by an explosion of research on the topic. However, much of this work has focused on the *consequences* of China's participation in world markets. In this paper, we instead focus on uncovering the *causes* of Chinese trade: what explains

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[1] Average annual export growth in the latter period was 5.8% if one excludes 2009 (during which there was a sharp decline in exports due to the Great Recession) and 2010 (in which export growth was high due to recovery from the Great Recession).

the dynamics of Chinese exporting? To provide answers, we study detailed transactions-level trade data and firm-level production data for Chinese firms from 2000 to 2013. We first document how patterns of Chinese exporting have changed over the sample period, focusing on four key margins: (i) the destination market for exports; (ii) the ownership of exporting firms; (iii) the location of export production in China; and (iv) the sector of goods being exported. We show that there have been important changes in the structure of Chinese trade, most notably a rapid increase in exporting and entry by private Chinese firms and a slowdown in exporting by foreign firms operating within China.

To explain these patterns, we investigate multiple potential drivers of the dynamics in Chinese trade patterns. Specifically, we examine how changes in the following factors have affected Chinese export growth: (i) foreign demand for Chinese exports; (ii) foreign competition in Chinese export markets; (iii) entry barriers into export markets for firms operating in China; (iv) firm entry barriers within China; (v) labor supplies in each Chinese province; (vi) capital accumulation by firms in China; (vii) access to imported intermediates in China; (viii) quality upgrading by firms in China; and (ix) factor productivities for firms in China.

To quantify the contribution of each of these factors to changes in Chinese export patterns, we construct a structural model of Chinese trade with heterogeneous firms, endogenous entry, multiple internal production locations, and input-output linkages between multiple sectors. In the model, firms of distinct ownership types produce in different provinces and export a range of products to various international markets. The structure of the model allows us to map each of the above-mentioned drivers of Chinese trade to a corresponding structural parameter that can be either estimated or calibrated using our data. We then simulate counterfactuals within the model to predict what patterns of Chinese exporting would have looked like in the absence of changes to each factor.

This paper is most closely related to recent work by Liu and Ma (2018), who also study the factors driving Chinese exports in the context of a quantitative structural trade model. There are several important differences between their approach and ours. First, they study drivers of long differences in Chinese exports between 1990 and 2005, using trade transactions data for only one year of Chinese exports (2005). In contrast, we focus on the evolution of Chinese exporting and its driving factors over a 14-year period, from 2000 to 2013, using trade transactions data for each year. We document that there are important differences in the dynamic patterns of Chinese exports over this time frame. Second, Liu and Ma (2018) focus on changes in tariffs and barriers to internal migration within China. As such, they develop a model in which an exogenous measure of firms sort across production locations. In contrast, we focus on endogenous entry by firms into China, and show that there are important changes in entry costs over the sample period. Finally, we emphasize the margin of firm ownership, and show that there are important differences in productivity dynamics between foreign and domestic firms operating in China.

This paper also builds on a growing body of research studying productivity and firm dynamics in China. Brandt et al. (2012) estimate firm-level productivity for China's manufacturing sector for the years 1998-2006, and find high rates of productivity growth on average, with firm entry playing a key role in aggregate productivity dynamics. Brandt et al. (2017) study the effects of China's accession to the WTO, and find that tariff reductions raised both firm- and sector-level productivity. Khandelwal et al. (2013) find similar productivity-enhancing effects from the removal of quotas for Chinese textile and clothing exports.

This paper is also complementary to the rapidly-growing literature on the impact of Chinese trade. Autor et al. (2013, 2016), Feenstra and Sasahara (2018), and Pierce and Schott (2016) document the effects of Chinese import competition on labor markets in the US, finding negative effects on employment and wages. Hsieh and Ossa (2016) and di Giovanni et al. (2014) estimate the effects of Chinese productivity growth on the rest of the world through trade, finding generally small effects on real income but positive effects from productivity growth in certain Chinese sectors. Several papers have also studied the effects of Chinese trade on innovation in other countries. For example, Autor et al. (2017) document a negative impact of Chinese import competition on innovation by US firms, while Bloom et al. (2016) find positive impacts on innovation by European firms. Hombert and Matray (2018) provide evidence that R&D intensive US firms are more resilient to the negative effects of competition from Chinese imports.

The outline of the paper is as follows. Section 2 describes the main data sources that we use to study the patterns of Chinese trade and documents some key patterns in Chinese exports over the last two decades. Section 3 then develops a structural model of Chinese trade that we use to study the drivers of Chinese exports, both in the cross-section and over time. Section 4 then describes the estimation procedure that we use to connect the model with data and also presents our main estimates of the structural drivers of Chinese exporting. Section 5 describes the counterfactual exercises that we use to quantify the drivers of Chinese trade. Finally, Section 6 concludes.

2 Data and Empirical Patterns

2.1 Data sources

2.1.1 Chinese customs data

The main source of trade data that we study is a transactions-level dataset of Chinese exports and imports collected by the Customs Administration of China. These data are available for the years 2000-2013, and provide measures of exporting and importing by destination and source country respectively, firm ownership (state-owned enterprise, private domestic, or foreign), sector (at the HS-8 classification), and location of production (province) of the exported goods. We focus on trade in manufacturing (HS-2 codes 28-97), which accounts for more than 90% of the value of Chinese exports in each year.

2.1.2 Annual Survey of Manufacturing and Industrial Census

In addition to the customs data, we utilize information from the Chinese Annual Survey of Manufacturing (ASM) and the industrial census. The ASM collects data for all state-owned enterprises and all non-state firms with sales above a certain threshold.[2] The ASM is available for the period 1998-2013 and for CIC-2 codes 13-42 (manufacturing; excluding agriculture, mining, and utilities). The industrial census collects information on all industrial firms in China irrespective of size, and is available for three years (1995, 2004, and 2008) and CIC-2 codes 13-46 (manufacturing and utilities; excluding agriculture and mining). We employ information from these datasets for several purposes.

First, to measure the propensity for Chinese firms to export, we require information not only on the total number of exporting firms, but counts of non-exporters as well. The ASM and census data allow us to estimate for each available year the total number of firms in operation by ownership (SOE, private domestic, or foreign), province, and main industry (at the CIC4 classification). Second, to decompose production costs, we also obtain information on capital stocks, wages, value-added, and gross output from the ASM and Census data.

[2] For years before and including 2010, the size threshold is 5 million RMB (approximately 600,000 USD) in sales. For 2011 and after, the size threshold increases to 20 million RMB (approximately 2.4 million USD). To maintain consistency across years, we exclude firms with sales below 20 million RMB from the datasets for before and including 2010.

2.1.3 Input-output data

In studying the drivers of Chinese exports, we will take sector-level input-output linkages into account. To do so, we use data on inter-sectoral sales and expenditures for the Chinese economy from the World Input-Output Database (WIOD), which provides input-output data by industry (at the ISIC-2 classification) for multiple countries (including China), for the years 2000-2014. We also obtain from the WIOD estimates of domestic final consumption by sector in China.

2.1.4 Aggregate trade data

To measure world demand for goods from each sector, we use data on aggregate imports by HS-2 sector from each country in the world, obtained from the UN COMTRADE database.

2.1.5 Concordances

As the various datasets that we study in this paper categorize product sectors using different classifications, we utilize several concordances between these classifications. First, to match the customs data with the manufacturing census data (for firm counts and wages), we construct a correspondence between CIC-4 and HS-2. There are 434 unique CIC-4 industry codes. Of these, 59.7% map into a unique HS-2 code, 24.2% map into two HS-2 codes, and the remainder of 16.1% map into more than two HS-2 codes. For the cases with one-to-many mapping, we use export shares at the HS-2 level as weights. Second, to match the customs data with the input-output data from WIOD, we construct a correspondence between ISIC-2 (Rev. 4) and HS-2.[3]

2.2 Patterns of Chinese exports

We first study how Chinese exports vary along four margins: the destination market for exports (d), the ownership of the exporting firm (n), the production location of the exported goods (h), and the sector of goods exported (s). In what follows, we study export data for 2000-2013 and use the following categorizations. Destination markets d are 11 geographic regions.[4] Firm ownership categories n are $\{\text{Foreign}, \text{Private Domestic}, \text{SOE}\}$. Production locations h are the 31 Chinese provinces. Sectors s are HS-2 manufacturing categories (HS-2 codes 28-97), of which there are 69 in total.

2.2.1 Export volumes

Figure 1 shows the composition of Chinese export volumes from 2000 to 2013 by destination market, firm ownership, production location, and sector. The rapid growth in Chinese exports is readily apparent.

By destination, the ranking of markets in terms of total demand for Chinese exports remains fairly stable over the sample period, with North America, Western Europe, East Asia, and South East Asia accounting for the majority of Chinese exports.[5] Export growth to East Asia and South East Asia was slightly higher compared with North America and Western Europe, but each of these regions witnessed rapid increases in

[3]The WIOD data uses the ISIC-2 (Rev. 4) classification. We map this to HS-2 using the concordance ISIC Rev. 4 and ISIC Rev. 3 from Eurostat, and between ISIC Rev.3 and HS from WITS.

[4]We use the following groupings of countries: North America; East Asia; Hong Kong and Macau; South East Asia; Western Europe; Middle East; Eastern Europe, Russia, and Central Asia; Central and South America; South Asia; Africa; and the Rest of the World.

[5]A significant fraction of Chinese exports are recorded as being exported to Hong Kong and Macau. A large share of these exports are most likely re-exported to other countries, but we are unable to observe the final destination of these exports in the Chinese customs data.

Chinese exports between 2000 and 2013 of between 15-25% per annum on average. Exports to countries outside of the four main export regions also grew in importance over the sample period, accounting for 13.6% of total exports in 2000 and 25.8% of total exports in 2013.

By firm ownership, the most noticeable development over the sample period was the simultaneous slowdown in export volumes accounted for by foreign firms operating in China and the rapid growth in exports by privately-owned Chinese firms. Over the first half of the sample period (2000-2006), average annual export growth by foreign-owned firms was 29.8%, whereas in the second half of the sample (2007-2013) this figure fell sharply to 7.5%. On the other hand, private Chinese firms accounted for less than 1% of total exports in 2000 but accounted for a sizable 40.3% of total exports by 2013. Much of this growth was at the expense of China's state-owned enterprises, for whom export growth averaged a more modest 7.2 per annum.

By production location, the majority of Chinese exports were unsurprisingly produced in coastal provinces and cities (the top five locations are Guangdong, Jiangsu, Shanghai, Zhejiang, and Shangdong). The main coastal export provinces all witnessed high rates of export growth, and the ranking of provinces in terms of total export volumes remained fairly stable over time. However, an interesting development over the sample period was the shift inland of Chinese export production: coastal provinces accounted for 92.8% of total export production in 2000 but only 85.5% in 2013.

By sector, the main sources of Chinese exports over the sample period were machinery and electrical products, textiles, metals, and transportation goods. Among the main export sectors, textiles witnessed the slowest export growth, with an average annual growth rate of 15.5% between 2000 and 2013. Overall, however, the ranking of sectors by export volume remained fairly stable over time and the sectoral composition of Chinese exports does not appear to have changed significantly.

2.2.2 Exporter Counts

Figure 2 shows the counts of Chinese exporters from 2000 to 2013 by destination market, firm ownership, production location, and sector. In the structural model developed below, an "exporter" is an establishment that produces a single product in a single location. Hence, the exporter counts in Figure 2 are based on this definition of exporters as well.[6] The dynamics of this extensive margin of Chinese exporting broadly reflects the dynamics of Chinese export volumes, although there are important differences.

By destination, there was significant entry into all of the main Chinese export markets. In the second half of the sample period (2008-2013), however, even though total export volumes continued to grow, exporter entry into the main Chinese export markets slowed noticeably.

By ownership, the slowdown in exporting by foreign firms and the rapid increase in exporting by private Chinese firms are also reflected in exporter counts. From 2008 onwards, the number of foreign exporters was fairly stagnant. In contrast, by 2008, three out of four exporters from China were privately-owned Chinese firms. Even for these private Chinese firms, however, rates of exporter entry were also fairly stagnant in the last few years of the sample period.

By production location, there were high rates of exporter entry from all the main coastal provinces over the first half of the sample period, while inland provinces also witnessed an increase in exporter counts. In 2000, 89.9% of exporters were operating in coastal provinces, whereas this figure dropped to 82.9% in 2013.

By sector, all the main Chinese export sectors witnessed high rates of exporter entry in the first half of the sample period (2000-2007), with significantly lower rates of growth in the second half of the sample period (2008-2013).

[6] For example, if the same firm produces shoes in Shanghai and books in Beijing, we count this as two exporters.

2.2.3 Exports per Exporter

Figure 3 shows the average value of exports per exporter by destination market, firm ownership, production location, and sector. As in the preceding section, an exporter is defined as an establishment that produces a single product in a single province.

By destination, exporters that exported to larger markets also tended to have higher average export values, while the average value of exports was fairly constant throughout the sample period for all the main Chinese export markets.

By ownership, the average foreign-owned exporter was noticeably larger than the average Chinese exporter, while SOE exporters were significantly larger than privately-owned Chinese exporters. The average values of exports for foreign, private Chinese, and SOE exporters all increased throughout the sample period, with the largest rate of growth observed for private Chinese exporters. However, these growth rates were small compared to the overall growth in Chinese export volumes. Together with the patterns documented in the preceding sections, this suggests that the rapid growth in exporting by private Chinese firms occurred mainly along the extensive margin (exporter entry) rather than the intensive margin.

By production location, exporters from the largest export provinces also tended to have higher average export values. Growth in the intensive margin of exporting was minimal across most of the main coastal exporting provinces.

By sector, exporters in the machinery and electrical and transportation sectors were noticeably larger than exporters from the other main Chinese export sectors. As above, intensive margin export growth across most sectors was small compared to overall export growth.

2.2.4 Export Propensity

Figure 4 shows the export propensities (i.e. fraction of firms that export) among firms operating in China by destination market, firm ownership, production location, and sector. Since the Chinese customs data is informative only about exporting firms, we compute these export propensities from the ASM data for each year. Although the ASM data covers all SOEs, it includes only above-scale non-state firms. Hence, to the extent that export propensities are higher among larger firms, this likely overstates the true propensity of exporting among all firms in China. Nonetheless, we view the dynamics of export propensities among all firms except the smallest as interesting and worth investigation in its own right.

By destination, these export propensities are generally higher for larger Chinese export markets and are fairly similar among the largest markets. Even for the top Chinese export destinations, however, only a small fraction (between 10% and 20%) of firms in China are active exporters to each market in any given year. This is consistent with empirical findings from other sources of international trade data that exporting is a relatively rare activity at the firm-level.

By ownership, however, there are stark differences in export propensities for foreign versus Chinese firms. In any given year, around 60% of foreign firms in China were active exporters, whereas the export propensity among private Chinese firms remains fairly constant at around 20% over the sample period. The latter fact indicates that the rapid growth in entry into exporting by private Chinese firms occurred in parallel with rapid growth in the overall number of such firms. As might be expected, SOEs are characterized by higher export propensities than for private Chinese firms (around 50%), although the rate of exporting for these firms is still smaller than that for foreign firms.

By location and sector, there is substantial heterogeneity in export propensities both across locations and sectors as well as over time. The fact that export propensities at the location- and sector-levels generally decline with time is mainly due to a compositional effect: the share of firms accounted for by private Chinese firms increases over the sample period, and private Chinese firms tend to have much lower export propensities than foreign firms and SOEs.

3 Model

To investigate the underlying drivers of the patterns in Chinese export dynamics documented above, we now develop a structural model of Chinese trade. This model will serve two purposes. First, it provides an accounting framework that allows us to keep track of multiple potential drivers of Chinese exports in a structurally-consistent way. Second, the structure of the model will allow for counterfactual simulations, which we will use to quantify the contribution of each driver to changes in Chinese exports. To study the variation of Chinese exports along the four margins described above, the model will feature heterogeneous firms that export to multiple destination markets (d), vary in ownership type (n), produce in various locations in China (h), and produce output in different sectors (s). We index time (years) by y.

Specifically, we will develop a structural decomposition of exports R_{dnhsy} to market d by firms of ownership n operating in location h producing sector s goods in year y into the following driving factors: (i) export demand (E_{dsy}); (ii) foreign competition (P^*_{dsy}/τ_{dsy}); (iii) marketing costs for exporting (f^M_{dnhsy}); (iv) entry costs for firms in China (f^E_{nhsy}); (v) labor supplies (L_{hy}); (vi) investment shocks (θ_{nsy}) that determine capital accumulation; (vii) accesses to imported inputs (P^I_{nsy}) ; and (viii) labor, capital, and total factor productivities (T^L_{nsy}, T^K_{nsy}, T_{nhsy}).

3.1 General Environment

We first define the *margins* of Chinese exports as follows: (i) markets, $d \in \Omega_D \equiv \{0, \cdots, D\}$, where market 0 is the domestic Chinese market and the remaining markets are export markets; (ii) firm ownership types , $n \in \Omega_N \equiv \{1, \cdots, N\}$; (iii) production locations in China, $h \in \Omega_H \equiv \{1, \cdots, H\}$; and (iv) sectors, $s \in \Omega_S \equiv \{1, \cdots, S\}$.

Within an $\{n, h, s\}$-triplet, we allow firms to be heterogeneous in idiosyncratic TFP ϕ. The distribution (CDF) of ϕ amongst $\{n, h, s\}$ firms in operation is denoted by G_{nhs}, while the measure of $\{n, h, s\}$ firms in operation (including non-exporters) is denoted by N_{nhsy}. Our assumptions about firm entry and exit will imply that one can treat G_{nhsy} as both exogenous and time-invariant, while N_{nhsy} is endogenously determined in each period. Firm heterogeneity within an $\{n, h, s\}$-triplet allows us to model selection into exporting, as $\{n, h, s\}$ firms will serve market d in year y in equilibrium if and only if $\phi \geq \phi^M_{dnhsy}$, where ϕ^M_{dnhsy} is an endogenous cutoff productivity.

We also assume that every production location has a finite but time-varying quantity of inelastically-supplied labor that is immobile across locations. The supply of labor in location h in year y is denoted by L_{hy} while its wage is denoted by P^L_{hy}. In addition, there are stocks of ownership-sector-specific capital denoted by K_{nsy} with price P^K_{nsy}, which are freely mobile across production locations.[7] We abstract from population growth, migration within China, and labor supply decisions. Hence, we treat $\bar{L}_{hy}$ as exogenous and P^L_{hy} as endogenous. In addition, both capital stocks and prices will be endogenously determined as a result of investment decisions.

[7] Capital stocks are ownership-sector-specific in the sense that they can only be used for production by firms of the corresponding ownership-sector type.

3.2 Demand

3.2.1 Export demand

Foreign consumers in export market d spend nominal income E_{dsy} on imports of sector s goods in year y from all source countries. Within each sector, these consumers have CES preferences over differentiated varieties from all source countries with elasticity of substitution σ_s across varieties. Hence, demand in market d for Chinese exports by $\{n, h, s, \phi\}$ firms takes a constant-elasticity form:

$$X_{dnhsy}(\phi) = A_{dnhsy} q_{nsy} p_{dnhsy}(\phi)^{-\sigma_s} \tag{1}$$

where $p_{dnhsy}(\phi)$ is the price charged by a $\{n, h, s, \phi\}$ firm in market d. We allow exports to differ in terms of quality q_{nsy} by ownership and sector. The term A_{dnhsy} is a demand shifter that we assume can be written as:

$$A_{dnhsy} = A_{dsy} \nu_{dnhsy} \tag{2}$$

where ν_{dnhsy} is a preference weight and A_{dsy} is a destination-sector specific component of the demand shifter. The latter is in turn given by:

$$A_{dsy} = \frac{E_{dsy}}{\left(P^{*}_{dsy}\right)^{1-\sigma_s} + \left(\tau_{dsy} P^{X}_{dsy}\right)^{1-\sigma_s}} \tag{3}$$

where P^{*}_{dsy} is a measure of competition from firms outside of China and P^{X}_{dsy} is a price index of sector s varieties exported to market d by firms in China net of iceberg trade costs $\tau_{dsy} \geq 1$. In what follows, we will treat E_{dsy} and P^{*}_{dsy} as exogenous variables, while the Chinese export price index P^{X}_{dsy} will be endogenously determined.[8]

3.2.2 Domestic demand

Domestic households are assumed to have identical Cobb-Douglas preferences in all locations:

$$U_{hy} = \prod_{s=1}^{S} \left(X^{F}_{hsy}\right)^{\gamma_s} \tag{4}$$

where X^{F}_{hsy} is final consumption in location h of sector s output and $\sum_{s=1}^{S} \gamma_s = 1$. We assume that all goods are freely tradable across locations in China. Hence, total final expenditure on each sector is a constant fraction of total household expenditure E:

$$\sum_{h=1}^{H} P_{sy} X^{F}_{hsy} = \gamma_{sy} E_y \tag{5}$$

where P_{sy} denotes the price of sector s output. Note also that all household expenditure is assumed to be allocated to domestic output, such that importing is performed only by firms and not directly by households.

[8] The demand shifter for the Chinese market A_{0s} is also endogenous and determined in general equilibrium.

3.3 Production

3.3.1 Firm-level production

Production technologies Firms produce output using four types of inputs: local labor, capital, domestic intermediates, and imported intermediates. The production technology is as follows. Each $\{n,h,s,\phi\}$ firm produces value-added $V_{nhsy}(\phi)$ by combining local labor $L_{nhsy}(\phi)$ and capital $K_{nhsy}(\phi)$ using a CES production function:

$$V_{nhsy}(\phi)=\left[\left(\omega^{V}\right)^{\frac{1}{\epsilon_s^V}}\left(T^{L}_{nsy}L_{nhsy}(\phi)\right)^{\frac{\epsilon_s^V-1}{\epsilon_s^V}}+\left(1-\omega^{V}\right)^{\frac{1}{\epsilon_s^V}}\left(T^{K}_{nsy}K_{nhsy}(\phi)\right)^{\frac{\epsilon_s^V-1}{\epsilon_s^V}}\right]^{\frac{\epsilon_s^V}{\epsilon_s^V-1}} \tag{6}$$

Note that the elasticity of substitution between labor and capital, ϵ_s^V, is allowed to vary by sector. We also allow for both labor-augmenting productivity T^L_{nsy} and capital-augmenting productivity T^K_{nsy} at the ownership-sector-year level, which will enable the model to match observed labor shares of value-added and value-added shares of total production costs. As we describe in section 4.2, these shares exhibit clear trends throughout the sample period for most ownership types and sectors.[9]

Each $\{n,h,s,\phi\}$ firm also produces materials $M_{nhsy}(\phi)$ by combining an imported input bundle $M^I_{nhsy}(\phi)$ and a domestic input bundle $M^D_{nhsy}(\phi)$ using a CES production function:

$$M_{nhsy}(\phi)=\left[\left(\omega^{M}\right)^{\frac{1}{\epsilon_s^M}}M^{I}_{nhsy}(\phi)^{\frac{\epsilon_s^M-1}{\epsilon_s^M}}+\left(1-\omega^{M}\right)^{\frac{1}{\epsilon_s^M}}M^{D}_{nhsy}(\phi)^{\frac{\epsilon_s^M-1}{\epsilon_s^M}}\right]^{\frac{\epsilon_s^M}{\epsilon_s^M-1}} \tag{7}$$

Again, note that the elasticity of substitution between imported and domestic materials, ϵ_s^M, is allowed to vary by sector. Since we do not model production outside China and abstract from trade costs within China, we assume that the imported input bundle is available at an exogenous price P^I_{nsy} that varies by ownership-sector-year but that is constant across locations and firms within an $\{n,s\}$-pair.[10] Variation in these import prices will allow the model to match imported shares of material expenditures, which as we discuss in section 4.2 exhibit clear trends throughout the sample period. The domestic input bundle, on the other hand, is assumed to be a Cobb-Douglas aggregate of inputs from all sectors:

$$M^D_{nhsy}(\phi)=\prod_{s'=1}^{S}\left[\frac{M^D_{nhss'y}(\phi)}{\alpha_{ss'}}\right]^{\alpha_{ss'}} \tag{8}$$

where $M_{nhss'y}(\phi)$ denotes usage of domestic intermediates from sector s' and $\{\alpha_{ss'}\}_{s,s'\in\Omega_S}$ is the sector-level input-output matrix with $\sum_{s'=1}^{S}\alpha_{ss'}=1$ for all $s\in\Omega_S$.[11]

Finally, output $X_{nhsy}(\phi)$ is produced by combining value-added and materials using a CES production

[9]The data is in fact rich enough to allow estimation of factor productivities at the ownership-*location*-sector level. However, observed labor and value-added shares tend to be much more volatile at this level of disaggregation. Hence, we choose to match factor shares only at the ownership-sector level.

[10]The import price P^I_{nsy} captures not only the cost of imported inputs but also differences in quality and productivity of imported versus domestic inputs. Hence, we do not include productivity terms in the materials production function.

[11]We assume a Cobb-Douglas technology in (8) to simplify the calibration of sector-level input-output shares using observable input-output data.

function:

$$X_{nhsy}(\phi) = \phi T_{nhsy} \left[\left(\omega^X\right)^{\frac{1}{\epsilon_s^X}} V_{nhsy}(\phi)^{\frac{\epsilon_s^X - 1}{\epsilon_s^X}} + \left(1 - \omega^X\right)^{\frac{1}{\epsilon_s^X}} M_{nhsy}(\phi)^{\frac{\epsilon_s^X}{\epsilon_s^X - 1}} \right]^{\frac{\epsilon_s^X}{\epsilon_s^X - 1}} \tag{9}$$

Note that the elasticity of substitution between value-added and materials, ϵ_s^X, is again allowed to vary by sector. Furthermore, total factor productivity consists of a firm-specific component ϕ and a term T_{nhsy} that is common to all firms within an $\{n, h, s\}$-triplet. The latter will account for residuals in estimated marginal production costs at the ownership-location-sector-year level once observed factor inputs and estimated factor productivities have been accounted for.[12]

Production costs The above assumptions imply that the marginal cost of production for an $\{n, h, s, \phi\}$ firm is given by:

$$\eta_{nhsy}(\phi) = \eta_{nhsy}/\phi \tag{10}$$

where η_{nhsy} is the aggregate component of marginal cost:

$$\eta_{nhsy} = \frac{1}{T_{nhsy}} \left[\omega^X \left(P_{nhsy}^V\right)^{1-\epsilon_s^X} + \left(1 - \omega^X\right) \left(P_{nhsy}^M\right)^{1-\epsilon_s^X} \right]^{\frac{1}{1-\epsilon_s^X}} \tag{11}$$

The price of value-added is a function of the relevant prices of labor and capital:

$$P_{nhsy}^V = \left[\omega^V \left(P_{hy}^L / T_{nsy}^L\right)^{1-\epsilon_s^V} + \left(1 - \omega^V\right) \left(P_{nsy}^K / T_{nsy}^K\right)^{1-\epsilon_s^V} \right]^{\frac{1}{1-\epsilon_s^V}} \tag{12}$$

while the intermediate input price index is a function of the relevant imported and domestic input bundle prices:

$$P_{nhsy}^M = \left[\omega^M \left(P_{nsy}^I\right)^{1-\epsilon_s^M} + \left(1 - \omega^M\right) \left(P_{sy}^D\right)^{1-\epsilon_s^M} \right]^{\frac{1}{1-\epsilon_s^M}} \tag{13}$$

Finally, the domestic intermediate input price is given by:

$$P_{sy}^D = \prod_{s'=1}^{S} \left(P_{s'y}\right)^{\alpha_{ss'}} \tag{14}$$

where P_s denotes the price of sector s output.[13]

Since firms within an ownership-location-sector are heterogeneous only in terms of Hicks-netural TFP ϕ, profit-maximizing behavior will result in identical factor shares for all firms within an $\{n.h.s\}$-triplet. The value-added share of total cost, labor share of value-added, and imported share of material costs are given

[12]Since production uses four types of inputs (L_{nhsy}, K_{nhsy}, M_{nhsy}^D, M_{nhsy}^I) with four terms that shift productivity of these inputs (T_{nhsy}^L, T_{nhsy}^K, T_{nhsy}, P_{nsy}^I), we also assume without loss of generality that the production function weights $\{\omega^X, \omega^V, \omega^M\}$ are constant across time. These weights will play no role in the analysis or quantitative results.

[13]Since we assume that goods are freely tradable across locations in China, the materials price P_{nhs}^M is common across locations h within every ownership-sector pair. Furthermore, since firms of different ownership types have the same technology (8) for producing the domestic input bundle, P_s^D varies only by sector.

respectively by:

$$s_{nhsy}^{V}=\frac{\omega^{X}\left(P_{nhsy}^{V}\right)^{1-\epsilon_{s}^{X}}}{\omega^{X}\left(P_{nhsy}^{V}\right)^{1-\epsilon_{s}^{X}}+\left(1-\omega^{X}\right)\left(P_{nhsy}^{M}\right)^{1-\epsilon_{s}^{X}}} \tag{15}$$

$$s_{nhsy}^{L}=\frac{\omega^{V}\left(P_{hy}^{L}/T_{nsy}^{L}\right)^{1-\epsilon_{s}^{V}}}{\omega^{V}\left(P_{hy}^{L}/T_{nsy}^{L}\right)^{1-\epsilon_{s}^{V}}+\left(1-\omega^{V}\right)\left(P_{nsy}^{K}/T_{nsy}^{K}\right)^{1-\epsilon_{s}^{V}}} \tag{16}$$

$$s_{nsy}^{I}=\frac{\omega^{M}\left(P_{nsy}^{I}\right)^{1-\epsilon_{s}^{M}}}{\omega^{M}\left(P_{nsy}^{I}\right)^{1-\epsilon_{I}}+\left(1-\omega^{M}\right)\left(P_{sy}^{D}\right)^{1-\epsilon_{I}}} \tag{17}$$

Note in particular that since we abstract from trade costs within China, the import share s_{nsy}^{I} does not vary by production location h.

Output, exports, and factor demand In equilibrium, all firms producing in sector s will face a constant demand price elasticity of $-\sigma_s$. We assume a market structure of monopolistic competition. Hence, all firms within a sector s charge a common and constant markup $\mu_s \equiv \frac{\sigma_s}{\sigma_s-1}$ over their respective marginal costs. Sales and profits are then given by:

$$R_{dnhsy}\left(\phi\right)=\Phi_{dnhsy}\phi^{\sigma_{s}-1} \tag{18}$$

$$\pi_{dnhsy}\left(\phi\right)=\frac{1}{\sigma_{s}}\Phi_{dnhsy}\phi^{\sigma_{s}-1} \tag{19}$$

where Φ_{dnhsy} is an aggregate sales shifter:

$$\Phi_{dnhsy}\equiv A_{dnhsy}\left(\mu_{s}\tau_{dsy}\tilde{\eta}_{nhsy}\right)^{1-\sigma_{s}} \tag{20}$$

and $\tilde{\eta}_{nhs} \equiv \eta_{nhs}/q_{ns}$ denotes quality-adjusted marginal cost. Aggregate exports by $\{n,h,s\}$ firms to market d are then given by:

$$R_{dnhsy}=\Phi_{dnhsy}\int_{\phi_{dnhsy}^{M}}^{\infty}\phi^{\sigma_{s}-1}dG_{nhs}\left(\phi\right)N_{nhsy} \tag{21}$$

while aggregate cost among all $\{n,h,s\}$ firms can be expressed as:

$$C_{nhsy}=\mu_{s}^{-\sigma_{s}}\tilde{\eta}_{nhsy}^{1-\sigma_{s}}N_{nhsy}\sum_{d=0}^{D}A_{dnhsy}\tau_{dsy}^{1-\sigma_{s}}\int_{\phi_{dnhsy}^{M}}^{\infty}\phi^{\sigma_{s}-1}dG_{nhs}\left(\phi\right) \tag{22}$$

Finally, aggregate factor demands at the sector-level are given by:

$$P_{hy}^{L}L_{nhsy}=s_{nhsy}^{L}s_{nhsy}^{V}C_{nhsy} \tag{23}$$

$$P_{nsy}^{K}K_{nhsy}=\left(1-s_{nhsy}^{L}\right)s_{nhsy}^{V}C_{nhsy} \tag{24}$$

$$P_{nsy}^{I}M_{nhsy}^{I}=s_{nsy}^{I}\left(1-s_{nhsy}^{V}\right)C_{nhsy} \tag{25}$$

$$P_{s'y}M_{nhss'y}^{D}=\alpha_{ss'}\left(1-s_{nsy}^{I}\right)\left(1-s_{nhsy}^{V}\right)C_{nhsy} \tag{26}$$

3.3.2 Sector-level production

Sector-level output is produced under perfect competition and free entry using a CES technology combining firm-level output from firms across all ownership-locations:

$$M_{sy} = \left[\sum_{n=1}^{N} \sum_{h=1}^{H} \int_{\phi_{0nhsy}^{M}}^{\infty} N_{nhsy} \left[q_{nsy} X_{0nhsy} (\phi) \right]^{\frac{\sigma_s - 1}{\sigma_s}} dG_{nhs} (\phi) \right]^{\frac{\sigma_s}{\sigma_s - 1}} \tag{27}$$

Note that the elasticity of substitution in the sectoral production function σ_s is assumed to be the same as the price elasticity in final demand (1). Furthermore, we assume that for each ownership-sector unit, product quality q_{nsy} is identical for exports and domestic sales. Domestic demand for output of a $\{n, h, s, \phi\}$ firm is then given by:

$$X_{0nhsy} (\phi) = A_{0sy} q_{nsy}^{\sigma_s - 1} p_{0nhsy} (\phi)^{-\sigma_s} \tag{28}$$

where the demand shifter is:

$$A_{0sy} \equiv M_{sy} \left(P_{sy} \right)^{\sigma_s} \tag{29}$$

Since all firms within a sector s charge a constant markup μ_s over their respective marginal costs, the sector price can be expressed as:

$$P_{sy} = \mu_s \left[\sum_{n=1}^{N} \sum_{h=1}^{H} N_{nhsy} \tilde{\eta}_{nhsy}^{1-\sigma_s} \int_{\phi_{0nhsy}^{M}}^{\infty} \phi^{\sigma_s - 1} dG_{nhs} (\phi) \right]^{\frac{1}{1-\sigma_s}} \tag{30}$$

3.4 Market entry costs

To model the extensive margin of how many firms export to a given destination market, we assume that selling to market d in year y requires an $\{n, h, s\}$-firm to pay a market entry cost f_{dnhsy}^{M}. We assume that this cost is paid in units of sector output and is incurred in every period that a firm actively exports. Since firm export sales are increasing in idiosyncratic TFP ϕ, this implies that if not all $\{n, h, s\}$-firms export to a market d, then the marginal firm that does export must have idiosyncratic TFP ϕ_{dnhsy}^{M} that satisfies the following market entry condition:

$$\frac{1}{\sigma_s} \Phi_{dnhsy} \left(\phi_{dnhsy}^{M} \right)^{\sigma_s - 1} = P_{sy} f_{dnhsy}^{M} \tag{31}$$

The price index for Chinese exports in sector s to foreign market d net of iceberg trade costs is then given by:

$$P_{dsy}^{X} = \mu_s \left[\sum_{n=1}^{N} \sum_{h=1}^{H} N_{nhsy} \tilde{\eta}_{nhsy}^{1-\sigma_s} \nu_{dnhsy} \int_{\phi_{dnhsy}^{M}}^{\infty} \phi^{\sigma_s - 1} dG_{nhs} (\phi) \right]^{\frac{1}{1-\sigma_s}} \tag{32}$$

We assume that $f_{0nhsy}^{M} = 0$, so that $\phi_{0nhsy}^{M} = 0$ and all firms in China sell to the domestic market.

3.5 Capital investment

The capital stock for $\{n, s\}$-firms is assumed to evolve according to the following law of motion:

$$K_{nsy} = \left(\frac{K_{ns,y-1}}{\xi_s} \right)^{\xi_s} \left(\frac{\theta_{nsy} I_{nsy}}{1 - \xi_s} \right)^{1-\xi_s} \tag{33}$$

where I_{nsy} denotes investment and θ_{nsy} is an investment shock. Since we will not impose restrictions on the mean level of the investment shocks, we assume that output in sector s can be transformed one-for-one into investment. Hence, the relevant price of investment in sector s at date y is P_{sy}. Note also that the parameter ξ_s controls the rate of capital depreciation conditional on a given level of investment.

Since we assume that capital stocks are ownership-sector specific, the number of distinct types of capital (NS) can be large. As a result, solving for the optimal investment paths within each ownership-sector using standard computational techniques can be challenging. Hence, to improve tractability of the model, we assume that all profits from investment are bid away by allowing for free-entry of investors. Specifically, we assume that households own all capital stocks in the economy and sell investment contracts for each type of capital. An investment contract for $\{n, s\}$-capital sells at date y for a nominal price P^{θ}_{nsy} and grants an investor the right to improve upon one unit of the existing $\{n, s\}$-capital stock for one period. In equilibrium, free-entry of investors will imply that the bid price P^{θ}_{nsy} exactly offsets any profits that are gained from investment. As a result, investment decisions can be characterized as a sequence of static problems.

With the above assumptions, the profit-maximization problem for a potential $\{n, s\}$-investor is:

$$\pi^{\theta}_{nsy} = \max_{k_{ns,y-1}, i_{nsy}} \left\{ P^{K}_{nsy} k_{nsy} - P_{sy} i_{nsy} - P^{\theta}_{nsy} k_{ns,y-1} \right\} \tag{34}$$

$$\text{s.t. } k_{nsy} = \left(\frac{k_{ns,y-1}}{\xi_s} \right)^{\xi_s} \left(\frac{\theta_{nsy} i_{nsy}}{1-\xi_s} \right)^{1-\xi_s} \tag{35}$$

The optimal level of aggregate investment is hence:

$$\frac{I_{nsy}}{K_{ns,y-1}} = \frac{1-\xi_s}{\xi_s} \left(\theta_{nsy}\right)^{\frac{1-\xi_s}{\xi_s}} \left(\frac{P^{K}_{nsy}}{P_{sy}} \right)^{\frac{1}{\xi_s}} \tag{36}$$

which implies that the aggregate capital stock growth rate is given by:

$$\frac{K_{nsy}}{K_{ns,y-1}} = \frac{1}{\xi_s} \left(\frac{\theta_{nsy} P^{K}_{nsy}}{P_{sy}} \right)^{\frac{1-\xi_s}{\xi_s}} \tag{37}$$

Furthermore, the free-entry condition for investors requires $\pi^{\theta}_{nsy} = 0$, which implies the following investment bid price:

$$P^{\theta}_{nsy} = \left(P^{K}_{nsy}\right)^{\frac{1}{\xi_s}} \left(\frac{P_{sy}}{\theta_{nsy}} \right)^{-\frac{1-\xi_s}{\xi_s}} \tag{38}$$

Hence, investment, capital growth, and the investment bid price are all increasing in the capital price and investment shock but are decreasing in the cost of investment.

3.6 Firm entry and exit

To model firm entry, we assume that to enter as a potential producer at date y, each $\{n, h, s\}$ firm must pay an entry cost f^{E}_{nhsy} in units of sector output. In addition, firms are subject to an exogenous rate of exit denoted by δ_{nhsy}, so that the law of motion for the measure of active $\{n, h, s\}$ firms is:

$$N_{nhs,y+1} = \left(1 - \delta_{nhsy}\right) N_{nhsy} + N^{E}_{nhs,y+1} \tag{39}$$

where N^E_{nhsy} denotes the measure of $\{n,h,s\}$-entrants at date y.[14] We also assume that idiosyncratic TFP ϕ for $\{n,h,s\}$ firms evolves according to a stationary Markov process, with TFP values for new entrants drawn from the stationary distribution G_{nhs}.

To characterize the firm entry decision, first let $\bar{\pi}_{nhsy}(\phi)$ denote total profit net of marketing costs for an $\{n,h,s,\phi\}$ firm:

$$\bar{\pi}_{nhsy}(\phi) = \sum_{d=0}^{D} \left[\pi_{dnhsy}(\phi) - P_{sy} f^M_{dnhsy}\right] \mathbf{1}_{\left[\phi \geq \phi^M_{dnhsy}\right]} \tag{40}$$

The value of being an $\{n,h,s,\phi\}$ firm at date y then satisfies the following Bellman equation:

$$\mathcal{V}_{nhsy}(\phi) = \bar{\pi}_{nhsy}(\phi) + (1-\delta_{nhsy})\,\mathbb{E}\left[\max\left\{\mathcal{V}_{nhs,y+1}(\phi'),0\right\}|\phi\right] \tag{41}$$

Note that we assume perfect foresight with respect to aggregate variables. Hence, the only uncertainty at the firm-level is with respect to idiosyncratic TFP ϕ. Furthermore, since we assume zero fixed costs of operation, firm exit is purely exogenous. This implies that the equilibrium distribution of idiosyncratic TFPs is also exogenous and equal to G_{nhs}. Consequently, the stochastic process for idiosyncratic TFP ϕ is irrelevant for aggregate variables and requires no further assumptions beyond stationarity. The expected value of an $\{n,h,s\}$-firm then satisfies the aggregate version of (41):

$$\mathcal{V}_{nhsy} = \bar{\pi}_{nhsy} + (1-\delta_{nhsy})\,\mathcal{V}_{nhs,y+1} \tag{42}$$

where $\bar{\pi}_{nhsy} \equiv \int_0^\infty \bar{\pi}_{nhsy}(\phi)\,dG_{nhs}(\phi)$. Finally, the free-entry condition requires:

$$P_{sy} f^E_{nhsy} = \mathcal{V}_{nhsy} \tag{43}$$

3.7 Market clearing

To close the model, we impose market clearing. At the firm level, total output produced must be equal to total output sold in each market $d \in \Omega_D$:

$$X_{nhsy}(\phi) = \sum_{d=0}^{D} X_{dnhsy}(\phi) \tag{44}$$

At the sector level, output produced in each sector s must be equal to output used for final consumption M^F_{sy}, domestic intermediate inputs M^D_{sy}, marketing costs M^M_{sy}, entry costs M^E_{sy}, and investment M^θ_{sy}:

$$M_{sy} = M^F_{sy} + M^D_{sy} + M^M_{sy} + M^E_{sy} + M^\theta_{sy} \tag{45}$$

[14] We allow for negative entry ($N^E_{nhsy} < 0$) in the following sense: a firm that survives the exogenous exit shock can also choose to liquidate at the start of period y and receive a liquidation value equal to f^E_{nhsy} units of sector s output.

where the components of sector-level demand are:

$$M_{sy}^F = \sum_{h=1}^{H} X_{hsy}^F \tag{46}$$

$$M_{sy}^D = \sum_{n=1}^{N} \sum_{h=1}^{H} \sum_{s'=1}^{S} M_{nhs'sy}^D \tag{47}$$

$$M_{sy}^M = \sum_{d=1}^{D} \sum_{n=1}^{N} \sum_{h=1}^{H} N_{nhsy} f_{dnhsy}^M \int_{\phi_{dnhsy}^M}^{\infty} dG_{nhs}(\phi) \tag{48}$$

$$M_{sy}^E = \sum_{n=1}^{N} \sum_{h=1}^{H} N_{nhsy}^E f_{nhsy}^E \tag{49}$$

$$M_{sy}^\theta = \sum_{n=1}^{N} I_{nsy} \tag{50}$$

Market clearing for local labor in location h requires:

$$\sum_{n=1}^{N} \sum_{s=1}^{S} L_{nhsy} = L_{hy} \tag{51}$$

while market clearing for $\{n, s\}$-capital requires:

$$\sum_{h=1}^{H} N_{nhsy} K_{nhsy} = K_{nsy} \tag{52}$$

Finally, household income is equal to the sum of labor income, capital income, aggregate firm profits, and the trade deficit:

$$E_y = \sum_{h=1}^{H} P_{hy}^L L_{hy} + \sum_{n=1}^{N} \sum_{s=1}^{S} P_{nsy}^\theta K_{ns,y-1} + \sum_{n=1}^{N} \sum_{h=1}^{H} \sum_{s=1}^{S} \left(N_{nhsy} \bar{\pi}_{nhsy} - N_{nhsy}^E f_{nhsy}^E P_{sy} \right) + D_y \tag{53}$$

where the trade deficit is given by:

$$D_y = \sum_{n=1}^{N} \sum_{h=1}^{H} \sum_{s=1}^{S} P_{nsy}^I M_{nhsy}^I - \sum_{d=1}^{D} \sum_{n=1}^{N} \sum_{h=1}^{H} \sum_{s=1}^{S} R_{dnhsy} \tag{54}$$

3.8 Equilibrium Definition and Solution Method

Having described the structure of the model, we now define equilibrium concepts. We emphasize that numerical solution of the model is not required for the estimation and calibration of the model's parameters as discussed in section 4. Instead, numerical solutions are required only for the simulation of model counterfactuals discussed in section 5.

3.8.1 Static Equilibrium with Fixed Entry

We first define a static equilibrium of the model with fixed entry.

Definition 1. Given measures of operating firms and entrants $\left\{ N_{nhsy}, N_{nhsy}^E \right\}$ and existing capital stocks

$K_{ns,y-1}$, a static equilibrium with fixed entry at date y is a set of sector prices $\left\{P_{sy}, P^X_{dsy}\right\}$, factor prices $\left\{P^V_{nhsy}, P^K_{nsy}, P^M_{nsy}, P^D_{sy}\right\}$, investment contract prices P^θ_{nsy}, marginal costs η_{nhsy}, factor shares $\left\{s^V_{nhsy}, s^L_{nhsy}, s^I_{nhsy}\right\}$, factor demands $\left\{L_{nhsy}, K_{nhsy}, M^I_{nhsy}, M^D_{nhss'y}\right\}$, sector output quantities M_{sy}, domestic and foreign demand shifters A_{dsy}, aggregate exports R_{dnhs}, aggregate costs C_{nhs}, sales shifters Φ_{dnhs}, market entry cutoffs ϕ^M_{dnhs}, investment and capital levels $\{I_{nsy}, K_{nsy}\}$, and household income E_y, all of which jointly satisfy equations (2), (11)-(14), (20)-(17), (29), (30)-(32), (36)-(38), (45), and (52)-(53).

3.8.2 Dynamic Equilibrium

Having defined a static equilibrium with fixed entry, we can now define a dynamic equilibrium of the model as follows.

Definition 2. Given initial values of operating firm measures and entrants $\left\{N_{nhs0}, N^E_{nhs0}\right\}$, initial capital stocks K_{ns0}, and terminal continuation values $\mathcal{V}_{nhs,Y+1}$, a dynamic equilibrium of the model for a set of periods $y \in \{1, \cdots, Y\}$ is a sequence of static equilibrium variables for each date y satisfying the conditions in Definition 1, and a set of sequences of operating firm measures, entrant measures, and firm values $\left\{N_{nhsy}, N^E_{nhsy}, \mathcal{V}_{nhsy}\right\}$ for each date y that satisfies (39), (42), and (43).

4 Calibration Procedure and Results

The model developed in section 3 offers a framework for studying how various structural factors determine patterns of Chinese exporting. We now discuss the procedure that we adopt to estimate and calibrate the structural parameters of the model.

4.1 Calibration Procedure

The exogenous parameters of the model for periods $y \in \{1, \cdots, Y\}$ are: (i) foreign market-sector import expenditures, E_{dsy}; (ii) foreign market-sector competition, P^*_{dsy}; (iii) trade costs, τ_{dsy}; (iv) product qualities, q_{nsy}; (v) market entry costs, f^M_{dnhsy}; (vi) employment, L_{hy}; (vii) investment shocks, θ_{sy}; (viii) imported input prices, P^I_{nsy}; (ix) labor, capital, and total factor productivities, $\left\{T^L_{nsy}, T^K_{nsy}, T_{nhsy}\right\}$; (x) firm entry costs, f^E_{nhsy}; (xi) firm exit rates, δ_{nhsy}; (xii) the time discount factor β; (xiii) elasticities of substitution across varieties within each sector, σ_s; (xiv) elasticities of substitution in the firm-level production functions, $\left\{\epsilon^X_s, \epsilon^V_s, \epsilon^M_s\right\}$; (xv) factor weights in the firm-level production functions, $\left\{\omega^X, \omega^V, \omega^M\right\}$; (xvi) sector-level consumption shares, γ_s; (xvii) sector-level input-output shares, $\alpha_{ss'}$; (xviii) investment shares in capital formation, ξ_s; and (ixx) idiosyncratic TFP distributions, G_{nhs}. The dimensions $\{d, n, h, s\}$ used in the estimation are the same as those described in section 2.2, and to calibrate these parameters, we proceed in five steps.

Step 1: Calibrating parameters directly observable from data

In the first step, we calibrate a set of parameters directly from data or by borrowing from estimates in the literature.

We first parameterize the cumulative distribution functions of idiosyncratic firm-level TFPs, G_{nhs}, as log-normal CDFs with zero mean and calibrate the standard deviation of each distribution $\sigma_{\phi,nhs}$ as well as the elasticity of substitution for each sector σ_s using measures of sales and TFP dispersions.[15] Next, the consumption shares and input-output coefficients $\gamma_s, \alpha_{ss'}$ are calibrated using the WIOD input-output data. We also obtain direct measures of exit rates at the ownership-province-sector level from the ASM data to calibrate δ_{nhsy}. Data on total imports by HS-2 sector for each country in the world from the UN COMTRADE database are used to calibrate E_{dsy}. The production function weights are normalized without loss of generality to $\omega^X = \omega^V = \omega^M = \frac{1}{2}$, and we set the share of lagged capital in capital formation at $\xi_s = .9$, which implies that the ratio of investment expenditure to the value of the contemporaneous capital stock is 10%.

Finally, as is well-known, identifying the substitution elasticities $\left\{\epsilon_s^X, \epsilon_s^V, \epsilon_s^M\right\}$ while simultaneously allowing for factor-biased technological change (through the time-varying factor productivities $\left\{T_{nsy}^L, T_{nsy}^K\right\}$) is challenging.[16] Hence, our approach is as follows. First, we assume that the elasticity of substitution between imported and domestic inputs within a sector, ϵ_s^M, is the same as the elasticity of substitution across varieties within that sector, σ_s. Next, we calibrate the factor productivities $\left\{T_{nsy}^L, T_{nsy}^K\right\}$ as described below and borrow estimates of the substitution elasticities between value-added and materials and between capital and labor from the literature. Specifically, we use values of $\left\{\epsilon_s^X, \epsilon_s^V\right\}$ reported by Oberfield and Raval (2019), who estimate these using plant-level data in the US. The capital-labor elasticities ϵ_s^V are estimated at the sector-level and are all reported to be less than unity (implying that capital and labor are complements in all sectors). The value-added-materials elasticity is estimated at the economy-wide level at a value of approximately $\epsilon_s^X = 0.65$ (implying that value-added and materials are also complements).[17]

Step 2: Controlling for entry

In the second step of the estimation, we solve for marketing costs f_{dnhsy}^M, export productivity cutoffs ϕ_{dnhsy}^M, and sales shifters Φ_{dnhsy} from (21), (31), and the fraction of exporters to a market:

$$R_{dnhsy} = \Phi_{dnhsy} \int_{\phi_{dnhsy}^M}^{\infty} \phi^{\sigma_s - 1} dG_{nhs}(\phi)\, N_{nhsy} \tag{55}$$

$$\frac{1}{\sigma_s} \Phi_{dnhsy} \left(\phi_{dnhsy}^M\right)^{\sigma_s - 1} = P_{sy} f_{dnhsy}^M \tag{56}$$

$$\frac{N_{dnhsy}}{N_{nhsy}} = \int_{\phi_{dnhsy}^M}^{\infty} dG_{nhs}(\phi) \tag{57}$$

Here, firm counts N_{nhsy} (including non-exporters) are estimated from the ASM and customs data using a procedure described in section A.3 of the appendix.[18] This step of the estimation effectively adjusts observed export values R_{dnhsy} for differences in the extensive margin (number of exporters), giving us an estimate of the intensive margin of exporting Φ_{dnhsy}. This also yields values for the nominal marketing costs $P_{sy} f_{dnhs}^M$, which we use to compute real marketing costs below.

[15] The former are obtained from the ASM data while the latter are obtained from Brandt et al. (2012). Specifically, the model predicts that firm-level log sales for sector s firms with idiosyncratic TFP ϕ are given by a constant plus $(\sigma_s - 1)\log\phi$. Hence, the standard deviation of log TFP is given by the standard deviation of log sales divided by $\sigma_s - 1$.

[16] For example, see León-Ledesma et al. (2010).

[17] We use the estimates reported by Oberfield and Raval (2019) based on data for 1997, which is the closest year to the start of our sample period. We use their estimates of the capital-labor elasticities at ISIC-2 classification and concord these to the HS-2 classification.

[18] Some firms in the data export in multiple HS-2 sectors and produce goods in multiple provinces, but the model abstracts from multi-product firms operating in multiple locations. Hence, we deal with this by treating each exporter-province-sector observation in the data as a separate firm. This matters for our quantitative results only to the extent that firm operating decisions are made jointly across province-sector units of production rather than independently.

Step 3: Separating demand from quality-adjusted marginal cost

In the third step, we decompose the sales shifter Φ_{dnhsy} obtained from above into the following demand-side and supply-side components:

$$\Phi_{dnhsy} \equiv \mu_s^{1-\sigma_s} \times \underbrace{A_{dsy}\tau_{dsy}^{1-\sigma_s}}_{\text{destination-sector-year}} \times \underbrace{\tilde{\eta}_{nhsy}^{1-\sigma_s}}_{\text{ownership-location-sector-year}} \times \underbrace{\nu_{dnhsy}}_{\text{residual}} \tag{58}$$

where $A_{dsy}\tau_{dsy}^{1-\sigma^s}$ can be interpreted as an export demand shifter and $\tilde{\eta}_{nhsy} \equiv \eta_{nhsy}/q_{nsy}$ is quality-adjusted marginal cost. The factors on the right-hand side of (58) are then estimated via linear fixed effects regression. The key identifying assumption here is that within each sector s, the preference weights ν_{dnhsy} are uncorrelated with both the export demand shifter and quality-adjusted marginal cost. This implies a restriction on the manner in which demand shifters and quality-adjusted marginal cost can vary: the former is assumed to vary only across destination-sectors, while the latter is assumed to vary across ownership-location-sectors. For example, foreign consumers may have a preference for Chinese imports that are produced by firms of one ownership type over another or that are produced in one Chinese production location over another, but the identifying assumption requires that these preference biases are not systematically correlated with, for example, total import expenditures E_{dsy} across destinations.

Note that identification of the fixed effects in (58) also requires normalization of one factor per sector. Our approach is to calibrate the demand shifter $A_{dsy}\tau_{dsy}^{1-\sigma_s}$ directly for North America.[19] Specifically, in each year of our analysis, we use data on total imports by HS-2 sector for the US to calibrate $E_{NA,s}$ and data on the import index by HS-2 sector for the US to calibrate $\bar{P}_{NA,sy} \equiv \left[\left(P_{NA,sy}^{*}\right)^{1-\sigma_s} + \left(P_{NA,sy}\right)^{1-\sigma_s}\right]^{\frac{1}{1-\sigma_s}}$.[20] Next, we calibrate $\tau_{NA,sy}$ using measures of average tariffs at the HS-2 sector level applied by the US to imports from China. Finally, we normalize $A_{NAsy}\tau_{NA,sy}^{1-\sigma_s} = 1$ in the first year of our analysis for every sector and use growth rates of $A_{NA,sy}\tau_{NA,sy}^{1-\sigma_s}$ relative to the base year as our normalization for the fixed-effects regression of equation (58).[21]

Step 4: Separating quality from cost

In the fourth step, we decompose our estimates of quality-adjusted marginal costs $\tilde{\eta}_{nhsy}$ into product qualities q_{nsy} and marginal costs η_{nhsy}. To do so, we first compute unit export prices from the customs data at the ownership-sector-year level. Since we define sectors at a fairly coarse level of aggregation (HS-2), we compute unit prices at the HS-6 classification and aggregate these up to unit prices at the HS-2 level using a methodology outlined in section A.1 of the appendix. Hence, these measured unit prices account for the fact that within an HS-2 sector, firms of different ownership types may also record different unit export values at the HS-6 level.

The model equivalent of these ownership-sector unit export prices is then:

$$P_{nsy}^{u} = \frac{R_{nsy}}{X_{nsy}} \tag{59}$$

[19] The North American market is comprised of the USA and Canada. In the average sample year, the US accounts for 93.3% of Chinese exports to North America.

[20] The import data is obtained from the UN COMTRADE database, while the import price indices are constructed by the US Bureau of Labor Statistics.

[21] Note that since we are utilizing only growth rates of $A_{NA,sy}\tau_{NA,sy}^{1-\sigma_s}$ for the normalization, any components of this term that remain constant over time are irrelevant for the analysis. In particular, in calibrating the trade cost $\tau_{NA,sy}$, we can reasonably ignore the contribution of distance and transportation costs.

where $R_{nsy} = \sum_{d=1}^{D} \sum_{h=1}^{H} R_{dnhsy}$ is the aggregate value of exports and X_{nsy} is the aggregate quantity of exports for $\{n, s\}$-firms in year y. The latter can be written as:

$$X_{nsy} = \sum_{d=1}^{D} \sum_{h=1}^{H} \frac{\Phi_{dnhsy}}{\mu_s q_{nsy} \tilde{\eta}_{nhsy}} \int_{\phi_{dnhsy}^M}^{\infty} \phi^{\sigma_s} dG_{nhs}(\phi) N_{nhsy} \tag{60}$$

Hence, solving for q_{nsy} gives:

$$q_{nsy} = P_{nsy}^u \sum_{d=1}^{D} \sum_{h=1}^{H} \left(\frac{R_{dnhsy}}{R_{nsy}} \right) \left(\frac{\int_{\phi_{dnhsy}^M}^{\infty} \phi^{\sigma_s} dG_{nhs}}{\int_{\phi_{dnhsy}^M}^{\infty} \phi^{\sigma_s - 1} dG_{nhs}} \right) \frac{1}{\mu_s \tilde{\eta}_{nhsy}} \tag{61}$$

The key identifying assumption that allows quality to be separately identified from cost here is that differences in prices within a sector (both in the model and data) reflect only differences in marginal costs of production and not differences in quality.[22] Intuitively, we infer product quality to be high when estimated quality-adjusted marginal costs ($\tilde{\eta}_{nhsy}$) are low after controlling for unit export values and after adjusting for heterogeneity within an ownership-sector pair in terms of export destinations and export production location. Given q_{nsy}, we can then recover marginal costs as $\eta_{nhsy} = \tilde{\eta}_{nhsy} q_{nsy}$.

Step 5: Calibrating remaining parameters

In the fifth step, we calibrate all remaining parameters of the model using the relevant equilibrium conditions. These parameters are: foreign competition prices, trade costs, imported input prices, factor productivities, investment shocks, labor supplies, and entry costs.

Foreign competition prices and trade costs (market access). First, since we treat foreign competition prices P_{dsy}^* as exogenous, only the ratios of these prices to the corresponding iceberg trade costs τ_{dsy} are relevant for determining equilibrium outcomes. We refer to the ratio P_{dsy}^*/τ_{dsy} as *market access* for firms in China, which is high if either the foreign competition price is high or trade costs are low. The market access terms are then identified from variation in observed Chinese export market shares.

The market share for firms in China in export destination d, sector s, year y is:

$$s_{dsy}^X = \frac{\left(P_{dsy}^X\right)^{1-\sigma_s}}{\left(P_{dsy}^*/\tau_{dsy}\right)^{1-\sigma_s} + \left(P_{dsy}^X\right)^{1-\sigma_s}} \tag{62}$$

Hence, we first compute domestic sector prices P_{sy} and export prices P_{dsy}^X from (30) and (32) given the estimates of $\tilde{\eta}_{nhsy}$ and ϕ_{dnhs}^M above.[23] We then measure the market shares s_{dsy}^X using Chinese export values and our measures of total import expenditures E_{dsy} from UN COMTRADE data. The market access terms are then recovered as:

$$\frac{P_{dsy}^*}{\tau_{dsy}} = \left(\frac{s_{dsy}^X}{1 - s_{dsy}^X} \right)^{\frac{1}{\sigma_s - 1}} P_{dsy}^X \tag{63}$$

Intuitively, market access is estimated to be high if firms operating in China have a large share of an export market after controlling for estimated Chinese export prices.

[22] Prices also include markups, but these are assumed to be constant within a sector.

[23] The estimates of P_{sy} also allow us at this point to compute real marketing costs from estimates of $P_{sy} f_{dnhsy}^M$ in (56).

Imported input prices. Second, imported input prices P^I_{nsy} are identified from observed imported shares of total material expenditures s^I_{nsy}. We measure this as the ratio of total import expenditure in the customs data to total materials expenditure in the ASM data.[24] We then calibrate the imported input prices from (17) as:

$$P^I_{nsy} = \left[\left(\frac{1-\omega^M}{\omega^M}\right)\left(\frac{s^I_{nsy}}{1-s^I_{nsy}}\right)\right]^{\frac{1}{1-\epsilon^M_s}} P^D_{sy} \tag{64}$$

where the domestic intermediate input price index P^D_{sy} is computed from (14) given our estimates of sector prices P_{sy}. Intuitively, import prices are estimated to be high if imported shares of materials expenditure are low after controlling for estimated domestic input prices.[25]

Labor and capital productivities. Third, labor and capital productivities $\left\{T^L_{nsy}, T^K_{nsy}\right\}$ are identified from variation in value-added shares of production costs and labor shares of value-added $\left\{s^V_{nsy}, s^L_{nsy}\right\}$ observed in the ASM data.[26] Note that we calibrate these factor productivities at the ownership-sector level and hence target factor shares at this level of disaggregation as well. These shares can be expressed as weighted averages of the corresponding shares at the ownership-*location*-sector level:

$$s^V_{nsy} = \sum_{h=1}^{H} s^V_{nhsy}\hat{C}_{nhsy} \tag{65}$$

$$s^L_{nsy}s^V_{nsy} = \sum_{h=1}^{H} s^L_{nhsy}s^V_{nhsy}\hat{C}_{nhsy} \tag{66}$$

where $\hat{C}_{nhsy} \equiv C_{nhsy}/\sum_{h'=1}^{H} C_{nh'sy}$ is the share of total production cost for $\{n,s\}$-firms accounted for by such firms operating in province h. To compute production costs, we use measures of domestic sales $P_{sy}M_{sy}$ (total sales minus exports) from the ASM data to back out the implied output quantities M_{sy} given our estimates of sector prices P_{sy} above.[27] This allows us to compute the implied domestic demand shifter A_{0sy} from (29) and hence aggregate costs C_{nhsy} from (22).

Now note from equations (12), (15), and (16) that the shares s^V_{nhsy} and s^L_{nhsy} are functions of only factor productivities $\left\{T^L_{nsy}, T^K_{nsy}\right\}$ and input prices $\left\{P^L_{hy}, P^K_{nsy}, P^M_{nsy}\right\}$. Hence, estimating factor productivities from (65) and (66) first requires estimating factor prices. To do so, we measure unit labor costs P^L_{hy} directly from the ASM data at the province-year level by taking the ratio of total labor costs to total employment. The price of materials P^M_{nsy} can be computed from (13) given our estimates of imported input prices and domestic input prices from above. Finally, capital prices are computed from the capital demand and market clearing

[24]Since firms are not matched between the customs and ASM data, mapping imports to sectors of production is only possible if a firm simultaneously imports and exports. However, in the average year, more than 90% of total import value is accounted for by exporters. Hence, we include in the import share measures only the import transactions by exporting firms.

[25]Recall that we assume imported inputs and domestic inputs are substitutes in the baseline estimation.

[26]To compute s^V_{nsy}, we measure ratios of value-added to gross output and scale these by μ_s. To compute s^L_{nsy}, we measure ratios of total labor costs to value-added. As pointed out by Hsieh and Klenow (2009), labor shares of value-added in the raw ASM data are typically very low since these do not include non-wage compensation. Hence, we follow their approach and scale total labor costs by a time-invariant factor such that the aggregate labor share of value-added in 2000 is equal to 43.5%, which is the value reported for manufacturing in the Chinese National Bureau of Statistics National Accounts input-output table.

[27]Since the measure of domestic sales from the ASM is truncated due to omission of below-scale private firms, we adjust the domestic sales measure using a procedure described in section A.2 of the appendix that ensures the implied value of final consumption within each sector is consistent with the values reported in the WIOD tables. The correlation between log domestic sales in the ASM and our adjusted measure is 0.768 in the average year.

conditions (24) and (52) as:

$$P^K_{nsy} = \frac{s^V_{nsy} C_{nsy}}{K_{nsy}} \tag{67}$$

where we obtain measures of capital stocks at the ownership-sector level from the ASM data.[28] With these estimates of input prices, we then solve the system of equations (65)-(66) to obtain estimates of labor and capital productivities $\left\{T^L_{nsy}, T^K_{nsy}\right\}$. Intuitively, controlling for factor prices, variation in observed factor shares is informative about factor productivities.

Total factor productivities. Fourth, we identify total factor productivities as the residual in estimated marginal production costs after controlling for input prices and labor and capital productivities. From equation (11), we have:

$$T_{nhsy} = \frac{1}{\eta_{nhsy}} \left[\omega^X \left(P^V_{nhsy}\right)^{1-\epsilon^X_s} + \left(1-\omega^X\right)\left(P^M_{nhsy}\right)^{1-\epsilon^X_s}\right]^{\frac{1}{1-\epsilon^X_s}} \tag{68}$$

Intuitively, TFPs are inferred to be high if marginal costs are low after controlling for input prices, labor productivities, and capital productivities.

Labor supplies. Fifth, we identify labor supplies from variation in observed wages and estimated labor costs. From the labor demand and market clearing equations (23) and (51), we compute the implied value of employment in each province-year as:

$$L_{hy} = \frac{\sum_{n=1}^{N} \sum_{s=1}^{S} s^L_{nhsy} s^V_{nhsy} C_{nhsy}}{P^L_{hy}} \tag{69}$$

where the factor shares s^L_{nhsy} and s^V_{nhsy} are computed from (15)-(16) given estimated input prices and productivities from above. Intuitively, employment is estimated to be high if estimated labor costs are high controlling for measured unit wages.[29]

Investment shocks. Sixth, investment shocks θ_{nsy} are identified from variation in observed capital stock stock growth rates, estimated capital prices, and estimated sector prices (which are equal to the cost of investment in the model). From (37), we have:

$$\theta_{nsy} = \xi_s^{\frac{\xi_s}{1-\xi_s}} \left(\frac{K_{nsy}}{K_{ns,y-1}}\right)^{\frac{\xi_s}{1-\xi_s}} \frac{P_{sy}}{P^K_{nsy}} \tag{70}$$

Intuitively, we infer investment shocks to be high if observed capital growth rates are high controlling for the cost of investment and the value of capital.

[28] Capital stock measures are constructed based on a perpetual inventory method using reported firm-level capital stock values at original purchase prices net of depreciation and deflators for structures and equipment reported by the Chinese National Bureau of Statistics.

[29] Note that we could alternatively measure employment directly in the data and compute estimates of model-implied wages. These approaches yield similar results, since the wage estimates are highly correlated using either approach, as are the employment estimates.

Firm entry costs. Finally, we identify firm entry costs from variation in estimated firm values. Specifically, we compute $\mathcal{V}_{nhsy}$ from equation (42) and calibrate the firm entry costs f^E_{nhsy} using the entry condition (43).[30] Intuitively, we infer entry costs to be high if the model-implied value of a firm is high.

4.2 Calibration Results

The online appendix to the paper provides a comprehensive description of our numerical results for each calibrated model parameter, moments in the data underlying identification of these parameters, as well as various equilibrium variables in the model. Here, we highlight the key findings.

Foreign import demand. Figure 5 shows total import expenditures E_{dsy} by destination market (d) and sector (s). By destination, import expenditures rose steadily over the first half of the sample period (2000-2007) for all the main Chinese export markets. However, over the second half of the sample period (2008-2013), import demand was fairly stagnant for the three largest markets (North America, Western Europe, and East Asia), with demand growth observed only for South East Asia. The slowdown in international trade during the recession of 2009 is also clearly evident. Similar patterns are observed at the sector level, with growth in import demand for most of the major Chinese export sectors occurring primarily between 2000 and 2007 and noticeable slower growth from 2008 onward.

Foreign market competition. Figure 6 shows the estimates of the market access terms P^*_{dsy}/τ_{dsy} by destination market (d) and sector (s). Recall that market access is identified from variation in Chinese export market shares after controlling for estimated Chinese export prices. Hence, larger values of P^*_{dsy}/τ_{dsy} indicate that firms from China were relatively more competitive compared with firms outside of China for the sector s market in region d in year y.

At the destination level, market access rises gradually throughout the sample period for most of the major Chinese export markets, with the highest rate of increase observed for South East Asia from 2007 onward. This reflects China's growing share of these export markets. For example, across all manufacturing sectors, China's share of total imports by North America was 4.2% in 2000, 13.2% in 2007, and 18.1% by 2013. Similarly, China's share of total imports by South East Asian countries was 4.4% in 2000, 13.8% in 2007, and 23.4% in 2013. In levels, the estimates imply that firms from China faced lower market access in Western Europe, Eastern Europe, and Russia relative to the other major export markets. At the sector level, market access is fairly stable over time, although there is substantial heterogeneity in the levels of these estimates across sectors. Specifically, firms from China faced relatively less market access in the machinery and electrical sectors and relatively more market access in the textiles and metals sectors.

Firm entry costs. Figure 7 shows the estimates of entry costs f^E_{nhsy} by ownership (n), production location (h), and sector (s). At the ownership level, estimated entry costs are fairly constant for all ownership types before 2007, then increase gradually for foreign and private Chinese firms and rise sharply for state firms after 2007. In light of the rapid growth in firm entry implied by Figures 2 and 4, these mildly positive growth rates in entry costs may seem somewhat surprising. However, these estimates reflect the fact that despite high rates of firm entry, the average value of a firm experienced moderate growth. For example, between

[30] Note that this requires values for the terminal continuation values $\mathcal{V}_{nhs,Y+1}$ in the last year of available data. We assume that these values are given by the present discounted value of future profits under a scenario in which average profits $\bar{\pi}_{nhsy}$ grow at a constant rate equal to the growth rate of aggregate profits across all firms over the last two years of the sample. This growth rate is equal to 5.76%.

2000 and 2013, the average annual growth rates in sales per firm for foreign, private Chinese, and state firms were 3.1%, 1.2%, and 5.6% respectively.

At the sector level, estimated entry costs are initially around 2.5 times higher in the main coastal export provinces than in other provinces on average. Over the first half of the sample period, entry costs in these coastal provinces then decline to levels that approach the lower entry costs observed in other provinces, before rising again near the end of the sample. Similar dynamics are observed at the sector level. In addition, we estimate entry costs to be substantially higher (by around seven times) in the machinery and electrical sectors than in other sectors.

Export marketing costs. Figure 8 shows the estimates of marketing costs f^M_{dnhsy} by destination market (d), ownership (n), production location (h), and sector (s). Viewed along any of these dimensions, marketing costs consistently rise throughout the sample period. As with entry costs, these estimates reflect the positive growth in the intensive margin of Chinese exporting (average exports per exporter) documented in Figure 3.

In levels, we estimate marketing costs to be higher for the largest Chinese export markets (North America, Western Europe, and East Asia) than for other markets. At the ownership level, foreign firms are estimated to face higher marketing costs than Chinese firms. This may seem surprising given that export propensities are much higher for foreign firms, but this is again largely driven by the fact that the average foreign exporter also earns a much higher value of export sales than the average Chinese exporter. Across provinces, estimated marketing costs are generally higher in the main coastal export provinces (especially Jiangsu) than in other provinces, while at the sector level, we estimate marketing costs to be substantially higher in machinery and electrical sectors than in other sectors.

Marginal costs. Figure 9 shows the estimates of marginal costs η_{nhsy} by ownership (n), production location (h), and sector (s). At the start of the sample period, marginal costs are estimated to be highest for foreign firms and lowest for private Chinese firms. For example, in 2000, the median estimated cost for foreign firms is 112.3% higher than the median cost for private Chinese firms and 24.2% higher than the median cost for state firms. Throughout the sample period, estimated marginal costs then grow consistently for all firms. However, the average annual growth rate of median costs for foreign firms (6.2%) is estimated to be lower than the growth rates for private firms (9.9%) and state firms (10.1%). As a result, by the end of the sample in 2013, the median cost for foreign firms is 77.3% higher than the median cost for private Chinese firms and 22.7% *lower* than the median cost for state firms. At the province level, marginal costs generally increase across most provinces, while at the sector level, marginal costs increase for some sectors (e.g. machinery and electrical) but are fairly constant for others (e.g. textiles).

Wages and employment. Figure 10 shows the estimates of wages P^L_{hy} and employment L_{hy} by production location (h). Unsurprisingly, there is substantial growth in estimated wages across all provinces, with a mean annual growth rate averaged across provinces of 13.2%. There is also substantial cross-sectional heterogeneity in wages across provinces, with the highest average log wages observed in Shanghai, Guangdong, and Beijing. The growth in wages is observed in parallel with moderate growth in employment in most of the main export provinces, especially in the first half of the sample period. Estimated manufacturing employment in the top five export provinces grew at an average annual growth rate of 7.5% between 2000 and 2007, but exhibited negative average annual growth of -2.2% between 2008 and 2013. To validate our estimates of employment, we also measure manufacturing employment at the province-year level directly from the ASM data. The correlation of log employment implied by the model and measured in the ASM data is 0.852 pooling all provinces and years.

Investment shocks. Figure 11 shows the estimates of investment shocks θ_{nsy} by ownership (n) and sector (s). The estimated investment shocks are fairly constant across most firm ownership types and sectors, with the one noticeable exception being the rapid decline for private Chinese firms from 2000 to 2007 starting from an initial level that is substantially higher than the level for foreign and state firms. From equation (70), we can interpret the dynamics of investment shocks as reflecting dynamics of three factors: growth rates of capital stocks ($K_{nsy}/K_{ns,y-1}$), the cost of investment (P_{sy}), and the value of capital (P^K_{nsy}). Among these, the dominant force driving the decline in investment shocks for private Chinese firms in the first half of the sample is a rapid increase in the price of capital: the average annual growth rate of the median capital price for private Chinese firms between 2000 and 2007 is 74.3%. On the other hand, capital stock growth rates for private Chinese firms between 2000 and 2007 were fairly constant at around 20%, while the median cost of investment declined by only 3.5% in the average year. Since we observe rapid growth in the value of capital but fairly constant growth in capital stocks and investment costs, we infer that investment productivity as measured by θ_{nsy} must have been declining for private Chinese firms during this time.

Imported input prices. Figure 12 shows the estimates of imported input prices P^I_{nsy} by ownership (n) and sector (s). At the ownership level, we unsurprisingly find that foreign firms are estimated to face the lowest import prices while private Chinese firms face the highest import prices. This largely reflects differences in imported shares of material expenditures across the different firm ownership types. For example, at the start of the sample, the median imported share of materials expenditure was 46.8% for foreign firms, 5.6% for private Chinese firms, and 9.6% for state firms. In addition, we observe that estimated import prices are generally declining across all ownership types from 2000 to 2007, fairly constant for foreign and state firms from 2008 onwards, and increasing for private Chinese firms from 2008 onwards. Despite the declines in estimated import prices in the first half of the sample, however, we observe that imported shares of materials expenditure *decline* for all firm ownership types throughout the sample: by 2013, for example, the median imported share of materials expenditure was 29.4% for foreign firms, 1.2% for private Chinese firms, and 8.5% for state firms. This reflects the fact that domestic input prices were also falling throughout the period, inducing a shift toward domestic sourcing.

At the sector level, we estimate fairly constant import prices in most of the main Chinese export sectors, except for textiles and metals where we observe rapid growth in import prices. The growth in import prices for textiles and metals largely reflects the fact that the median import shares in both of these sectors declined substantially from around 20% in 2000 to around 1% in 2013.

Product quality. Figure 13 shows the estimates of product quality q_{nsy} by ownership (n) and sector (s). The dynamics of these quality estimates are qualitatively similar to the marginal cost estimates. At the ownership level, median quality at the start of the sample for foreign firms is estimated to be 3.9 times higher than median quality for private firms and 1.9 times higher than median quality for state firms. We then observe sustained growth in quality for all firm ownership types, with higher average annual growth rates of median quality for private Chinese firms (10.1%) and state firms (10.5%) than for foreign firms (3.2%). At the sector level, the most noticeable quality growth occurs in the machinery and electrical sectors, whereas quality improvements are more gradual in sectors with low R&D intensities such as textiles.

Labor and capital productivities. Figures 14 and 15 show the estimates of labor productivity T^L_{nsy} and capital productivity T^K_{nsy} respectively, by ownership (n) and sector (s).

At the ownership level, we observe that both labor and capital productivities are generally higher for foreign firms than Chinese firms at the start of the sample period. However, labor productivity is fairly stagnant for foreign firms throughout the sample period, while median capital productivities decline at an average annual rate of -11.4%. In contrast, we observe positive growth of both median labor and capital productivities for private Chinese firms between 2000 and 2007, with average annual growth rates of 9.3% and 43.4% respectively. SOEs exhibit positive labor productivity growth in the first half of the sample period but these firms are also characterized by declining capital productivities. In addition, there is a noticeable change in these productivity dynamics from 2008 onwards. Growth in labor productivity for Chinese firms dissipates, while capital productivity growth for private Chinese firms reverses and declines at an average annual rate of -4.0% between 2008 and 2013. Growth in median labor productivity for state firms also stagnates at 0.7% per year on average during this period.

At the sector level, we observe positive labor productivity growth in all of the main Chinese export sectors, but again, growth rates of median labor productivities decline substantially from 2008 onwards, especially in textiles, metals, and chemicals. Capital productivities, on the other hand, are generally either declining or stagnant in most of the main Chinese export sectors.

To interpret these productivity dynamics, recall from equations (65)-(66) that we infer changes in factor productivities based on changes in value-added shares of costs and labor shares of value-added. These shares exhibit two key trends throughout the sample period.

First, value-added shares of total production costs were *rising* substantially across all firm ownership types: in 2000, the median value-added share was 29.8% for foreign firms, 31.6% for private Chinese firms, 33.7% for state firms; in 2013, these shares were 48.4% , 43.8% , and 52.0% respectively. Controlling for our estimates of materials prices, these dynamics imply growth in the price of value-added over time across all firm ownership types and sectors. Second, labor shares of value-added were *declining* substantially across all firm ownership types throughout the sample period: in 2000, the median labor share was 57.1% for foreign firms, 59.7% for private Chinese firms, 72.4% for state firms; in 2013, these shares were 48.8%, 37.6%, and 47.0% respectively. Controlling for our estimates of factor prices, these declining labor shares imply growth in labor productivities relative to capital productivities. Taken together, the trends that we observe in value-added and labor shares hence imply generally positive labor productivity growth and negative capital productivity growth.

Total factor productivities. Finally, Figure 16 shows the estimates of total factor productivities T_{nhsy} by ownership (n), location (h), and sector (s). TFPs are generally either stagnant or gradually declining for most ownership types, provinces, and sectors. For example, the average annual growth rates of median TFP for foreign, private Chinese, and state firms are estimated to be -1.8%, -7.4%, and -7.5% respectively. This partially reflects the growth in marginal production costs documented above. However, quality-adjusted TFPs, $q_{nsy}T_{nhsy}$, were generally *increasing* through the sample period. For instance, the average annual growth rates of median quality-adjusted TFP for foreign, private Chinese, and state firms are estimated to be 2.5%, 2.3%, and 3.3% respectively. Hence, accounting for both changes in quality and TFP, the net effect of these dynamics was positive for most ownership types, provinces, and sectors.

4.2.1 Correlations of Structural Estimates

To assess potential comovements in the structural estimates described above, Tables 1 and 2 document correlations between estimates at the ownership-province-sector level in levels and changes respectively, where observations are weighted by the number of firms in each cell. In levels, the structural estimates are essentially uncorrelated. In changes, there is weak correlation between the labor, capital, and total factor productivity estimates, but beyond this, changes in the structural parameters are also largely uncorrelated. Hence, we interpret this as evidence that the structural factors are accounting for largely independent sources of variation.

5 Counterfactual Exercises

The estimation results discussed above illuminate several important trends in the potential drivers of Chinese export patterns. First and foremost, there is a noticeable difference in the dynamic patterns observed in the first half of the sample period as compared with the second half. Declining entry costs, moderate growth in labor productivity, and rapid growth in capital productivity for private Chinese firms are observed primarily between 2000 and 2007. From 2008 onward, entry costs are constant or rising, while factor productivities are typically in secular decline. In addition, throughout the sample period, the economy is characterized by sustained growth in foreign import demand, export marketing costs, quality, and marginal costs of production. To formally quantify how changes in these factors shaped the dynamic patterns of Chinese exporting over the sample period, we now use the structural model developed in section 3 to perform counterfactual exercises.

5.1 Methodology

To begin, note that if one were to solve for the model's equilibrium given the estimated structural parameters, the predicted values of exports R_{dnhsy} would exactly match the corresponding export values in the data by construction. Hence, to quantify the contribution of each structural factor to Chinese exports, we adopt the following approach. First, for each year y, let R_y denote the aggregate value of Chinese exports observed in the data. Then, for each year y and a given set of structural parameters Θ, let $\hat{R}_y^-(\Theta)$ denote the equilibrium value of exports when all structural parameters are set at their estimated values in year y except for Θ, which is set at its estimated value in year $y-1$. We then measure the contribution of changes in Θ to changes in aggregate Chinese exports in each year using the following statistic:

$$\delta_y^-(\Theta) \equiv R_y/R_{y-1} - \hat{R}_y^-(\Theta)/R_{y-1} \tag{71}$$

Intuitively, this measures the decline in percentage growth of aggregate exports between years $y-1$ and y that would result from eliminating changes in Θ between years $y-1$ and y.[31]

[31] In the online appendix, we also provide results based on an alternative counterfactual statistic, $\delta_y^+(\Theta) \equiv \hat{R}_{y-1}^+(\Theta)/R_{y-1} - 1$, where $\hat{R}_y^+(\Theta)$ denotes the equilibrium value of exports when all structural parameters are set at their estimated values in year y except for Θ, which is set at its estimated value in year $y+1$. This measures how many percentage points of aggregate export growth between years $y-1$ and y are accounted for solely by changes in Θ between $y-1$ and y. The main findings that we highlight below are qualitatively similar when looking at either δ_y^- or δ_y^+.

5.2 Results

Table 3 summarizes the main results of our counterfactual simulations. It shows the counterfactual statistic $\delta_y^-(\Theta)$ for the following drivers Θ of Chinese export growth: (i) foreign import demand, E_{dsy}; (ii) foreign market access, P^*_{dsy}/τ_{dsy}; (iii) firm entry,[32] N_{nhsy}; (iv) export marketing costs, f^M_{dnhsy}; (v) employment, L_{hy}; (vi) investment shocks, θ_{nsy}; (vii) imported input prices, P^I_{nsy}; (viii) labor productivity, $T^{;L}_{nsy}$; (ix) capital productivity, T^K_{nsy}; and (x) quality-adjusted TFP, $q_{nsy}T_{nhsy}$. For brevity, we show results for each of these factors in the aggregate, computing the counterfactual statistic $\delta_y^-(\Theta)$ by varying the relevant Θ for *all firms* in the economy. In addition, we compute changes on a year-to-year basis but present average results across four time periods: 2000-2004, 2004-2007, 2007-2010, and 2010-2013. We do so in order to highlight first-order patterns in the counterfactual quantification. In the online appendix, we provide counterfactual results for each factor by year, as well as along each of the relevant dimensions (destinations, ownership, province, and sector). There are several main takeaways from these counterfactual results.

First, changes in foreign import demand were an important positive driver of Chinese export growth throughout the sample period. However, the contribution of foreign import demand fell significantly during the Great Recession of 2008-2009, and only partially recovered from 2010 to 2013. When we examine changes in import demand by each geographic region separately, the decline in the contribution of this factor to aggregate export growth after 2008 is most pronounced for North America and Western Europe, whereas the contribution of import demand from South East Asia recovers quickly to pre-recession levels by 2010. By sector, the decline in the contribution of import demand growth after 2008 is observed across all the main Chinese export sectors, but is most pronounced for machinery.

Second, changes in firm entry were also an important positive factor driving Chinese export growth. This was especially true from 2000 to 2007, with the contribution of firm entry declining slightly from 2008 onwards. When we examine changes in entry separately for firms of different ownership types, we find that entry by private Chinese firms contributed about twice as much to aggregate export growth compared with entry by foreign firms. Changes in entry by state firms, on the other hand, typically had negative effects on aggregate export growth. Firm entry was also a positive driver of aggregate export growth in almost all of the main Chinese export provinces and sectors.

Third, changes in employment were a consistently positive driver of Chinese export growth for most of the sample period (we observe negative contributions in 2012 and 2013). By province, employment growth was most important for aggregate export growth in Guangdong, Jiangsu, and Zhejiang.

Fourth, falling import prices contributed positively to Chinese export growth from 2000 to 2007, but these dynamics reverse after 2008, as rising import prices begin to exert a negative effect on aggregate export growth. By ownership, we observe that falling import prices between 2000 and 2007 were most important in terms of aggregate export growth for foreign firms, but even for these firms, the positive effects of changes in import price dissipate in the second half of the sample period. By sector, the positive contribution of changes in import prices to aggregate export growth are observed almost exclusively in machinery sectors.

Fifth, changes in factor productivities were quantitatively the most important determinants of Chinese export growth. Labor productivity growth was especially important between 2000 and 2007, but these effects dissipate after 2008. Changes in capital productivities, on the other hand, had a consistently negative effect on export growth. In addition, when we examine the net effects of changes in quality and TFP, we find that

[32]To reduce the computational burden of simulating a large number of counterfactuals, we account for firm entry directly through the measures of operating firms N_{nhsy} instead of entry costs f^E_{nhsy}. This allows us to compute the counterfactuals for firm entry by solving for static equilibria (Definition 1) instead of the full dynamic equilibrium (Definition 2).

these factors were most important for aggregate export growth between 2004 and 2010, but by the end of the sample, these contributions decline substantially.

Finally, changes in foreign market access, investment shocks, and export marketing costs were quantitatively less important (and at times negative) contributors to aggregate export growth.

6 Conclusion

In this paper, we have documented that there are significant structural changes underlying the expansion of Chinese exporting over the last two decades. The initial years following China's entry into the WTO (2000-2007) were characterized by: (i) rising foreign demand for Chinese exports; (ii) rapid entry of private Chinese firms into exporting; (iii) sustained improvements in product quality with catch-up by private Chinese and state firms relative to foreign firms; (iv) moderate growth in labor productivity; and (v) substantial growth in productivity of private Chinese firm capital. From 2008 onward, however, many of these dynamic patterns appear to have changed substantially. The period 2008-2013 was characterized by: (i) a slowdown in foreign demand for Chinese exports; (ii) a slowdown in export growth by foreign firms; (iii) a slowdown in entry by both foreign and Chinese firms; and (iv) dissipations in factor productivity and quality growth.

Our quantitative accounting of these drivers of Chinese trade patterns suggest that growth in entry, increased foreign demand, and positive changes in labor productivities were the main factors underlying the rapid growth of Chinese exports between 2000 and 2007. However, stagnation in the dynamics of these same factors were also central to the relative slowdown in Chinese exporting between 2008 and 2013. Consequently, our findings suggest that the future path of the "China shock" very much depends on the dynamics of these key drivers in coming years.

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A Data Construction

A.1 Unit Values

Let s denote a HS-2 category and let Ω_s denote the set of HS-6 products within s. We assume that the unit price index for Chinese exports of sector s products takes the following CES form:

$$P_s = \left(\sum_{n=1}^{N} \sum_{\nu \in \Omega_s} \omega_s(\nu) \, p_{ns}(\nu)^{1-\sigma} \right)^{\frac{1}{1-\sigma}} \tag{72}$$

where $p_{ns}(\nu)$ is the unit price of exports of product ν by $\{n, s\}$ firms. The HS-2 level unit price index for $\{n, s\}$ firms that we are interested in is hence:

$$P_{ns}^{unit} = \left[\sum_{\nu \in \Omega_s} \omega_s(\nu) \, p_{ns}(\nu)^{1-\sigma} \right]^{\frac{1}{1-\sigma}} \tag{73}$$

Now note that the share of product ν in total exports of sector s is:

$$S_s(\nu) \equiv \frac{R_s(\nu)}{\sum_{\nu' \in \Omega_s} R_s(\nu')} = \frac{\omega_s(\nu) \, P_s(\nu)^{1-\sigma}}{P_s^{1-\sigma}} \tag{74}$$

where:

$$P_s(\nu) \equiv \left[\sum_{n=1}^{N} p_{ns}(\nu)^{1-\sigma} \right]^{\frac{1}{1-\sigma}} \tag{75}$$

We then construct the unit price indices P_{ns}^{unit} given data on HS-6 unit values at the ownership-sector level, $p_{ns}(\nu)$, and product shares, $S_s(\nu)$. We do this as follows. First, we set the elasticity of substitution at a baseline value of $\sigma = 2$. Next, we compute the HS-6 price indices $P_s(\nu)$ from (75). Then, from (74), we have:

$$\frac{\omega_s(\nu)}{\omega_s(\nu')} = \frac{S_s(\nu)}{S_s(\nu')} \left[\frac{P_s(\nu)}{P_s(\nu')} \right]^{\sigma-1} \tag{76}$$

Since the right-hand side is known, we compute the weights $\omega_s(\nu)$ using the normalization that $\sum_{\nu \in \Omega_s} \omega_s(\nu) = 1$. Finally, given the weights $\omega_s(\nu)$ and unit values $p_{ns}(\nu)$, we compute the price indices P_{ns}^{unit} from (73).

A.2 Adjustment of Domestic Sales Measure

The sector market clearing condition (45) can be written in terms of sales as:

$$R_{0sy} = R_{sy}^{F} + R_{sy}^{D} + R_{sy}^{M} + R_{sy}^{E} + R_{sy}^{\theta} \tag{77}$$

where $R_{sy}^{x} \equiv P_{sy} M_{sy}^{x}$ for $x \in \{F, D, M, E, \theta\}$. Given values for domestic sales in each sector and year, R_{0sy}, all the parameters of the model can be calibrated using the approach described in section 4. In particular, this yields implied values for expenditures in each sector and year on domestic intermediates R_{sy}^{D}, marketing costs R_{sy}^{M}, entry costs R_{sy}^{E}, and investment R_{sy}^{θ}. We then measure data on final sales in each sector and year, R_{sy}^{F}, from the WIOD tables for China. The sector market clearing condition above then implies a new set of values for domestic sales, $\hat{R}_{0sy}$. Our adjustment procedure for domestic sales involves using the ASM domestic sales data as initial guesses for R_{0sy} and iterating using the above procedure until $\hat{R}_{0sy} = R_{0sy}$.

This requires iteration on the entire estimation procedure described in section 4. In effect, this delivers estimates of domestic sales that ensure the model's predicted values of final sales are consistent with the WIOD data.

A.3 Estimating Firm Counts

To estimate total firm counts N_{nhsy}, we combine the customs data with the ASM data and adopt the following imputation procedure for each $\{n, h, s, y\}$ unit. First, for units with a positive exporter count in customs and a positive exporter count in the ASM, we compute the propensity of exporting in the ASM data as $p^{exp}_{nhsy} = N^{exp,asm}_{nhsy}/N^{asm}_{nhsy}$, and then impute total firm counts as $N_{nhsy} = N^{exp,customs}_{nhsy}/p^{exp}_{nhsy}$.[33] The implicit assumption is that the probability of observing a firm in the ASM is the same for exporters versus non-exporters. This is of course unlikely to hold exactly, since the ASM surveys only above-scale non-state firms and larger firms are more likely to export. Nonetheless, the ASM provides the best available means of measuring export propensities. Second, for units with a positive exporter count in customs and a zero exporter count in the ASM, we compute the propensity of exporting by collapsing the ASM data to the province-sector, ownership-sector, ownership-province, and sector levels, in that order.[34] At each step, we use the aggregated export propensities to impute total firm counts given the observed exporter counts in the customs data. [35] Using this procedure, every $\{n, h, s, y\}$ unit with a positive exporter count in the customs data is assigned an imputed firm count $N_{nhsy} \geq N^{exp}_{nhsy}$. Finally, for units with a zero exporter count in customs and a positive firm count in the ASM, we simply impute $N_{nhsy} = N^{asm}_{nhsy}$. [36]

[33] These units account for around 95% of total export values in the customs data in each year. There are no observations for which ASM export propensity is greater than one.

[34] These units account for less than 5% of total export values in the customs data in each year.

[35] For example, at the sector-province level, the estimated propensity of exporting in the ASM is $p^{exp}_{hsy} = \frac{\sum_{n=1}^{N} N^{exp,asm}_{nhsy}}{\sum_{n=1}^{N} N^{asm}_{nhsy}}$, and the imputed firm count is $N_{nhsy} = N^{exp,customs}_{nhsy}/p^{exp}_{hsy}$.

[36] These units account for around 3% of total output in the ASM data on average across years. Note that within this set of units, there are some units that have a zero exporter count in customs but a positive exporter count in the ASM. These units account for less than 1% of total exports in the ASM on average across years. We treat these as misreported data (in the ASM), and ignore these export values and exporter counts.

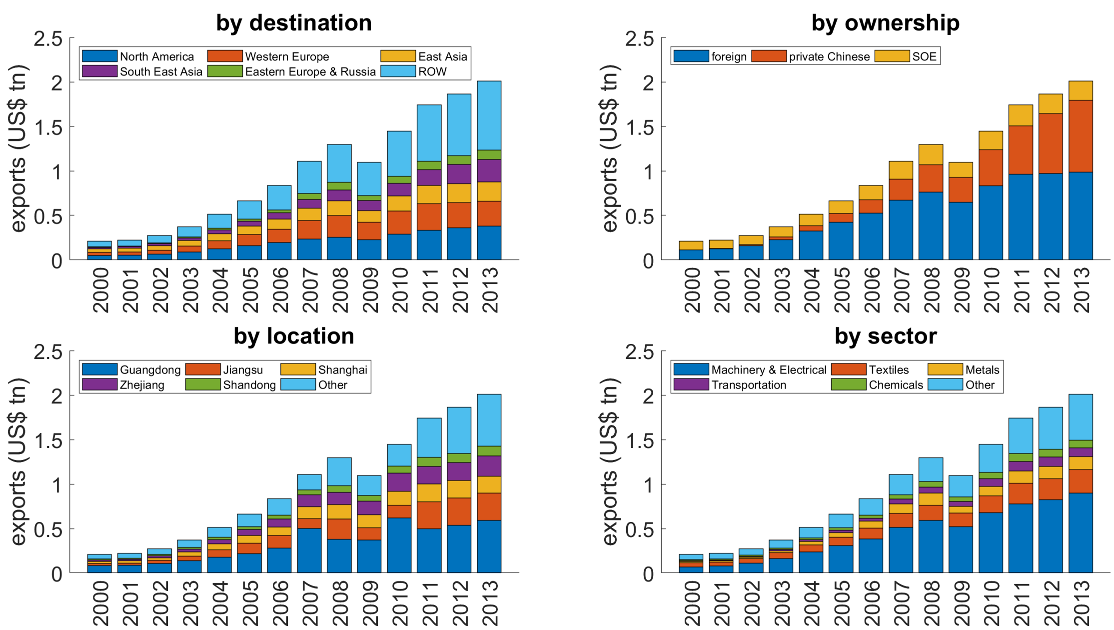


Figure 1: Exports by destination, firm ownership, production location, and sector

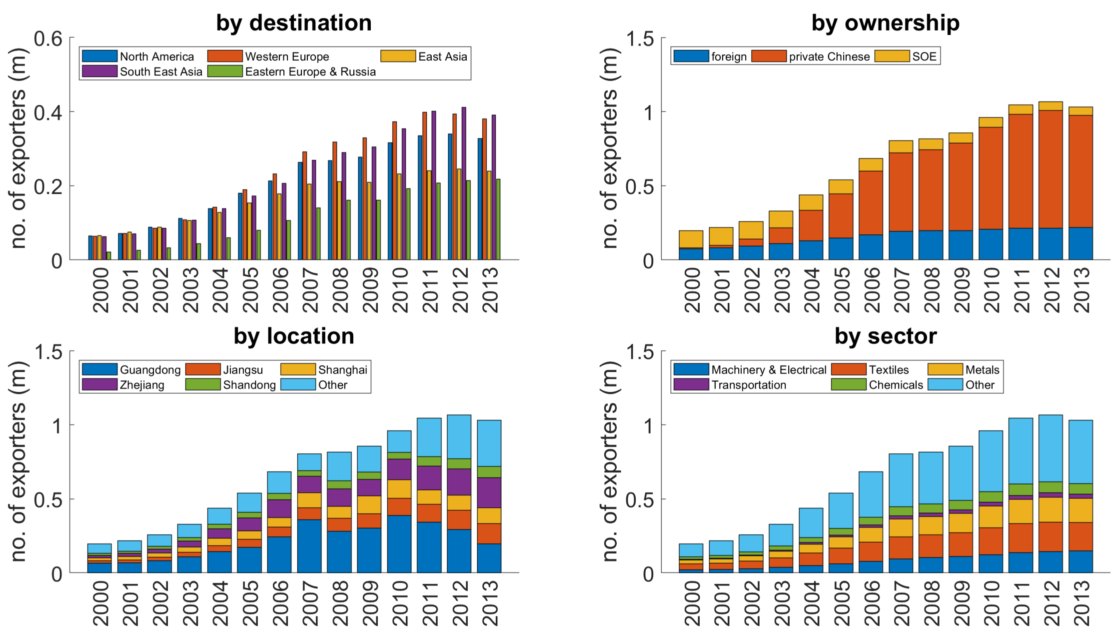


Figure 2: Exporter counts by destination, firm ownership, production location, and sector

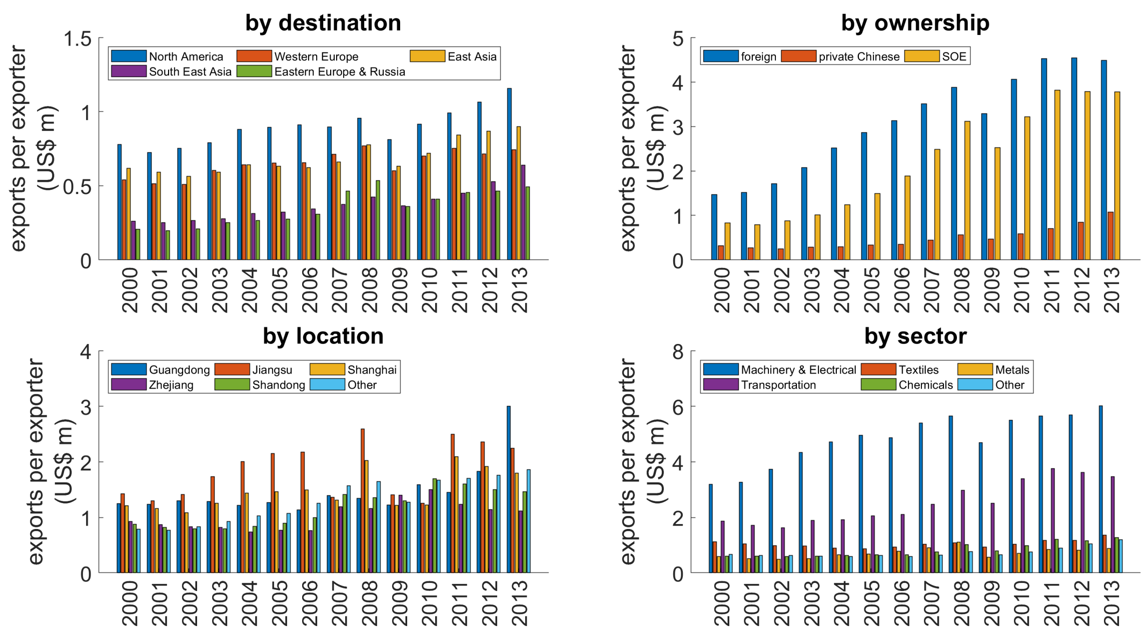


Figure 3: Exports per exporter by destination, firm ownership, production location, and sector

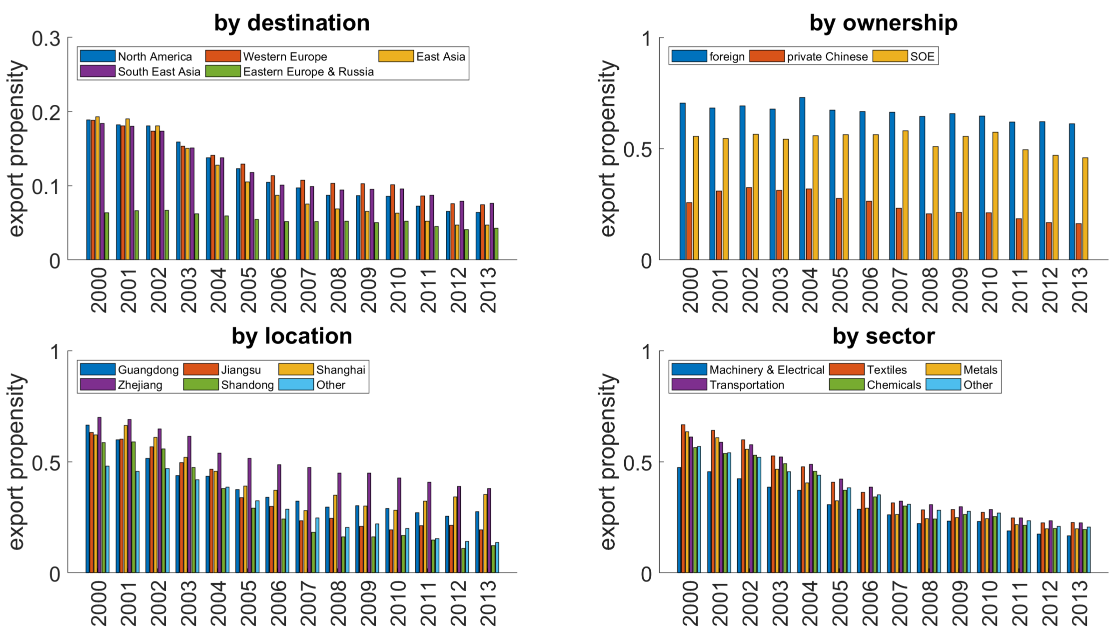
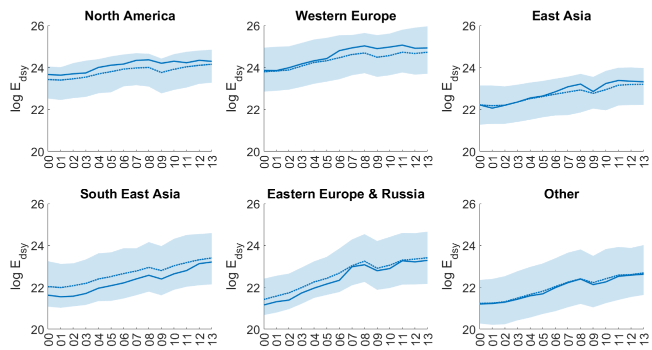


Figure 4: Export propensity by destination, firm ownership, production location, and sector

(a) Foreign Import Demand, By Destination



(b) Foreign Import Demand, By Sector

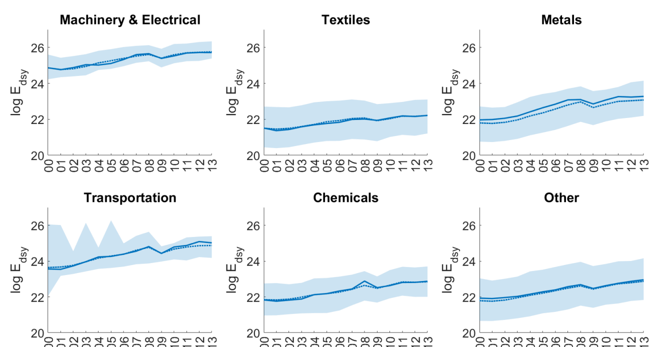
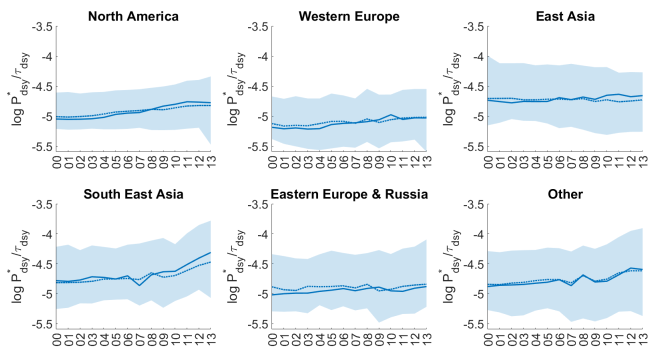


Figure 5: Estimates of foreign demand, E_{dsy}

Note: In each figure, the solid line indicates the median of the statistic across all firms within the respective group and year, the dotted line indicates the mean, and the shaded region indicates the inter-quartile range.

(a) Foreign Market Competition, By Destination



(b) Foreign Market Competition, By Sector

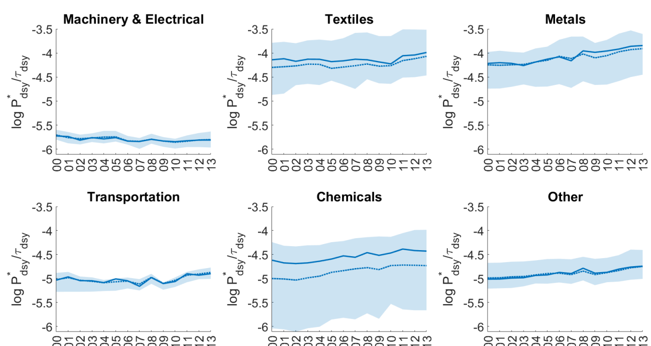
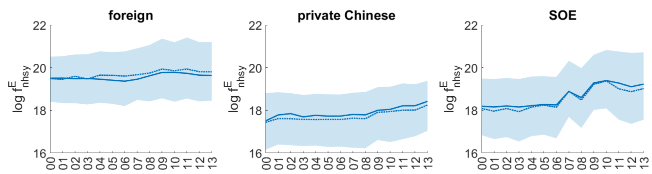


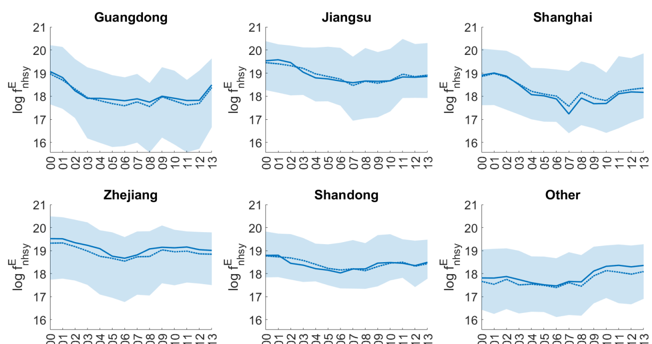
Figure 6: Estimates of foreign competition, P^*_{dsy}/τ_{dsy}

Note: In each figure, the solid line indicates the median of the statistic across all firms within the respective group and year, the dotted line indicates the mean, and the shaded region indicates the inter-quartile range.

(a) Entry Costs, By Ownership



(b) Entry Costs, By Province



(c) Entry Costs, By Sector

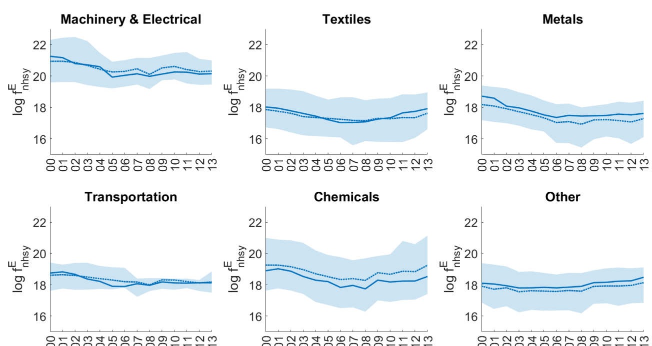


Figure 7: Estimates of entry costs, f^E_{nhsy}

Note: In each figure, the solid line indicates the median of the statistic across all firms within the respective group and year, the dotted line indicates the mean, and the shaded region indicates the inter-quartile range.

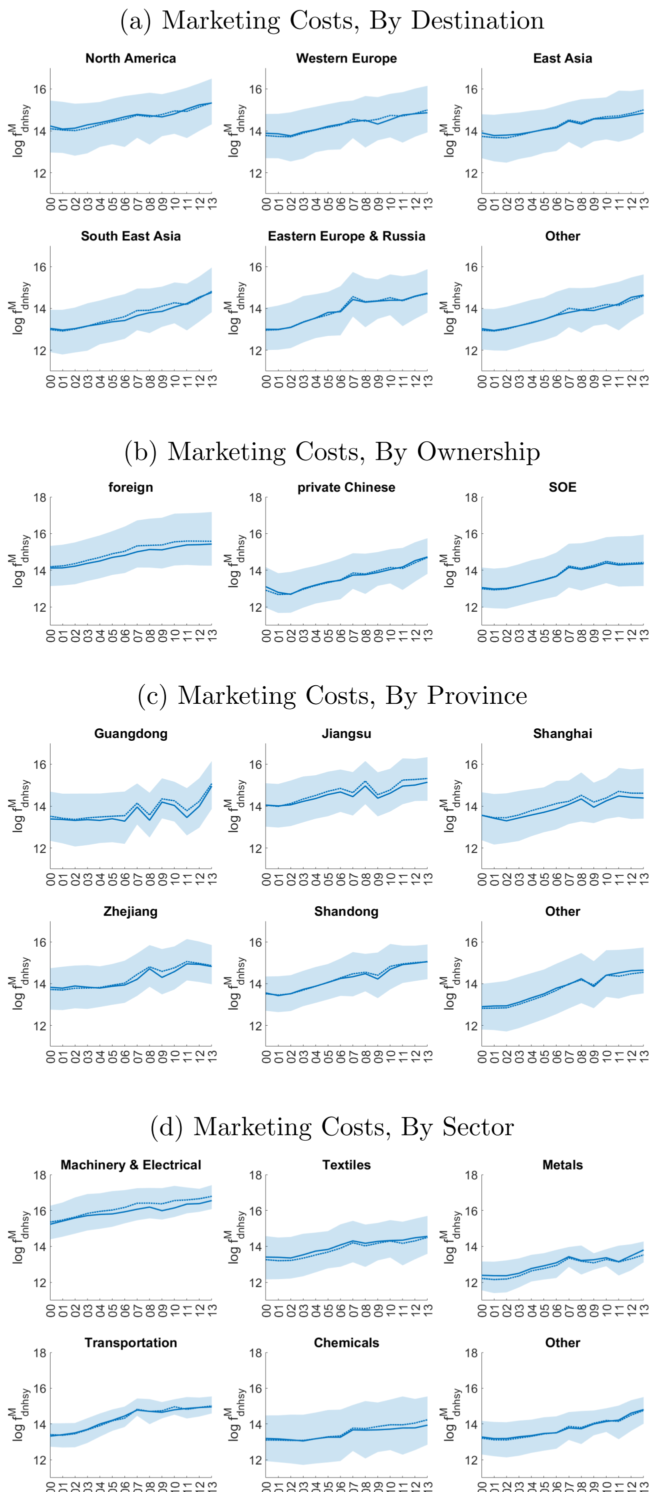
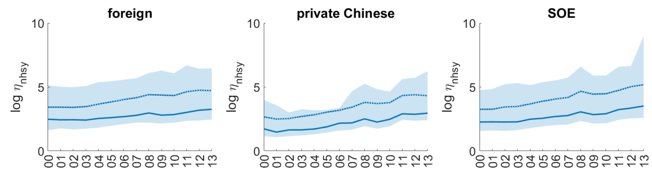


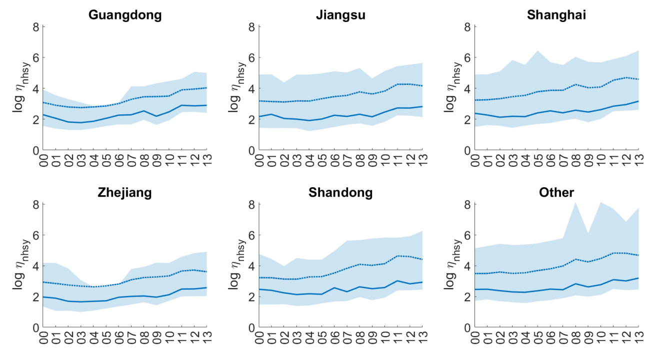
Figure 8: Estimates of marketing costs, f^M_{dnhsy}

Note: In each figure, the solid line indicates the median of the statistic across all firms within the respective group and year, the dotted line indicates the mean, and the shaded region indicates the inter-quartile range.

(a) Marginal Costs, By Ownership



(b) Marginal Costs, By Province



(c) Marginal Costs, By Sector

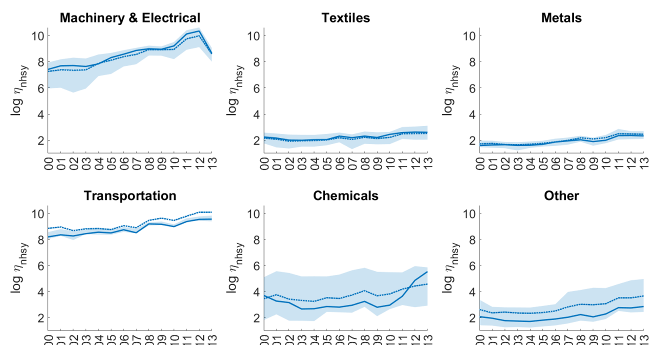
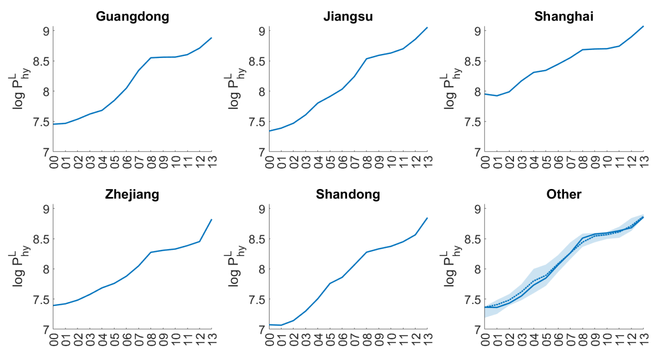


Figure 9: Estimates of marginal costs, η_{nhsy}

Note: In each figure, the solid line indicates the median of the statistic across all firms within the respective group and year, the dotted line indicates the mean, and the shaded region indicates the inter-quartile range.

(a) Wages, By Province



(a) Employment, By Province

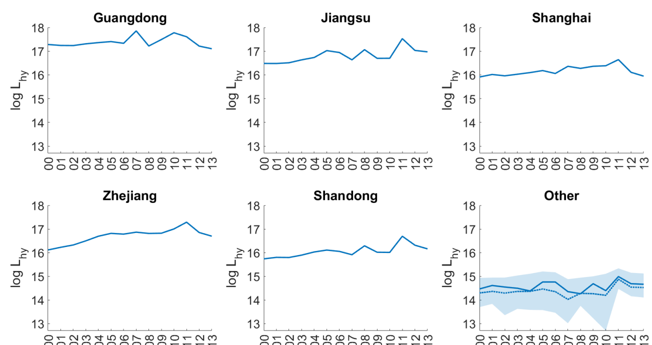
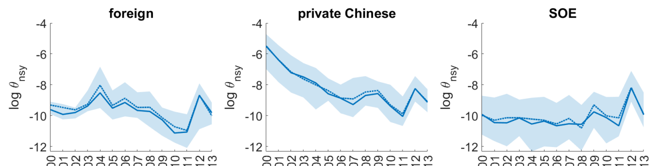


Figure 10: Estimates of wages, W_{hy}, and employment, L_{hy}

Note: In each figure, the solid line indicates the median of the statistic across all firms within the respective group and year, the dotted line indicates the mean, and the shaded region indicates the inter-quartile range.

(a) Investment Shocks, By Ownership



(b) Investment Shocks, By Sector

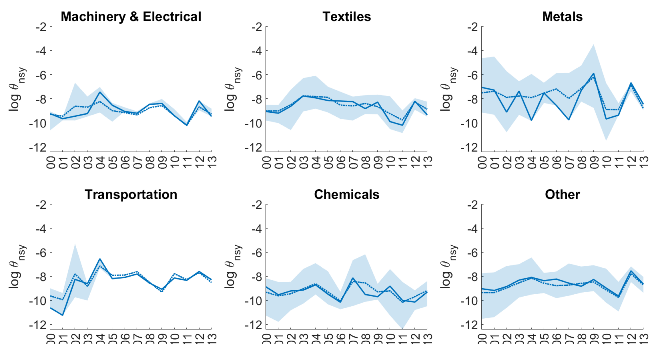
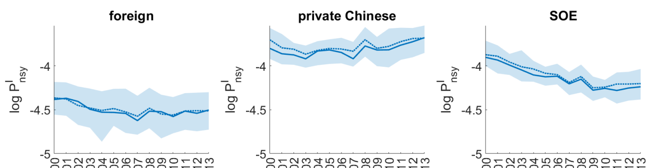


Figure 11: Estimates of investment shocks, θ_{nsy}

Note: In each figure, the solid line indicates the median of the statistic across all firms within the respective group and year, the dotted line indicates the mean, and the shaded region indicates the inter-quartile range.

(a) Import Prices, By Ownership



(b) Import Prices, By Sector

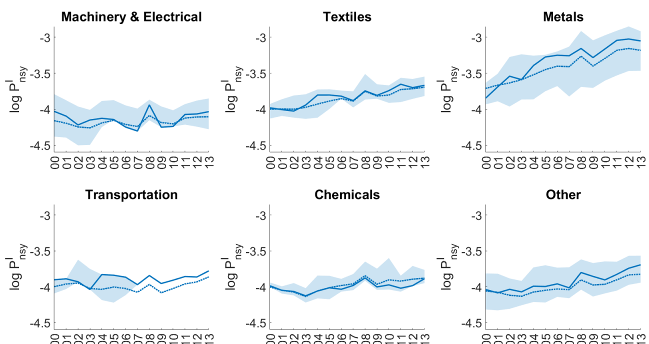
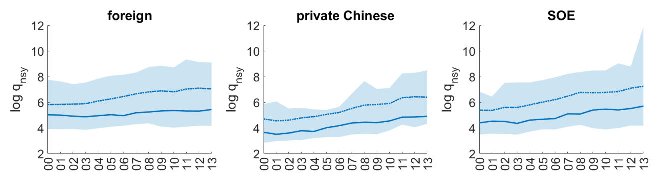


Figure 12: Estimates of imported input prices, P^I_{nsy}

Note: In each figure, the solid line indicates the median of the statistic across all firms within the respective group and year, the dotted line indicates the mean, and the shaded region indicates the inter-quartile range.

(a) Product Quality, By Ownership



(b) Product Quality, By Sector

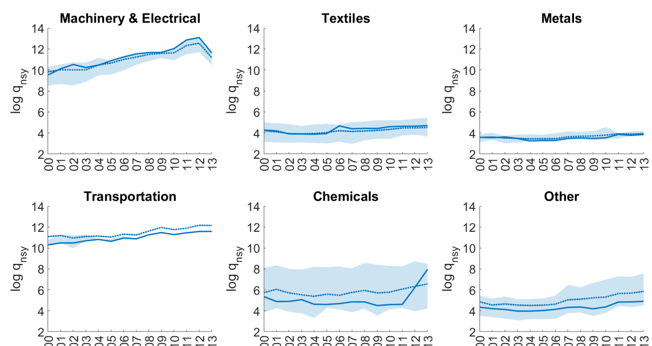
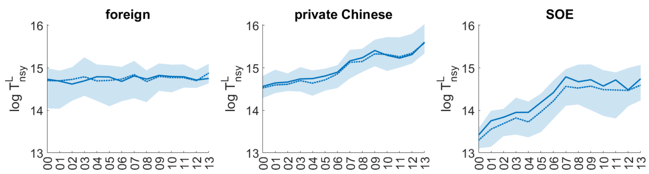


Figure 13: Estimates of product quality, q_{nsy}

Note: In each figure, the solid line indicates the median of the statistic across all firms within the respective group and year, the dotted line indicates the mean, and the shaded region indicates the inter-quartile range.

(a) Labor Productivities, By Ownership



(b) Labor Productivities, By Sector

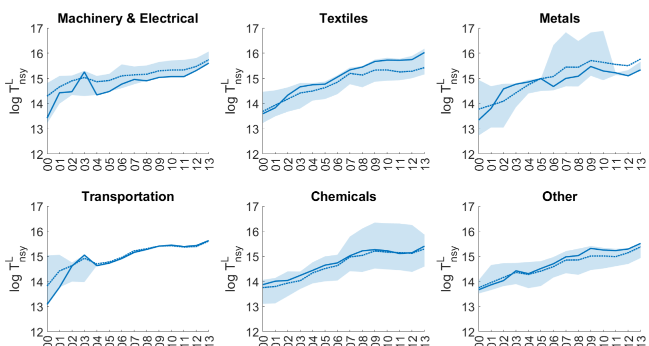
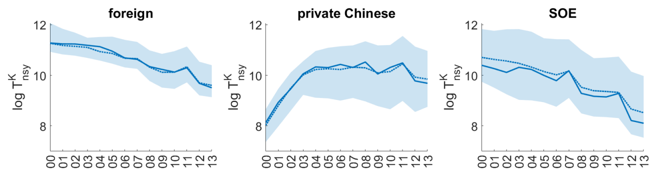


Figure 14: Estimates of labor productivities, T^L_{nsy}

Note: In each figure, the solid line indicates the median of the statistic across all firms within the respective group and year, the dotted line indicates the mean, and the shaded region indicates the inter-quartile range.

(a) Capital Productivities, By Ownership



(b) Capital Productivities, By Sector

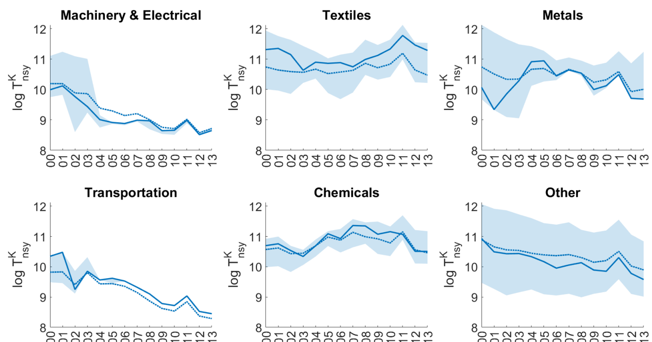
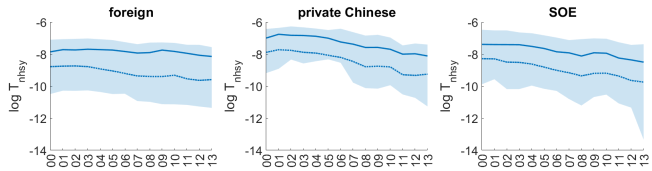


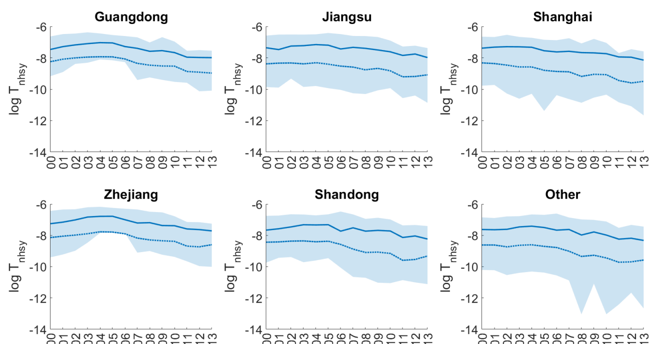
Figure 15: Estimates of capital productivities, T^K_{nsy}

Note: In each figure, the solid line indicates the median of the statistic across all firms within the respective group and year, the dotted line indicates the mean, and the shaded region indicates the inter-quartile range.

(a) Total Factor Productivities, By Ownership



(b) Total Factor Productivities, By Province



(c) Total Factor Productivities, By Sector

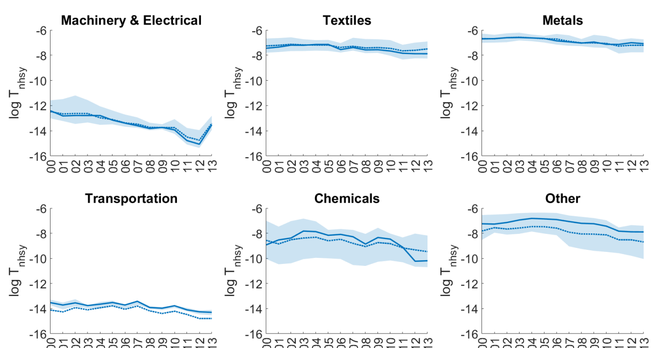


Figure 16: Estimates of total factor productivities, T_{nhsy}

Note: In each figure, the solid line indicates the median of the statistic across all firms within the respective group and year, the dotted line indicates the mean, and the shaded region indicates the inter-quartile range.

	f^{E}_{nhsy}	q_{nsy}	T_{nhsy}	T^{L}_{nsy}	T^{K}_{nsy}	L_{hy}	θ_{nsy}
q_{nsy}	.0021						
T_{nhsy}	.0206	.0008					
T^{L}_{nsy}	-.0136	-.0054	-.0860				
T^{K}_{nsy}	.0034	-.0004	-.0028	-.0014			
L_{hy}	.0114	-.0052	-.0032	.0093	.0024		
θ_{nsy}	-.0005	-.0002	-.0009	.0021	-.0001	-.0005	
P^{I}_{nsy}	-.0809	-.0172	-.0506	.2592	-.0162	-.0403	-.0048

Table 1: Correlations of Structural Estimates in Levels

	Δf^E_{nhsy}	Δq_{nsy}	ΔT_{nhsy}	ΔT^L_{nsy}	ΔT^K_{nsy}	ΔL_{hy}	$\Delta \theta_{nsy}$
Δq_{nsy}	-.0006						
ΔT_{nhsy}	.0834	.0003					
ΔT^L_{nsy}	-.0781	.0183	-.2566				
ΔT^K_{nsy}	-.0216	.0156	-.1991	.1159			
ΔL_{hy}	-.0602	-.0006	.0070	-.0788	.2108		
$\Delta \theta_{nsy}$	-.0012	-.0001	.0006	-.0004	-.0084	-.0012	
ΔP^I_{nsy}	-.1138	-.0071	-.0290	-.1714	.0800	.0631	.0058

Table 2: Correlations of Structural Estimates in Changes

Statistic: δ_y^-	2000-2004	2004-2007	2007-2010	2010-2013
foreign import demand, E_{dsy}	9.6	15.1	4.8	7.2
foreign market access, P^*_{dsy}/τ_{dsy}	-1.1	-4.5	0.6	5.3
export marketing costs, f^M_{dnhsy}	-6.4	-12.0	-12.2	-8.9
firm entry, N_{nhsy}	9.0	12.6	8.1	8.2
employment, L_{hy}	4.0	6.2	6.8	6.0
import prices, P^I_{nsy}	7.7	5.8	-2.2	-1.6
investment shocks, θ^I_{nsy}	3.2	0.9	1.5	0.9
labor productivity, T^L_{nsy}	10.3	13.9	-3.2	6.5
capital productivity, T^K_{nsy}	-9.0	-18.9	-42.4	-62.7
quality-adjusted TFP, $q_{nsy}T_{nhsy}$	5.1	22.6	22.4	-0.3

Table 3: Aggregate counterfacutal statistics, δ_y^-

Note: Values are shown in units of percentage points (%).