Accounting for Chinese Exports*

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October 18, 2019

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, rapid increases in productivity of private Chinese firm capital, and improvements in product quality were the key drivers of Chinese export growth from 2000 to 2006. Although product quality continued to improve from 2007 onward, stagnation in other key drivers of export growth were central to the relative slowdown in Chinese exporting from 2007 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 export growth rate of 474% from 2000 to 2008 compared with a much more meager growth rate of 47% from 2008 to 2016.

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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*Email: brandt@chas.utoronto.ca and kvn.lim@utoronto.ca. We thank workshop participants at CCER Peking University, IESR Jinan University, DIESW Aarhus University, SAET Ischia, CESI Peking University, and the University of Toronto for valuable feedback. We also thank Torsten Sochting Jaccard for excellent research assistance.
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: (i) changes in world demand for Chinese exports; (ii) changes in foreign competition and market access for Chinese firms in Chinese export markets; (iii) changes in costs of entry into export markets for Chinese firms; (iv) changes in costs of firm entry within China; (v) changes in labor costs within China; (vi) capital accumulation by firms in China; (vii) changes in access to imported intermediates for firms in China; and (viii) changes in productivity 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 available data. We then simulate counterfactuals within the model to predict what patterns of Chinese exporting would have looked like in the absence of 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 Sosahara (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 course 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. 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.

\[1\] 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.\textsuperscript{2}

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.\textsuperscript{3} Firm ownership categories \(n\) are \{Foreign, Private Domestic, 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.\textsuperscript{4} 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 large increases in

\textsuperscript{2}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.

\textsuperscript{3}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.

\textsuperscript{4}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 around two log points. 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. This reflects a stark change in the composition of Chinese exports. State-owned Chinese firms were a fairly stagnant source of exports, with an average annual export growth rate of 7.2%.

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 & electrical products, textiles, metals, and transportation goods. The ranking of sectors in terms of export volumes remained fairly stable over time. 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 sectoral composition of Chinese exports does not appear to have changed significantly over the sample period.

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.\(^5\) 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.

\(^5\)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 & 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 \( (P^{*}_{dsy}/\tau_{dsy}) \); (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 \( (\theta_{nhsy}) \) that determine capital accumulation; (vii) access to imported inputs \( (P^{I}_{nsy}) \); and (viii) labor, capital, and material productivities \( (T^{L}_{nhsy}, T^{K}_{nhsy}, T^{M}_{nhsy}) \).

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 \( \phi \). The distribution (CDF) of \( \phi \) 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 \( \phi^{M}_{dnhsy} \) 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.\(^6\) We abstract from population growth, migration within China, and labor supply decisions. Hence, we treat \( L_{hy} \) as exogenous.

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\(^6\) 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.
and $P_{by}^L$ as endogenous. In addition, both capital stocks and prices will be endogenously determined as a result of investment decisions.

### 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 $\sigma_s$ across varieties. Hence, demand in market $d$ for Chinese exports by $\{n, h, s, \phi\}$ firms takes a constant-elasticity form:

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

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:

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

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

$$A_{dsy} = \frac{E_{dsy}}{\left(P_{dsy}^* \right)^{1-\gamma_s} + \left(\tau_{dsy} P_X^{dsy}\right)^{1-\gamma_s}}$$

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.\(^7\)

#### 3.2.2 Domestic demand

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

$$U_{hy} = \prod_{s=1}^S (X_{hys}^F)^{\gamma_s}$$

where $X_{hys}^F$ 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 $E$:

$$\sum_{h=1}^H P_{sy} X_{hys}^F = \gamma_{sy} E_y$$

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.

\(^7\)The demand shifter for the Chinese market $A_{dnh}$ is also endogenous and determined in general equilibrium.
3.3 Production

3.3.1 Firm-level production

Production technologies. Firms produce using four distinct 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 with elasticity of substitution \( \epsilon^V \):

\[
V_{nhsy}(\phi) = \left[ (\omega^V)^{\frac{1}{\epsilon^V}} (T_{nhsy}^L L_{nhsy}(\phi))^\frac{\epsilon^V-1}{\epsilon^V} + (1 - \omega^V)^{\frac{1}{\epsilon^V}} (T_{nhsy}^K K_{nhsy}(\phi))^\frac{\epsilon^V-1}{\epsilon^V} \right]^{\frac{\epsilon^V}{\epsilon^V-1}} \tag{6}
\]

Note that we allow both labor productivity \( T_{nhsy}^L \) and capital productivity \( T_{nhsy}^K \) to vary by ownership-location-sector but assume that these are constant across firms within an \( \{n, h, s\} \)-triplet.\(^8\)

Similarly, each \( \{n, h, s, \phi\} \) firm produces materials \( M_{nhsy}(\phi) \) by combining an imported input bundle \( M_{nhsy}^I(\phi) \) and a domestic input bundle \( M_{nhsy}^D(\phi) \) using a CES production function with elasticity of substitution \( \epsilon^M \):

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

Since we choose not to model production outside China and also abstract from trade costs within China, we assume that the imported input bundle is available at an exogenous price \( P_{nhsy}^I \) that varies by ownership-sector but that is constant across locations and firms within an \( \{n, s\} \)-pair.\(^9\) The domestic input bundle, on the other hand, is assumed to be a Cobb-Douglas aggregate of inputs from all sectors:

\[
M_{nhsy}^D(\phi) = \prod_{s=1}^{S} \left[ M_{nhsy}^{D_{s,s'}}(\phi) \right]^{\alpha_{s,s'}} \tag{8}
\]

where \( M_{nhsy}^{D_{s,s'}}(\phi) \) denotes usage of domestic intermediates from sector \( s' \) and \( \{\alpha_{s,s'}\}_{s,s' \in \Omega_S} \) is the sector-level input-output matrix with \( \sum_{s'=1}^{S} \alpha_{s,s'} = 1 \) for all \( s \in \Omega_S \).\(^{10}\)

Finally, output \( X_{nhsy}(\phi) \) is produced by combining value-added and materials using a CES production function with elasticity of substitution \( \epsilon^X \):

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

Note that we allow materials productivity \( T_{nhsy}^M \) to vary by ownership-location-sector but assume that these are constant across firms within an \( \{n, h, s\} \)-triplet.\(^{11}\)

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\(^8\) Since we allow labor and capital productivities to vary by \( \{n, h, s\} \), we assume without loss of generality that the production function weight \( \omega^V \) is constant across all firms. This weight will play no role in the analysis or quantitative results.

\(^9\) The import price \( P_{nhsy}^I \) reflects 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.

\(^{10}\) We assume a Cobb-Douglas technology in (8) to simplify the calibration of sector-level input-output shares using observable input-output data.

\(^{11}\) As in the value-added production function, we assume without loss of generality that the output production function weight \( \omega^X \) is constant across all firms. This weight will play no role in the analysis or quantitative results. Furthermore, since there are four types of inputs \( \{L_{nhs}, K_{nhs}, M_{nhs}^I, M_{nhs}^D\} \) and four terms that shift productivity of these inputs \( \{T_{nhs}^L, T_{nhs}^K, T_{nhs}^M, T_{nhs}^P\} \), we normalize Hicks-neutral total factor productivity net of \( \phi \) to one.
Production costs  The above assumptions imply that the marginal cost of production for an \(\{n, h, s, \phi\}\) firm is given by:

\[
\eta_{nhsy}(\phi) = \eta_{nhsy}/\phi
\]

where \(\eta_{nhsy}\) is the aggregate component of marginal cost:

\[
\eta_{nhsy} = \left[ \omega^X \left( P^V_{nhsy} \right)^{1-\epsilon^X} + (1 - \omega^X) \left( P^M_{nhsy}/T^M_{nhsy} \right)^{1-\epsilon^X} \right]^{1/(1-\epsilon^X)}
\]

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

\[
P^V_{nhsy} = \left[ \omega^V \left( P^L_{hy}/T^L_{nhsy} \right)^{1-\epsilon^V} + (1 - \omega^V) \left( P^K_{nsy}/T^K_{nhsy} \right)^{1-\epsilon^V} \right]^{1/(1-\epsilon^V)}
\]

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

\[
P^M_{nhsy} = \left[ \omega^M \left( P^I_{nsy} \right)^{1-\epsilon^M} + (1 - \omega^M) \left( P^D_{sy} \right)^{1-\epsilon^M} \right]^{1/(1-\epsilon^M)}
\]

Finally, the domestic intermediate input price is given by:

\[
P^D_{sy} = \prod_{s'=1}^{S} (P^s_{sy})^{a_{ss'}}
\]

where \(P_s\) denotes the price of sector \(s\) output. \(^{12}\)

Furthermore, since firms within an ownership-location-sector are heterogeneous only in terms of Hicke

netural TFP \(\phi\), 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 respectively by:

\[
s^V_{nhsy} = \frac{\omega^X \left( P^V_{nhsy} \right)^{1-\epsilon^X}}{\omega^X \left( P^V_{nhsy} \right)^{1-\epsilon^X} + (1 - \omega^X) \left( P^M_{nhsy}/T^M_{nhsy} \right)^{1-\epsilon^X}}
\]

\[
s^L_{nhsy} = \frac{\omega^V \left( P^L_{hy}/T^L_{nhsy} \right)^{1-\epsilon^V}}{\omega^V \left( P^L_{hy}/T^L_{nhsy} \right)^{1-\epsilon^V} + (1 - \omega^V) \left( P^K_{nsy}/T^K_{nhsy} \right)^{1-\epsilon^V}}
\]

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

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

\(^{12}\)Since we assume that goods are freely tradable across locations in China, the materials price \(P^M_{nhs}\) 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, \(P^I_{ns}\) varies only by sector.
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:

$$R_{dnhsy}(\phi) = \Phi_{dnhsy}(\phi)^{\sigma_s - 1}$$  \hspace{1cm} (18)$$
$$\pi_{dnhsy}(\phi) = \frac{1}{\sigma_s} \Phi_{dnhsy}(\phi)^{\sigma_s - 1}$$  \hspace{1cm} (19)$$

where $\Phi_{dnhsy}$ is an aggregate sales shifter:

$$\Phi_{dnhsy} \equiv A_{dnhsy}(\mu_s \tau_{dsy} \tilde{\eta}_{nhsy})^{1-\sigma_s}$$ \hspace{1cm} (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:

$$R_{dnhsy} = \Phi_{dnhsy} \int_{\phi_{dnhsy}}^{\infty} \phi^{\sigma_s - 1} dG_{nhs}(\phi) N_{nhsy}$$ \hspace{1cm} (21)$$

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

$$C_{nhsy} = \mu_s^{-\sigma_s} \tilde{\eta}_{nhsy}^{1-\sigma_s} N_{nhsy} \sum_{d=0}^{D} A_{dnhsy} \tau_{dsy}^{\sigma_s - 1} \int_{\phi_{dnhsy}}^{\infty} \phi^{\sigma_s - 1} dG_{nhs}(\phi)$$ \hspace{1cm} (22)$$

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

$$P_{L_{hy}L_{nhsy}} = s_{nhsy}^L V_{nhsy} C_{nhsy}$$ \hspace{1cm} (23)$$
$$P_{K_{nsty}K_{nhsy}} = (1 - s_{nhsy}^L) V_{nhsy} C_{nhsy}$$ \hspace{1cm} (24)$$
$$P_{I_{nsy}M_{nsty}I_{nhs'}} = s_{nsty} s_{nhsy} (1 - s_{nhsy}^V) C_{nhsy}$$ \hspace{1cm} (25)$$
$$P_{s'y}M_{nhs's'y} = \alpha_{s's'} (1 - s_{nsty}^I) (1 - s_{nhsy}^V) C_{nhsy}$$ \hspace{1cm} (26)$$

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:

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

Note that the elasticity of substitution in the sectoral production function $\sigma_s$ 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 $q_{nhsy}$ is identical for exports and domestic sales. Domestic demand for output of a $\{n, h, s, \phi\}$ firm is then given by:

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

where the demand shifter is:

$$A_{0sy} \equiv M_{sy} (P_{sy})^{\sigma_s}$$ \hspace{1cm} (29)$$
Since all firms within a sector $s$ charge a constant markup $\mu_s$ over their respective marginal costs, the sector price can be expressed as:

$$P_{sy} = \mu_s \left[ \sum_{n=1}^{N} \sum_{h=1}^{H} N_{nhsy} \hat{h}_{nhsy} \int_{\phi_{0nhsy}}^{\infty} \phi^{\sigma_s - 1} dG_{nhs}(\phi) \right]^{\frac{1}{1-\sigma_s}}$$  \hspace{1cm} (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 $\phi$, 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 $\phi_{dnhsy}^M$ that satisfies the following market entry condition:

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

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

$$P_{dsy} = \mu_s \left[ \sum_{n=1}^{N} \sum_{h=1}^{H} N_{nhsy} \hat{h}_{nhsy} v_{dnhsy} \int_{\phi_{0nhsy}}^{\infty} \phi^{\sigma_s - 1} dG_{nhs}(\phi) \right]^{\frac{1}{1-\sigma_s}}$$  \hspace{1cm} (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:

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

where $I_{nsy}$ denotes investment and $\theta_{nsy}$ 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 $\xi_s$ 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 $P_{nsy}^\theta$ 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 $P_{nsy}^\theta$ 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:

\[
\pi_{n, s}^\theta = \max_{k_{n, s+1}} \left\{ P_{n, s}^k k_{n, s} - P_{s, n}^i k_{n, s} - P_{n, s}^\theta k_{n, s, y-1} \right\}
\]

(34)

s.t. \(k_{n, s} = \frac{(k_{n, s, y-1})}{\xi_s} \left( \frac{\theta_{n, s} i_{n, s}}{1 - \xi_s} \right)^{1 - \xi_s} \)

(35)

The optimal level of aggregate investment is hence:

\[
\frac{I_{n, s}}{K_{n, s, y-1}} = 1 - \xi_s \left( \theta_{n, s} P_{n, s}^k \right)^{1 - \xi_s} \left( \frac{P_{s, n}^i}{P_{s, y}^i} \right)^{\frac{1}{\xi_s}}
\]

(36)

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

\[
\frac{K_{n, s}}{K_{n, s, y-1}} = 1 - \xi_s \left( \theta_{n, s} P_{n, s}^k \right)^{1 - \xi_s} \left( \frac{P_{s, n}^i}{P_{s, y}^i} \right)^{\frac{1}{\xi_s}}
\]

(37)

Furthermore, the free-entry condition for investors requires \(\pi_{n, s}^\theta = 0\), which implies the following investment bid price:

\[
P_{n, s}^\theta = \left( \frac{P_{n, s}^k}{\theta_{n, s} P_{s, n}^i} \right)^{\frac{1}{\xi_s}} \left( \frac{P_{s, n}^i}{P_{s, y}^i} \right)^{\frac{1 - \xi_s}{\xi_s}}
\]

(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 \(f_{n, h, s}^E\) in units of sector output. In addition, firms are subject to an exogenous rate of exit denoted by \(\delta_{n, h, s}\), so that the law of motion for the measure of active \(\{n, h, s\}\) firms is:

\[
N_{n, h, s, y+1} = (1 - \delta_{n, h, s}) N_{n, h, s, y} + N_{n, h, s, y+1}^E
\]

(39)

where \(N_{n, h, s}^E\) denotes the measure of \(\{n, h, s\}\)-entrants at date \(y\).\(^13\) We also assume that idiosyncratic TFP \(\phi\) for \(\{n, h, s\}\) firms evolves according to a stationary Markov process, with TFP values for new entrants drawn from the stationary distribution \(G_{n, h, s}\).

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

\[
\pi_{n, h, s} (\phi) = \sum_{d=0}^D \left[ \pi_{d, n, h, s} (\phi) - P_{s, n}^i f_{d, n, h, s}^M \right] \mathbf{1}_{[\phi \geq \phi_{d, n, h, s}^M]}
\]

(40)

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

\[
V_{n, h, s} (\phi) = \pi_{n, h, s} (\phi) + (1 - \delta_{n, h, s}) \mathbb{E} \left[ \max \left\{ V_{n, h, s, y+1} (\phi'), 0 \right\} \mid \phi \right]
\]

(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 $\phi$. 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 $\phi$ 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):

$$V_{nhsy} = \bar{\pi}_{nhsy} + (1 - \delta_{nhsy}) V_{nhs,y+1}$$

(42)

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

$$P_{sy} f^E_{nhsy} = V_{nhsy}$$

(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 $d \in \Omega_D$:

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

(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 $M^\theta_{sy}$:

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

(45)

where the components of sector-level demand are:

$$M^F_{sy} = \sum_{h=1}^H X^F_{hnsy}$$

(46)

$$M^D_{sy} = \sum_{n=1}^N \sum_{h=1}^H \sum_{s'=1}^S M^D_{nhs'sy}$$

(47)

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

(48)

$$M^E_{sy} = \sum_{n=1}^N \sum_{h=1}^H N^E_{nhsy} f^E_{nhsy}$$

(49)

$$M^\theta_{sy} = \sum_{n=1}^N J_{nysy}$$

(50)

Market clearing for local labor in location $h$ requires:

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

(51)
while market clearing for \( \{n, s\} \)-capital requires:

\[
\sum_{h=1}^{H} N_{nhsy} K_{nhsy} = K_{nsy} \quad (52)
\]

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

\[
E_y = \sum_{h=1}^{H} P_{hys} L_{hsy} + \sum_{n=1}^{N} S \sum_{s=1}^{S} P_{nsy} K_{ns,y-1} + \sum_{n=1}^{N} \sum_{h=1}^{H} S \sum_{s=1}^{S} (N_{nhsy} \tilde{p}_{nhsy} - N_{nhsy} f_{nhsy}^E P_{sy}) + D_y \quad (53)
\]

where the trade deficit is given by:

\[
D_y = \sum_{n=1}^{N} \sum_{h=1}^{H} S \sum_{s=1}^{S} P_{nsy}^M M_{nhsy}^I - \sum_{d=1}^{D} \sum_{n=1}^{N} \sum_{h=1}^{H} S \sum_{s=1}^{S} R_{dnhsy} \quad (54)
\]

### 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 \( \{N_{nhsy}, N_{nhsy}^E\} \) and existing capital stocks \( K_{ns,y-1} \), a static equilibrium with fixed entry at date \( y \) is a set of sector prices \( \{P_{sy}, P_{Xsy}\} \), factor prices \( \{P_{Vnhsy}, P_{Knhsy}, P_{Mnhsy}, P_{Dnhsy}\} \), investment contract prices \( P_{nys}^0 \), marginal costs \( \eta_{nhsy} \), factor shares \( \{s_{Vnhsy}, s_{Knhsy}, s_{Mnhsy}, s_{Dnhsy}\} \), factor demands \( \{I_{nhsy}, K_{nhsy}, M_{nhsy}^I, M_{nhsy}^D\} \), sector output quantities \( M_{sy} \), domestic and foreign demand shifters \( A_{dsy}, A_{dsy}^F \), aggregate exports \( R_{dnhsy} \), aggregate costs \( C_{nhs} \), sales shifters \( \Phi_{dnhs} \), market entry cutoffs \( o_{dnhs}^M \), 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 \( \{N_{nhs0}, N_{nhs0}^E\} \), initial capital stocks \( K_{nst0} \), and terminal continuation values \( V_{nhs,Y+1} \), 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 \( \{N_{nhsy}, N_{nhsy}^E, V_{nhsy}\} \) for each date \( y \) that satisfies (39), (42), and (43).
4 Estimation 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 Estimation 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, \( P^s_{dsy} \); (iii) trade costs, \( \tau_{dsy} \); (iv) product qualities, \( q_{nsy} \); (v) market entry costs, \( f^M_{dnhsy} \); (vi) employment, \( L_{hy} \); (vii) investment shocks, \( \theta_{sy} \); (viii) imported input prices, \( P^I_{nsy} \); (ix) labor, capital, and material productivities, \( \{T^L_{nhsy}, T^K_{nhsy}, T^M_{nhsy}\} \); (x) firm entry costs, \( f^E_{nhsy} \); (xi) firm exit rates, \( \delta_{nhsy} \); (xii) the time discount factor \( \beta \); (xiii) elasticities of substitution across varieties within each sector, \( \sigma_s \); (xiv) elasticities of substitution in the firm-level production functions, \( \{\epsilon^X, \epsilon^V, \epsilon^M\} \); (xv) factor weights in the firm-level production functions, \( \{\omega^X, \omega^V, \omega^M\} \); (xvi) sector-level consumption shares, \( \gamma_s \); (xvii) sector-level input-output shares, \( \alpha_{ss'} \); (xviii) investment shares in capital formation, \( \xi^s \); and (ixx) idiosyncratic TFP distributions, \( G_{nhs} \). To estimate these parameters, we utilize several sources of data that are summarized in Table 1. The dimensions \( \{d, n, h, s\} \) used in the estimation are the same as those described in section 2.2, and the estimation proceeds in six stages.

4.1.1 Parameters directly observable from data

In the first stage, we calibrate a set of parameters directly from data. We assume that \( G_{nhs} \) is the CDF of a log-normal distribution with zero mean, and calibrate the standard deviation of each distribution \( \sigma_{\phi,nhs} \) as well as the elasticity of substitution for each sector \( \sigma_s \) using measures of sales and TFP dispersions.\(^{14}\) 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 employment at the province level, capital stocks at the ownership-sector level, and exit rates at the ownership-province-sector level from the ASM data to calibrate \( L_{hy}, K_{nsy}, \) and \( \delta_{nhsy} \) respectively.\(^{15}\) 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.\(^{16}\) 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 \( \omega^X = \omega^V = \omega^M = \frac{1}{3} \), 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, since the firm-level production function substitution elasticities are not identified by our methodology below, we set these at \( \epsilon^X = \epsilon^V = \frac{1}{2} \) (implying that capital, labor, and materials are complements to one another) and \( \epsilon^M = 5 \) (implying that imported and domestic materials are substitutes). We explore robustness of our quantitative results to different choices of these substitution elasticities in the online appendix.

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\(^{14}\)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 \( \phi \) 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 \( \sigma_s - 1 \).

\(^{15}\)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.

\(^{16}\)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.
4.1.2 Controlling for entry

In the second stage of the estimation, we solve for $\phi_{dnhsy}^M$, $f_{dnhsy}^M$, and $\Phi_{dnhsy}$ from (21), (31), and the fraction of exporters to a market:

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

(55)

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

(56)

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

(57)

This stage 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 $\Phi_{dnhsy}$. This also yields values for the nominal marketing costs $P_{sy} f_{dnhsy}^M$, which we will use to compute real marketing costs below.

4.1.3 Separating market access from quality-adjusted marginal cost

In the third stage, we decompose the sales shifter $\Phi_{dnhsy}$ obtained from above into the following components:

$$ \Phi_{dnhsy} = \mu_{1-\sigma_s} \times \frac{A_{dsy}^{1-\sigma_s}}{\text{destination-sector-year}} \times \frac{\bar{\eta}_{nhsy}}{\text{ownership-location-sector-year}} \times \nu_{dnhsy} \times \text{residual} $$

(58)

where $A_{dsy}^{1-\sigma_s}$ can be interpreted as a market access term and $\bar{\eta}_{nhsy} = \eta_{nhsy}/q_{nhsy}$ 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 $\nu_{dnhsy}$ are uncorrelated with both market access and quality-adjusted marginal cost. Note that this implies a restriction on the manner in which market access 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 market access term $A_{dsy}^{1-\sigma_s}$ directly for North America ($d = NA$). 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 $P_{NA,sy} = \left( \left( P_{NA,sy}^* \right)^{1-\sigma_s} + (P_{NA,sy})^{1-\sigma_s} \right)^{\frac{1}{1-\sigma_s}}$. 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 $A_{NA, sy}^{1-\sigma_s} \tau_{NA, sy}^{1-\sigma_s} = 1$ in the first year of our analysis for every sector and use growth rates of $A_{NA, sy}^{1-\sigma_s} \tau_{NA, sy}^{1-\sigma_s}$ relative to the base year as our normalization for the fixed-effects regression of equation (58).

17 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.

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

19 Note that since we are utilizing only growth rates of $A_{NA, sy}^{1-\sigma_s} \tau_{NA, sy}^{1-\sigma_s}$ for the normalization, any components of this term that
4.1.4 Separating quality from cost

In the fourth stage, we decompose our estimates of quality-adjusted marginal costs $\tilde{\eta}_{nhsy}$ into product qualities $q_{nsy}$ and marginal costs $\eta_{nhsy}$. 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:

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

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:

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

(60)

Hence, solving for $q_{nsy}$ gives:

$$q_{nsy} = \frac{P_{nsy}^u \tilde{X}_{nsy}}{\tilde{R}_{nsy}}$$

(61)

where $\tilde{X}_{nsy} = \sum_{d=1}^{D} \sum_{h=1}^{H} \Phi_{dnhsy} \mu_s q_{nsy} \tilde{\eta}_{nhsy}$ is quality-adjusted export quantity. Given $q_{nsy}$, we can then recover marginal costs $\eta_{nhsy} = \tilde{\eta}_{nhsy} q_{nsy}$.

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.\(^{20}\) Hence, as in the literature on export quality estimation (e.g. Khandelwal (2010)), firms that have higher export sales within a given destination-sector conditional on price are assigned higher quality.

4.1.5 Calibrating prices and production function parameters

In the fifth stage, we calibrate the remaining prices in the model as well as the parameters of the firm-level production functions. First, we compute domestic sector prices $P_{sy}$ and export prices $P_{dsy}^X$ from (30) and (32) given the estimates of $\tilde{\eta}_{nhsy}$ and $\phi_{dnhsy}^M$ above. Using our estimates of $A_{dsy} \tau_{dsy}^{1-\sigma_s}$ from (58) and $E_{dsy}$ from UN COMTRADE data, we then recover the foreign competition statistic $P_{dsy}^*$ relative to the iceberg trade cost from (2):

$$\left( \frac{P_{dsy}^*}{\tau_{dsy}} \right)^{1-\sigma_s} = \frac{E_{dsy}}{A_{dsy} \tau_{dsy}^{1-\sigma_s}} - P_{dsy}^{1-\sigma_s}$$

(62)

The estimates of $P_{sy}$ also allow us to compute real marketing costs from estimates of $P_{sy} \phi_{dnhsy}^M$ in (56).

Next, since total domestic sales in sector $s$ are given by $P_{sy} M_{sy}$, we use measures of domestic sales (total

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\(^{20}\)Prices also include markups, but these are assumed to be constant within a sector.

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.
sales minus exports) at the sector level from the ASM data to back out the implied output quantities \( M_{sy} \). This allows us to compute the implied domestic demand shifter \( A_{nhsy} \) from (29) and hence aggregate costs \( C_{nhsy} \) from (22). We then measure value-added shares of total cost \( s^V_{nhsy} \) and labor shares of value-added \( s^L_{nhsy} \) directly from the ASM data. With measures of total costs, factor shares, and factor stocks, we can then compute the prices of labor and capital from the factor demand equations (23)-(24) and factor market clearing conditions (51)-(52):

\[
P^L_{hy} = \frac{\sum_{n=1}^N \sum_{s=1}^S \frac{s^L_{nhsy} s^V_{nhsy} C_{nhsy}}{L_{hy}}}{L_{hy}}
\]

\[
P^K_{ns} = \frac{\sum_{h=1}^H \left(1 - s^L_{nhsy}\right) s^V_{nhsy} C_{nhsy}}{K_{nhsy}}
\]

Similarly, we compute import shares \( s^I_{nsy} \) as the ratio of total import expenditure in the customs data to total materials expenditure in the ASM data. This allows us to calibrate the imported input prices from (17) as:

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

where the domestic intermediate input price index \( P^D_{sy} \) is computed from (14).

In addition, measures of the sector and capital prices allow us to calibrate the investment shocks from (37) as:

\[
\theta_{nsy} = \left(\frac{\xi_s K_{nhsy}}{K_{nhsy, y-1}}\right)^{\frac{\xi_s}{\eta_{nhsy}}} \frac{P_{sy}}{P^K_{nsy}}
\]

while the investment contract price \( P^\theta_{nsy} \) is given by (38).

Finally, given factor prices and factor shares, we calibrate factor productivities by inverting the factor share equations (15)-(17):

\[
T^L_{nhsy} = \left(\frac{s^L_{nhsy}}{\omega^V}\right)^{\frac{1}{1 - \epsilon^V}} \left(\frac{s^V_{nhsy}}{\omega^X}\right)^{\frac{1}{1 - \epsilon^X}} \frac{P^L_{hy}}{\eta_{nhsy}}
\]

\[
T^K_{nhsy} = \left(\frac{1}{1 - \omega^V}\right)^{\frac{1}{1 - \epsilon^V}} \left(\frac{s^V_{nhsy}}{\omega^X}\right)^{\frac{1}{1 - \epsilon^X}} \frac{P^K_{nsy}}{\eta_{nhsy}}
\]

\[
T^M_{nhsy} = \left(\frac{1}{1 - \omega^X}\right)^{\frac{1}{1 - \epsilon^X}} \left(\frac{1}{1 - \omega^M}\right)^{\frac{1}{1 - \epsilon^M}} \frac{P^D_{sy}}{\eta_{nhsy}}
\]

---

21 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.

22 To compute \( s^V_{nhsy} \), we measure ratios of value-added to gross output and scale these by \( \mu_x \). To compute \( s^L_{nhsy} \), 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 scale total labor costs in each sector by a sector-specific time-invariant factor such that the average labor share in each sector from 2000-2006 matches the corresponding (time-invariant) labor share reported in Hsieh and Klenow (2009).

23 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.
There are two ways of interpreting the identification of factor productivities in (67)-(69). First, conditional on observed factor shares, factor productivities are estimated to be higher if the estimated factor prices are high relative to overall marginal costs. Second, conditional on factor prices and marginal costs, variation in estimated factor productivities is driven by variation in observed factor shares.

4.1.6 Calibrating firm entry costs

Conditional on the measures of operating firms $N_{nhsy}$ in each year, the static factors can be estimated year-by-year using the procedure described above. In the final calibration stage, we compute $V_{nhsy}$ from equation (42) and calibrate the firm entry costs $f_{nhsy}^E$ using the entry condition (43). Note that this requires values for the terminal continuation values $V_{nhsy,Y+1}$ 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%.

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.

4.2.1 Foreign import demand, $E_{dsy}$

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 (2000-2006) for all the main Chinese export markets. However, over the second half of the sample period (2007-2013), 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 2006 and noticeable slower growth from 2007 onward.

4.2.2 Foreign market competition, $P_{dsy}^*/\tau_{dsy}$

Figure 6 shows the estimates of foreign competition prices $P_{dsy}^*/\tau_{dsy}$ by destination market $(d)$ and sector $(s)$. These prices should be interpreted as partially reflecting Chinese market shares in each destination-sector market: given values for the Chinese export price index $P_{dsy}$, China’s market share for sector $s$ in destination $d$ is monotonically increasing in $P_{dsy}^*/\tau_{dsy}$. Hence, larger values of $P_{dsy}^*/\tau_{dsy}$ 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, foreign competition prices rise 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 face tougher competition
in Western Europe, Eastern Europe, and Russia relative to the other major export markets. At the sector level, foreign competition prices are fairly stable over time, although there is substantial heterogeneity in the levels of these prices across sectors. Specifically, firms from China are relatively less competitive in the machinery & electrical sectors and are relatively more competitive in the textiles and metals sectors.

4.2.3 Firm entry costs, $f_{E_{nhsy}}$

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 are reflecting the fact that despite high rates of firm entry, the average value of a firm experienced moderate growth. For example, between 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 one log point higher in the main coastal export provinces than in other provinces. 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 two log points) in the machinery and electrical sectors than in other sectors.

4.2.4 Export marketing costs, $f_{M_{dnhsy}}$

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.

4.2.5 Marginal costs, $\eta_{nhsy}$

Figure 9 shows the estimates of marginal costs $\eta_{nhsy}$ 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).

4.2.6 Wages, $P_{ny}^L$

Figure 10 shows the estimates of wages $P_{ny}^L$ 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 11.6%. This is despite the fact that labor supplies were also increasing steadily throughout the period, which average annual employment growth of 5.6% across all provinces and 8.0% across the top five export provinces. There is also substantial cross-sectional heterogeneity in wages across provinces, with the highest average log wages observed in Shanghai, Guangdong, and Beijing. To validate our estimates of wages, we also measure unit wages at the province-year level from the ASM data by computing the ratio of total labor costs to total employment. The correlation of log wages within a province across years implied by the model and measured in the ASM data is 0.50 on average across all provinces and 0.90 on average across the top five Chinese export provinces.

4.2.7 Investment shocks, $\theta_{nsy}$

Figure 11 shows the estimates of investment shocks $\theta_{nsy}$ 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 (66), 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 32.3%. 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 1.9% 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 $\theta_{nsy}$ must have been declining for private Chinese firms during this time.

4.2.8 Imported input prices, $P_{nsy}^I$

Figure 12 shows the estimates of imported input prices $P_{nsy}^I$ 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. Interestingly, we also observe that these import shares decline for all firm ownership types: by the end of the sample, 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. These declines are driven in
part by falling prices of domestic intermediates. Hence, we observe that estimated import prices are fairly constant (or even declining for state firms) despite the 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.

4.2.9 Product quality, $q_{nsy}$

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.

4.2.10 Factor productivities, $\{T^L_{nh,y}, T^K_{nh,y}, T^M_{nh,y}\}$

Finally, Figures 14, 15, and 16 show the estimates of labor productivity $T^L_{nh,y}$, capital productivity $T^K_{nh,y}$, and material productivity $T^M_{nh,y}$ respectively, by ownership $(n)$, production location $(h)$, and sector $(s)$.

At the ownership level, we first observe that median labor productivities are fairly constant or moderately declining for all three ownership types. The average annual growth rate of median labor productivity between 2000 and 2013 is estimated to be $-1.1\%$ for foreign firms and $2.5\%$ for state firms. There is positive growth in median labor productivity for private Chinese firms in the first year of the sample, but this is followed by an average annual growth rate of $-6.4\%$ in subsequent years. Second, median capital productivities are estimated to decline at average annual growth rates of $-18.7\%$ for foreign firms and $-25.9\%$ for state firms. For private Chinese firms, the first half of the sample is characterized by high growth of median capital productivity, with an average annual growth rate of 67.6% between 2000 and 2006. However, this trend reverses after 2006, with an average annual growth rate of $-18.8\%$ between 2007 and 2013. Third, material productivities are estimated to decline for all three ownership types, with annual average growth rates of median material productivities of $-10.5\%$ for foreign firms, $-15.4\%$ for private Chinese firms, and $-14.1\%$ for state firms. In sum, we estimate that median factor productivities were generally constant or declining for all three firm ownership types, with the one notable exception being a period of high growth in capital productivity for private Chinese firms between 2000 and 2006.\footnote{We also examine the dynamics of quality-adjusted factor productivities - for example, quality-adjusted labor productivity defined as $T^L_{nh,y} q_{nsy}$. Adjusting for quality, we find: (i) average annual growth rates of median labor productivity are 4.0% for foreign firms, 11.6% for private Chinese firms, 10.8% for state firms; (ii) average annual growth rates of median capital productivity are $-5.3\%$ for foreign firms, 52.1% for private Chinese firms between 2000 and 2006 and $-2.9\%$ between 2007 and 2013, and $-8.6\%$ for state firms; and (iii) average annual growth rates of median labor productivity are 1.0% for foreign firms, 0.2% for private Chinese firms, 1.9% for state firms.}

At the province level, growth in labor productivity is observed mainly between 2000 and 2006. From 2007 onwards, median labor productivities are either constant or declining in the main Chinese export provinces. Capital and materials productivities, on the other hand, exhibit more secular declines throughout the sample.
period in most provinces. We observe qualitatively similar factor productivity dynamics at the sector level as well.

Note from equations (67)-(69) that we infer values of factor productivities based on two drivers: factor shares and the ratio of factor prices to marginal cost. Hence, to interpret the dynamics of estimated factor productivities, we note the following. First, value-added shares of total production costs were rising substantially across all firm ownership types throughout the sample period: 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. 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. Finally, with regard to factor prices, we observe the following: wages were typically growing faster than marginal costs throughout the period; capital prices were fairly constant for foreign firms, for private firms after 2007, and for state firms, but were rising rapidly for private Chinese firms between 2000 and 2007; and domestic materials prices were in decline.

Taken together, these findings offer the following interpretation of productivity dynamics. First, low to negative growth in labor productivity is driven primarily by the rapid rise in observed value-added shares, which implies higher prices of value-added under our assumption that value-added and materials are complements. Second, negative growth in capital productivity is driven by rising value-added shares and falling labor shares - the latter implies higher productivity-adjusted prices of capital under our assumption that capital and labor are complements. For private Chinese firms between 2000 and 2007, these forces were offset by rapid growth in capital prices at an average annual rate of 87.7%, implying high growth rates of capital productivity during this period. Finally, negative growth in materials productivity is driven primarily by falling domestic materials prices and rising marginal costs.

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 2006. From 2007 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 several approaches. 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 $\xi$, let $\hat{R}_y(\xi)$ denote
the equilibrium value of exports when all structural parameters are set at their estimated values in year $y$ except for $\xi$, which is set at its estimated value in year $y + 1$. Similarly, let $\hat{R}_y^-(\xi)$ denote the equilibrium value of exports when all structural parameters are set at their estimated values in year $y$ except for $\xi$, which is set at its estimated value in year $y - 1$. We then measure the contribution of changes in $\xi$ to changes in aggregate Chinese exports in each year using the following two statistics:

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

$$\delta_y^+ (\xi) \equiv \hat{R}_{y-1}^+ (\xi) / R_{y-1} - 1$$

Intuitively, the first statistic $\delta_y^- (\xi)$ measures how many percentage points of aggregate export growth between years $y - 1$ and $y$ are accounted for solely by changes in $\xi$ between $y - 1$ and $y$. Similarly, the second statistic $\delta_y^+ (\xi)$ measures the decline in percentage growth of aggregate exports between years $y - 1$ and $y$ that would result from eliminating changes in $\xi$ between years $y - 1$ and $y$.

### 5.2 Results

Tables 2-12 show the results of our counterfactual simulations for the following eight drivers of Chinese export growth: (i) foreign import demand, $E_{dsy}$; (ii) foreign competition in Chinese export markets, $P_{dsy}/R_{dsy}$; (iii) firm entry; $N_{nhsy}$; (iv) export marketing costs, $f_{dnsy}^M$; (v) employment, $L_{by}$; (vi) investment shocks, $\theta_{nasy}$; (vii) imported input prices, $P_{nsp}^I$; (viii) product quality, $q_{nasy}$; and (ix) factor productivities, $\{T_{nhsy}^L, T_{nhsy}^K, T_{nhsy}^M\}$. For brevity, these tables show results only for the statistic $\delta_y^-$, while results for $\delta_y^+ (\xi)$ are relegated to the online appendix.

Each table shows the counterfactual estimates for a particular factor, both in the aggregate and along each of the relevant dimensions (destinations, ownership, province, and sector). As a concrete example, Table 2 for foreign demand $E_{dsy}$ shows the following. The first row of results shows estimates for $\delta_y^-$ holding constant (across each consecutive pair of years) $E_{dsy}$ for all destinations and sectors. The second block of results shows estimates for $\delta_y^-$ holding constant $E_{dsy}$ for different sets of destinations. The third block of results shows estimates for $\delta_y^-$ holding constant $E_{dsy}$ for different sets of sectors.

There are several main takeaways from these counterfactual results. First, in the aggregate, foreign import demand growth, less intense foreign competition, high rates of firm entry, and improvements in product quality were all important positive drivers of the rise in Chinese exports. Counterbalancing these sources of growth were higher barriers to exporting for Chinese firms and higher costs of imports.

Second, in parallel with the dynamics of the estimated structural factors discussed in section 4, there appears to have been significant structural changes in the contributions of these factors to Chinese export growth between 2000 and 2013. The positive contributions of foreign import demand drop sharply during the great recession of 2008-2009 and subsequently fail to recover to their pre-crisis levels. The positive contributions of firm entry to exporting also begin to diminish after 2006. In addition, labor and materials productivity growth contributed positively to Chinese export growth in the early years of the sample (2000-2003) but had a negative effect on export growth in later years, while declines in capital productivity also contributed to a slowdown in exports. Taken together, slowdowns in foreign import demand and firm entry together with negative factor productivity growth appear to largely account for the slowdown in aggregate

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25To 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 $f_{nhsy}^e$. 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).
Chinese exports observed after 2008.

Third, underlying these aggregate dynamics are important patterns of heterogeneity across various Chinese export markets, firm ownership types, Chinese provinces, and sectors. By destination, positive effects of foreign demand on export growth between 2000 and 2007 are observed primarily for developed country markets (North America, Western Europe, and East Asia). After 2008, the decline in these effects are also the sharpest for the developed country markets, whereas declines in demand contributions from South East Asia and the rest of the world were markedly more gradual.

By firm ownership, entry by foreign and private Chinese firms had large and positive effects on export growth, with a significant slowdown in these effects post-2008. Net exit of state firms, on the other hand, contributed negatively to export growth in most years. Similarly, positive contributions of product quality improvements were substantially higher for foreign and private Chinese firms than for state firms. Positive effects of capital productivity growth are also observed primarily for private Chinese firms, whereas factor productivity changes for foreign and state firms were generally negative drivers of exports. Improved access to imported inputs contributed positively to aggregate exports only for foreign firms and primarily before 2008.

By production location, firm entry in all of the main Chinese export provinces contributed positively to export growth before 2008, with smaller and more erratic effects observed from 2009 onwards. Entry appears to have had the most positive effects on export growth in the two largest export provinces, Guangdong and Jiangsu. The positive contributions of employment growth to exporting were also largest in these two provinces. The effects of factor productivity changes across sectors appears more erratic, contributing positively to exports in some provinces and years while contributing negatively in others with no clear pattern.

Finally, by sector, foreign import demand growth contributed most positively to Chinese exports in the machinery and electrical sectors, whereas entry was most important in chemical sectors. The effects of changes in foreign competition on export growth also differ across sectors, with Chinese firms losing competitiveness in machinery and electrical sectors but gaining in others (e.g. metals).
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 labor and capital productivity growth.

Our quantitative accounting of these drivers of Chinese trade patterns suggest that growth in entry, increased foreign demand, and positive changes in labor and capital productivities were the main factors underlying the rapid growth of Chinese exports between 2000 and 2006. However, stagnation in the dynamics of these very same factors were also central to the relative slowdown in Chinese exporting between 2007 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.
References


A Data Construction

A.1 Unit Values

Let $s$ denote a HS-2 category and let $\Omega_s$ 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:

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

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

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

The share of product $\nu$ in total exports is:

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

where:

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

We then construct the unit price indices $P_{ns}^{\text{unit}}$ 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 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):

$$\frac{\omega_s(\nu)}{\omega_s(\nu')} = \left[ \frac{S_s(\nu)}{S_s(\nu')} \right]^{\sigma-1}$$  \hspace{1cm} (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 $P_{ns}^{\text{unit}}$ from (73).

A.2 Adjustment of Domestic Sales Measure

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

$$R_{0xy} = R_{sy}^F + R_{sy}^D + R_{sy}^M + R_{sy}^E + R_{sy}^\theta$$  \hspace{1cm} (77)

where $R_{xy}^x = P_{sy} M_{sy}^x$ for $x \in \{F, D, M, E, \theta\}$. Given values for domestic sales in each sector and year, $\hat{R}_{0xy}$, 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 $R_{sy}^\theta$. 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, $\tilde{R}_{0xy}$. 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 $p_{nhsy}^{exp} = N_{nhsy}^{exp,asm} / N_{nhsy}^{asm}$, and then impute total firm counts as $N_{nhsy} = N_{nhsy}^{exp,customs} / p_{nhsy}^{exp}$. 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. At each step, we use the aggregated export propensities to impute total firm counts given the observed exporter counts in the customs data. Using this procedure, every $\{n,h,s,y\}$ unit with a positive exporter count in the customs data is assigned an imputed firm count $N_{nhsy} \geq N_{nhsy}^{exp}$. Finally, for units with a zero exporter count in customs and a positive firm count in the ASM, we simply impute $N_{nhsy} = N_{nhsy}^{asm}$.

---

26 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.

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

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

29 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
Figure 5: Estimates of foreign demand, $E_{d,asy}$

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 6: Estimates of foreign competition, $P_{dsy}^*/\tau_{dsy}$

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.
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, $f_{\text{dhsy}}^M$

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 9: Estimates of marginal costs, $\eta_{nhsy}$

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 10: Estimates of wages, $W_{hy}$

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.
Figure 11: Estimates of investment shocks, $\theta_{n,xy}$

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 12: Estimates of imported input prices, $P^I_{nay}$

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, $q_{nuy}$

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 14: Estimates of labor productivities, $T^{L}_{nhsy}$

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 15: Estimates of capital productivities, $T^K_{nhsy}$

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 16: Estimates of material productivities, $T_{nhsy}^M$

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.
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Table 2: Contribution of Changes in Foreign Demand $E_{dsy}$ to Chinese Export Growth

Note: Values are shown in units of percentage points (%).
\[
\delta_y \left( P_{dxy}^* / \tau_{dxy} \right)
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Table 3: Contribution of Changes in Foreign Competition \( P_{dxy}^* \) to Chinese Export Growth

Note: Values are shown in units of percentage points (\%).
Table 4: Contribution of Changes in Firm Entry $N_{nhsy}$ to Chinese Export Growth

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Note: Values are shown in units of percentage points (%).
Table 5: Contribution of Changes in Marketing Costs $f_{dny}^M$ to Chinese Export Growth

Note: Values are shown in units of percentage points (%).
Table 6: Contribution of Changes in employment $L_{hy}$ to Chinese Export Growth

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Table 7: Contribution of Changes in Investment Shocks $\theta_{nxy}$ to Chinese Export Growth

Note: Values are shown in units of percentage points (%).
Table 8: Contribution of Changes in Imported Input Prices $P_{xny}^I$ to Chinese Export Growth

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

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Table 9: Contribution of Changes in Product Quality $q_{n,y}$ to Chinese Export Growth

Note: Values are shown in units of percentage points (%).
<table>
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<tr>
<th>Stat.: $\delta_y \left( T_{nh, sy}^L \right)$</th>
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<th>2003-2006</th>
<th>2006-2009</th>
<th>2009-2013</th>
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Table 10: Contribution of Changes in Labor Productivities $T_{nh, sy}^L$ to Chinese Export Growth

Note: Values are shown in units of percentage points (%).
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Table 11: Contribution of Changes in Capital Productivities $T^{K \text{nh,by}}$ to Chinese Export Growth

Note: Values are shown in units of percentage points (%).
Table 12: Contribution of Changes in Materials Productivities $T_{nhsy}^M$ to Chinese Export Growth

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

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