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1 Introduction

From 1980 to 2005, the share of global trade of "Made in China" goods grew from 0.8% to 13%. While a large number of literature has focused on the consequences of China's export surge (see Autor, Dorn and Hanson, 2016, for a review), fewer papers have examined the sources causing China's export surge. In this paper, we jointly analyze several factors and quantify their relative contributions to China's export surge.

We build a multi-sector spatial general equilibrium model and combine rich data sources, to account for China's export surge between 1990 and 2005 from three policy changes: China's import tariffs, tariffs imposed against China's exports, and barriers to internal migration in China. In the model, workers choose which provinces and sectors to work in. Firms choose where to produce and whether to involve in processing or ordinary export regimes.[1] We explore provincial and sectoral variation on the changes in firm mass, migrant employment, and tariff exposure to discipline the model parameters. Finally, we jointly analyze the effect of tariff and migration policies on China's export surge, as well as the importance of equilibrium firm and worker adjustments.

Recent literature emphasizes that China's rural-to-urban migrants caused a substantial aggregate output gain (Tombe and Zhu, 2019; Hao, Sun, Tombe and Zhu, 2020). We document that migrant employment was prominent in export-intensive and possessing-oriented industries, improving China's aggregate export/output ratio. As migration policy reform prepared the country to become more export oriented, China enjoyed faster export growth after opening to trade than it would have otherwise. Through the lens of our model, we find that tariff and migration policies jointly accounted for 30% of China's export growth. These joint effects are larger than simply aggregating the effects of each individual policy, suggesting a positive interaction effect of tariff and migration policies.

Accompanied with China's substantial reductions in tariffs and internal migration costs was the massive entry of new firms (Brandt, Van Biesebroeck and Zhang, 2012) and the structure changes in export regimes (Brandt and Morrow, 2017). To motivate our quantitative model, we show, using reduced-form specifications, that firm location and regime decisions are sensitive to migration and tariff changes. First, we show that provinces and sectors that experienced larger rises in migrant employment also faced faster increases in the number of firms between 1990 and 2005. To address the endogeneity issues, we construct a Card-type instrument for changes in migrant employment by exploiting historical patterns of location and sector sorting for workers from different provinces of origin. Second, we explore vari-

[1] Export processing is the process where firms import raw materials or intermediate inputs from abroad and export the final goods after some processing (Feenstra and Hanson, 2005). Processing firms are not allowed to sell output domestically.

ation across sectors to show that the decreased import tariffs led to a rise in the relative number of ordinary firms to processing firms.[2] We use provincial import penetration and sectoral input-output table to construct changes in production costs resulting from import tariff reductions (WTO), and instrument potentially endogenous tariff changes with maximum tariff levels under the WTO agreement following Brandt, Van Biesebroeck, Wang and Zhang (2017). These reduced-form estimates will be targeted to discipline the key parameters that govern firm adjustments.

Our model has three key components. First, we build upon Arkolakis, Ramondo, Rodríguez-Clare and Yeaple (2018) (ARRY hereafter) to model firm location and ordinary and processing regime choices, with correlated productivity draws from a multivariate Pareto distribution (Arkolakis, Rodríguez-Clare and Su, 2016). The second is the inter-sectoral input-output linkages (Caliendo and Parro, 2015). Third, Chinese workers with heterogeneous location preferences and migration costs sort into provinces and sectors. A policy shock could impact the aggregate exports not only by affecting firms' decision on whether and how much to export (Chaney, 2008), but also by changing firms' decision on where to produce and their processing or ordinary regime choice. The aggregate trade elasticity, therefore, depends on the two structural parameters of productivity correlation across locations and across regimes, which, respectively, govern firm location and regime responses to policy shocks.

We use an indirect inference approach to discipline these productivity correlation parameters that match our reduced-form estimates on firm location and regime responses. Specifically, we obtain the productivity correlation across locations to target our reduced-form estimate on the response of the number of firms to migration shocks; and we obtain the productivity correlation between ordinary and processing regimes to target our reduced-form estimate on the effects of import tariff changes on the relative number of ordinary to processing firms. We provide additional evidence that shows each correlation parameter is indeed identified from the associated firm adjustment, but is insensitive to changes in other model components.

We combine detailed transaction-level customs data, firm-level data, international and intranational trade data, and micro-level population census data to account for China's export surge due to the three policy changes mentioned above. We measure the changes in internal migration costs following Head and Ries (2001)'s approach to match the changes in migration flows, and take tariff and migration shocks into a model of 29 sectors, 2 export regimes (processing and ordinary), 30 Chinese provinces, and 35 foreign countries. First, taking individual policy into the model one at a time, we find the reductions in China's import

[2] This channel was first studied in Brandt and Morrow (2017) who focused on how the value share of exports organized through ordinary trade responded to tariff changes.

tariffs explained 12.6%, whereas changes in foreign tariffs on China's exports and reductions in internal migration barriers each accounted for 7.7% and 7.2%, respectively. The major portion of China's export growth arose from three coastal provinces (Guangdong, Shanghai, and Jiangsu). We also find that import tariff reductions favored ordinary exports, whereas the reductions in migration barriers and in foreign tariffs on China's exports both favored processing exports.

Next, simultaneously incorporating three policy changes in the model, we find that they jointly accounted for 30% of China's export growth. This joint effect is 9% larger than the aggregation of individual effects (12.6%+7.7%+7.2%=27.5%), which suggests a positive interaction between trade and migration policies. The positive interaction effects we find may arise from three sources: (1) migrants accounted for a higher employment share in export-oriented provinces and sectors; even if migration cost changes were common across all provinces and sectors, employment would still expand more in export-oriented provinces and sectors, generating the positive interaction effects; (2) migration costs decreased more in export-oriented provinces, and thus geography also matters; and (3) migration costs were reduced more in export-oriented industries.[3] In evaluating the strength of each mechanism, we find that the first mechanism—the observed higher employment share in export-oriented provinces and sectors—is the main driver of the positive interaction effect.

In our final exercise, we study the role of firm and worker adjustments in China's export growth. We find that, in a model where firms' location and regime do not respond to policy changes, the joint effects of policies on export growth drop by nearly half; and in a model where workers do not adjust across locations or sectors, the export impacts of tariffs drop by 12%. Accounting for equilibrium adjustments of workers and firms is quantitatively important for evaluating China's export growth.

China experienced fast productivity growth in recent decades (Song, Storesletten and Zilibotti, 2011), and the decline of trade barriers and China's WTO accession had a significant contribution to China's productivity growth (Yu, 2015; Brandt et al., 2017) and the export structures (Brandt and Morrow, 2017). Brandt, Li and Morrow (2019) build an Eaton-Kortum model with ordinary and processing regimes to quantify the welfare losses of restricting processing output from selling domestically. Differing from these studies, we analyze migration and trade jointly, and show the policy interaction would have been missing if analyzing one policy at a time. Tombe and Zhu (2019), Fan (2019), Ma and Tang (2020) and Zi (2020) model migration and trade jointly in China's context. Our main departure is to distinguish processing and ordinary export regimes, and show the policy interaction is only present for processing export growth. Finally, Brandt and Lim (2019) account for China's export growth. Our

[3]We thank an anonymous referee for this suggestion.

approach differs from theirs in two main aspects. First, they focus on changes in productivity, demand, and labor and firm-entry costs between 2000 and 2013, whereas we jointly study migration and tariff policies. Second, they calibrate their model to analyze the evolution of China's export growth. We focus on China's export growth between 1990 and 2005 and use empirical estimates to discipline the degree of firm adjustments to barrier reductions.

Our paper also relates to the quantitative trade and spatial equilibrium literature that studies the impact of goods and labor market integration (Allen and Arkolakis, 2014; Redding and Rossi-Hansberg, 2017, among others). International trade theory has widely emphasized how opening to trade would cause factor relocation and the associated consequences on productivity (Melitz, 2003), yet the labor mobility in China used to be banned. In a well-studied area, researchers have shown that reducing the internal migration frictions can generate sizable aggregate output gains in developing countries (Bryan and Morten, 2019; Tombe and Zhu, 2019). Relatively less attention has been paid to the migrants' choices into detailed sectors and the associated impacts on exports. We argue that China's internal migration expanded the employment size in export-intensive industries, making China more export oriented. We also find that the interaction effect arose entirely from processing export growth but was absent for ordinary exports. These mechanisms would have been missing if migration and tariff policies were analyzed separately, or if processing and ordinary exports were not distinguished in the model.

Finally, by modeling firm location choices, our paper also relates to quantitative research on the production location choices of multinational firms (Ramondo and Rodríguez-Clare, 2013; Tintelnot, 2017; Arkolakis et al., 2018). Alviarez (2019) finds that omitting the sectoral allocation of multinational production leads to understate the gains from multinational production and trade openness. We apply this framework to show that firm location choice is important for driving the export impact of China's policy changes.

This paper proceeds as follows: Section 2 presents facts to motivate our analysis; Section 3 presents our model; Section 4 calibrates the model parameters and Section 5 presents the quantitative results. Section 6 concludes.

2 Motivating Facts

This section shows that China's internal migration expanded employment in export-oriented provinces and industries, which caused an aggregate productivity gain and improved China's export/output ratio. We also provide reduced-form evidence on firm location and regime responses to migration and tariff changes. Below we first describe our data sources.

2.1 Data

Our analysis includes 29 sectors, 30 Chinese provinces, 35 foreign countries and a rest of the world.[4] We aggregate the 2-digit International Standard Industrial Classification (ISIC Rev 3) industries into 16 tradable sectors and 13 non-tradable sectors (see Table C.2). We summarize the data sources below and provide the full details in Appendix C.

Migration. We use China's Population Census in 1990 (1%) and China's Population Survey 2005 (0.2% mini census), to measure China's inter-provincial migration flows, wages, and sectoral employment. We study inter-provincial migrants—individuals whose *Hukou* is not registered in the province where they are currently working.

Firms. We measure the total number of firms in 1990 and 2005 by province and sector, using the 2004 Firm Census (for 2005) and the Industrial Statistical Yearbook (for 1990). Both sources provide full coverage of manufacturing firms.[5] We also obtain the number of processing and ordinary firms by province and sector, using China's Annual Survey of Industrial Firms merged with China's Customs Transactions Database.

Output. We obtain province-sector-level output from China's regional input-output tables in 2007 (Liu, Chen, Tang, Liu, Han and Li, 2012). Since the output of processing firms is not allowed to be sold domestically, we measure provincial and sectoral output of processing firms using the total amount of processing exports obtained from China's Customs Transactions Database. We measure ordinary production as the difference between gross province-sector-level output and the processing output. The output values of each export regime are used in the quantitative analysis.

Trade. We measure inter-provincial trade flows primarily based on inter-provincial input-output tables, and measure trade between foreign countries using the STAN Bilateral Trade Database. We measure trade flows (by processing and ordinary) between China's provinces and foreign countries using China's Customs Transactions Database.

2.2 Migrants' Employment and Manufacturing Exports

China's internal migrants make up an important portion of manufacturing employment. For the broad manufacturing sector, Figure 1 plots migrants' employment shares against export-output ratios across provinces, in 2005. Provinces where migrants comprised larger portions of manufacturing employment were more export oriented and had higher export volumes (reflected by the circle size). Notably, in Guangdong and Shanghai, migrants accounted for

[4]We exclude Tibet due to the lack of data.

[5]Because Firm Census is not available in the year 1990, we obtain the number of firms in each province and sector from the Industrial Statistical Yearbook.

60% and 45% of provincial manufacturing employment, respectively. This spatial movement of labor expanded the manufacturing employment in export-oriented provinces, improving the country's export/output ratio.[6]

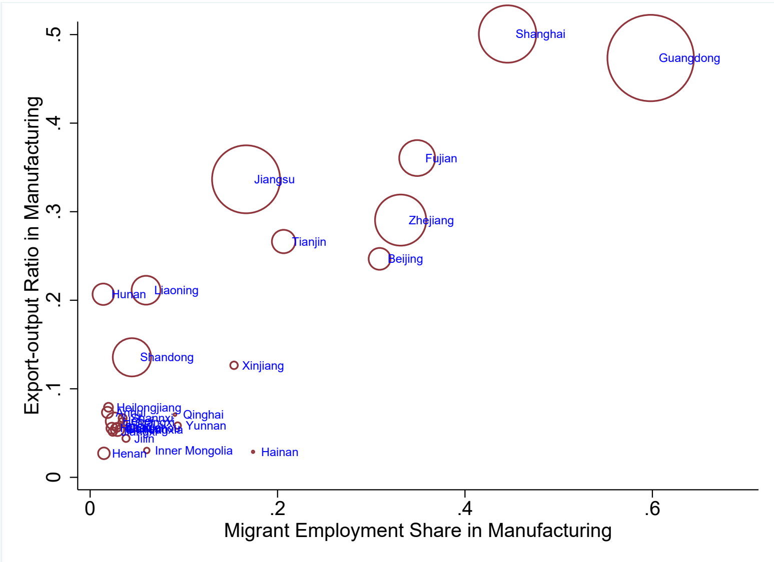


Figure 1: Migrants' Manufacturing Employment Shares against Provincial Export-Output Ratios. The Circle Size Measures Provincial Export Volume.

We next focus on five coastal provinces (Guangdong, Jiangsu, Shanghai, Zhejiang, and Fujian), and examine migrant sorting across 16 detailed manufacturing sectors. The five provinces combined accounted for 73% of inter-provincial migrants, 79% of China's manufacturing exports and 84% of processing exports in 2005. Figure 2 (left) plots export-output ratios against migrant employment shares across 16 detailed manufacturing sectors. Migrant employment shares varied dramatically and were higher in more export-oriented sectors. For this reason, we use 16 manufacturing sectors, at a more disaggregated level than the previous literature did.[7] We discuss the productivity and export implications in Section 2.3.

These export-oriented manufacturing sectors (e.g., electronics, electrical machinery) are also those highly processing-oriented sectors. Replacing the y-axis by the share of processing exports, Figure 2 (right) resembles closely to what we see in Figure 2 (left). As the pattern holds systematically among China's exporting provinces, migrants expanded employment in export-intensive and processing-oriented industries, again, improving the country's export/output ratio.[8]

[6]To double confirm that internal migration increased manufacturing employment size relative to the overall employment, Appendix B shows that internal migrants were overpresented in manufacturing sectors in destination provinces relative to other sectors.

[7]Tombe and Zhu (2019) and Hao et al. (2020) distinguish migrant sorting into agricultural and non-agricultural sectors. Fan (2019) analyzes three broad sectors, whereas Ma and Tang (2020) analyze two broad sectors.

[8]In Appendix B, we show a similar and strong positive association holds in Guangdong province, which accounted for 39% of China's processing exports in 2005. There are also positive associations in Zhejiang and

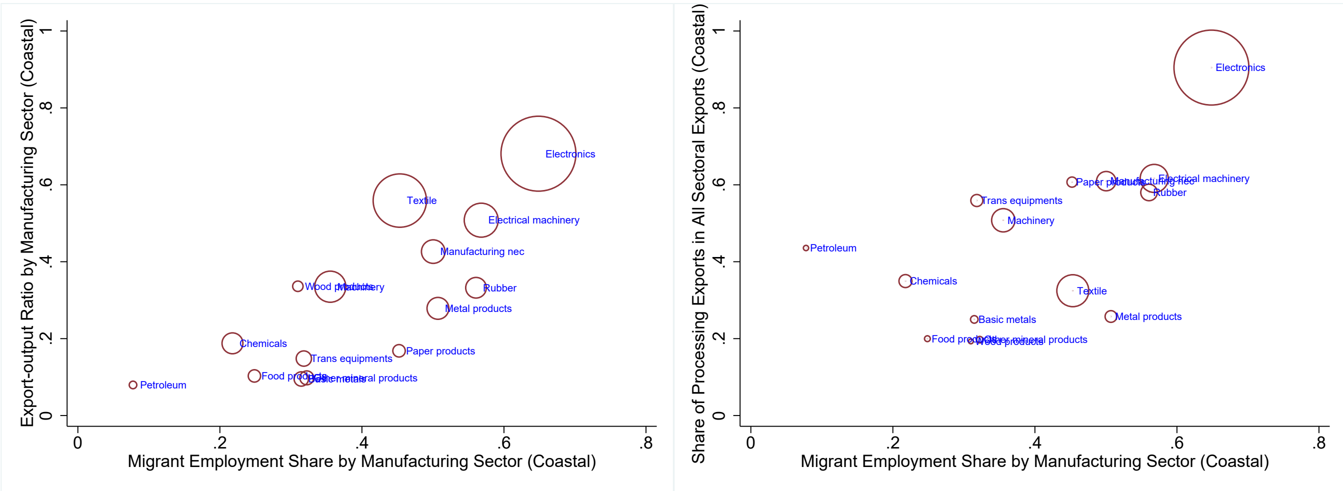


Figure 2: Migrants' Sectoral Employment Shares against Sectoral Export-Output Ratios — Coastal Provinces (left); Migrants' Sectoral Employment Shares against Sectoral Share of Processing Exports — Coastal Provinces (right)

Notes: Both plots use data from five provinces (Guangdong, Jiangsu, Shanghai, Zhejiang, and Fujian). The circle size reflects sectoral export volume on the left, and processing export volume in each sector on the right.

The sectoral sorting pattern of migrants is likely driven by two economic forces. One is that migrants were less educated compared to Hukou residents in destination provinces and thus more likely to work in processing export activities that require few skills (Dai, Maitra and Yu, 2016). Another force is that the reduction in migration regulations was potentially more aggressive in major exporting sectors in coastal areas. In particular, as China's exports boomed after the WTO accession (Feenstra and Wei, 2010), local governments had incentives to relax migration regulations to stimulate the local economy (Tian, 2019).[9] We use the patterns of sectoral sorting to calibrate policy parameters in Section 4.1.

2.3 The Intuition

What are the mechanisms through which China's internal migration promoted export growth? First, migration expanded employment in more productive provinces and sectors, which caused an aggregate output gain (Tombe and Zhu, 2019; Hao et al., 2020). Second, employment expanded more in export-oriented provinces and sectors, which raised China's aggregate export/output ratio.[10]

Jiangsu provinces, despite their migrant employment shares were relatively small. The positive association holds for Shanghai when weighting industries by export volumes.

[9] Tian (2019) collects a dataset that measures the degree of city-level migration regulations. She finds that Chinese cities that faced larger increases in access to export markets had a larger degree of relaxation of migration regulations. Also see Yang (2005), who shows that faced with labor shortage due to reasons such as agricultural reforms, local governments and firms improved access to welfare of migrant workers, especially for export processing activities which had to live with very low pay and abysmal working conditions.

[10] This theoretical insight has been discussed by Cosar and Fajgelbaum (2016).

We illustrate these potential channels with a back-of-the-envelope calculation based on a simple model. Consider a counterfactual economy in which we set migrant employment in province (l) and sector (s) to the level of year 1990 and denote migrant employment changes as $\Delta L_{l,s}$.[11] Those whose province of Hukou registration is the same as the place of work (or locals) do not contribute to $\Delta L_{l,s}$. We decompose the impact of $\Delta L_{l,s}$ on aggregate export growth as

$$\underbrace{\Delta \log \text{Export}}_{2.57 \text{ p.p. annual growth}} = \underbrace{\Delta \log \text{Output}}_{1.07 \text{ p.p. annual growth}} + \underbrace{\Delta \log \frac{\text{Export}}{\text{Output}}}_{1.50 \text{ p.p. annual growth}} . \tag{1}$$

The first term is changes in aggregate exports, calculated as $\Delta \log \text{Export} \approx \sum_{l,s} \frac{\text{Export}_{l,s}}{L_{l,s}} \Delta L_{l,s} \Big/ \text{Export}$. The second term captures the contribution from changes in aggregate output, which is calculated as $\Delta \log \text{Output} \approx \sum_{l,s} \frac{\text{Output}_{l,s}}{L_{l,s}} \Delta L_{l,s} \Big/ \text{Output}$. The last term measures the contribution from changes in the aggregate export/output ratio, which is the difference between the first two terms. We calculate $\frac{\text{Output}_{l,s}}{L_{l,s}}$ and $\frac{\text{Export}_{l,s}}{L_{l,s}}$ as the observed output and exports per worker in province l and sector s, respectively. Given $\Delta L_{l,s}$ as the shock, our calculation shows a 1.07 p.p. increase in annual output growth and a 1.5 p.p. increase in annual growth of the export/output ratio.[12]

The gain in aggregate export intensity is because employment expanded in places that were more export oriented. To support the argument, Figure 3 (left) plots the effects of $\Delta L_{l,s}$ on aggregate sectoral output growth against sectoral export/output ratios. We find that more export-oriented sectors experienced faster output growth, and the largest effect is a 3.6 p.p increase in annual growth of the electronics sector. Two underlying mechanisms potentially contributed to larger output increases in export-intensive industries. First, employment expanded faster in export-oriented sectors, as evidenced in Figure 2. Second, in export-oriented sectors, workers were reallocated from less to more productive regions, which led to an improvement in allocative efficiency.

To support the second mechanism, Figure 3 (right) replaces the y-axis with the annual growth of output per worker. It shows that output per worker increased in most sectors, but fell in a few industries such as electrical machinery. In China's top two exporting sectors, electronics and textiles, output per worker increased by 0.21% and 0.06% annually. As the

[11] We compute $\Delta L_{l,s} = \sum_g L_g(\Lambda_{g,l,s,2005} - \Lambda_{g,l,s,1990})$. Here, L_g is the amount of workers with their Hukou registered in province g, for which we use data from 2005 to avoid the effects of changes in population. $\Lambda_{g,l,s,1990}$ and $\Lambda_{g,l,s,2005}$ are the shares of group g workers choosing province l and sector s in 1990 and 2005, respectively.

[12] We convert the 15-year growth to annual growth by applying the formula $1 + g_{15} = (1 + g)^{15}$, where g_{15} is the 15-year growth rate and g is annual growth rate. We find that inter-provincial migration increased aggregate output (including nontradable sectors not analyzed in this section) by 9.6%. Because we only analyze inter-provincial migration, the aggregate output impact we obtained is smaller than partial-equilibrium gains (10.8%) computed by Tombe and Zhu (2019) who also consider rural-urban migration. The period we focus on also differs from Tombe and Zhu (2019) who focus on 2000-2005.

aggregate export-output ratio increased, China enjoyed faster export growth from the trade liberalization than it would have without the migration policy reform. This is the source of the interaction effect of migration and trade policies on exports, which we will quantify in Section 5.

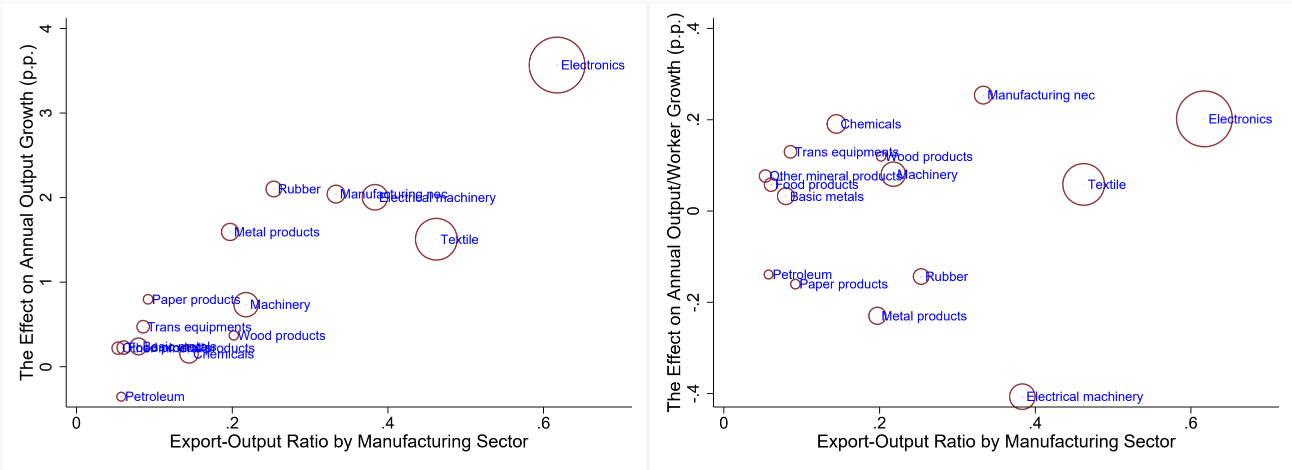


Figure 3: The Effect of Migration on Annual Output Growth against Sectoral Export-Output Ratio (left); The Effect of Migration on Annual Output/Worker Growth against Sectoral Export-Output Ratio (right); The Circle Size Reflects the Sectoral Export Volumes.

Our calculation overlooks several economic forces. First, we ignore the general equilibrium wage adjustments of increasing sectoral labor supply and the consequent adjustments of the province-sector-level export intensity.[13] As migration labor supply would lower local wages, coastal provinces might become more export oriented. Second, our calculation treats labor as the only factor and ignores intermediate materials and the input-output linkages across sectors. Third, changes in economic policies (migration and tariff policies) could change firms' market access to consumers, and affect firm decisions of where to produce. Previous literature argues the massive entry of new firms has been an important source of China's productivity (Brandt et al., 2012) and export growth (Khandelwal, Schott and Wei, 2013). Section 3 builds a general equilibrium model that incorporates these forces. Before that, we provide reduced-form evidence on firms' adjustments.

2.4 Reduced-form Evidence

We estimate firm location and regime responses to migration and tariff changes. The exercises serve for two purposes. First, they motivate our quantitative model that features firm location and export regime choices. Second, we use the reduced-form estimates to pin down

[13]Assuming that $\Delta L_{l,s}$ has no impact on wages and foreign income, the province-sector-level export intensity would not change.

two key structural parameters in Section 4.2.

2.4.1 Internal Migration and the Number of Firms

We estimate the impact of migrant labor supply on the number of firms between 1990 and 2005, using the following reduced-form specification

$$\Delta M_{l,s} = \beta_0 + \beta_1 \Delta N^m_{l,s} + \gamma x_{l,s} + \epsilon_{l,s}. \tag{2}$$

The dependent variable is growth in the total number of firms in province l and sector s between 1990 and 2005, which is constructed as $(M_{l,s,2005} - M_{l,s,1990})/\frac{1}{2}(M_{l,s,2005} + M_{l,s,1990})$. $M_{l,s,t}$ is the number of firms in province l and sector s at year t.[14] The independent variable is the changes in migrant share in province l and sector s between 1990 and 2005, constructed as $\Delta N^m_{l,s} = (N^m_{l,s,2005} - N^m_{l,s,1990})/\frac{1}{2}(N_{l,s,2005} + N_{l,s,1990})$. Here $N^m_{l,s,t}$ and $N_{l,s,t}$ are the number of migrant workers and the overall employment in province l and sector s at year t, respectively.

The increase in migrant labor force might attract more firms by lowering the local wages, generating industrial agglomeration, or changing firms' market access. The reduced-form parameter β_1, therefore, captures the mixture of these effects.[15] $x_{l,s}$ denotes province and sector control variables, including log output per worker in 1990, and changes in non-tariff barriers, FDI restrictions, and input/output tariffs between 1990 and 2005.[16]

The OLS regression in equation (2) would be biased if provinces and sectors that have high unobserved productivity attract more firms and migrant workers. We construct a Card-type instrument as follows

$$\Delta \widetilde{N}^m_{l,s} = \sum_g \Delta N^{-l,-s}_g \times \Lambda_{g,l,s,t_0}, \tag{3}$$

where g indexes for workers whose *Hukou* is registered in province g, and $\Delta N^{-l,-s}_g$ is the change in the total number of group g migrants between 1990 and 2005, excluding those who migrated to province l and sector s. Λ_{g,l,s,t_0} is the share of workers choosing province l and sector s in the year t_0 among those who migrated.[17]

Our instrument aims to capture plausibly exogenous supply-driven variation in migration flows that are orthogonal to the unobserved local demand. The identification of shift-

[14] This way of defining growth follows from Davis and Haltiwanger (1992) and allows growth rates to lie in the closed interval $[-2, 2]$, which avoids extreme values.

[15] Our specification is similar to the widely adopted reduced-form specification in the immigration literature (e.g, Card, 2001; Borjas, 2003; Olney, 2013). Moreover, with migration labor supply as the independent variable, we can construct an instrumental variable to better identify the parameter.

[16] Output per worker in 1990 is drawn from the Industrial Statistical Yearbook. Non-tariff barriers, FDI restrictions, and input and output tariffs are drawn from Brandt et al. (2017).

[17] We use the 1990 Population Census to measure internal migration in the initial year, based on workers' current province of residence and province of residence in the year 1985.

Table 1: The Impact of Internal Migration on the Number of Firms

	OLS (1)	2SLS (2)	2SLS (3)	2SLS (4)	2SLS (5)
	Dep Var: Growth in Num of Firms, 1990–2005				
Δmigrant share	1.018***	0.987***	0.957***	0.750**	1.191**
	(0.225)	(0.327)	(0.274)	(0.182)	(0.531)
AKM 95% Confidence Intervals		[0.466,1.509]	[0.367,1.547]	[0.320,1.180]	[0.167,2.216]
Controls	No	No	Yes	Yes	Yes
Sector Fixed Effects	No	No	No	Yes	Yes
First-stage F		76.42	58.30	63.24	3.44
Obs	420	420	420	420	420
R-squared	0.233	0.232	0.457	0.544	0.496

Notes: This table presents the results from estimating regression (2) across provinces and sectors. The instrument is the Card-type instrument to predict exogenous labor supply shifts (measured in units of millions of people). AKM confidence intervals are constructed according to Adao, Kolesár and Morales (2019). In the last column, we still follow equation (3) to construct the instrument, but in the instrument, we use the increase in migration to all provinces except province l as the shift. Regressions are weighted by firm numbers in each province-sector pair in 1990. We report first-stage Kleibergen-Paap F-statistic on the excluded instrument. Standard errors are in parenthesis and clustered by province. Significance levels: 10% * 5% ** 1% ***.

share instrumentals in the form of equation (3) can be obtained if either the shifts or the shares are randomly assigned (Borusyak, Hull and Jaravel, 2022). In our case, the identification holds if $\Delta N_g^{-l,-s}$ or Λ_{g,l,s,t_0} is orthogonal to the initial province-sector-level productivity in the year 1990. These orthogonality conditions tend to hold because each province-sector cell we consider is small and has little power in driving the national aggregate migration pattern.

It appears that $\Delta\widetilde{N}_{l,s}^m$ strongly predicts the actual migration pattern $\Delta N_{l,s}^m$, with the coefficient of 0.525 and the standard error of 0.046.[18] The OLS regression shows a strong and positive association, as reported in Column (1) of Table 1. Columns (2)–(4) report the IV estimates under different specifications, where we add local controls in Column (3) and sector fixed effects in Column (4).[19] All IV estimates are smaller than the OLS result, where the upward bias in the OLS regression likely reflects that fast-growing regions or sectors attracted more migrants and firms.

Given the fact that several provinces (e.g., Guangdong and Shanghai) accounted for a substantial share of manufacturing employment, we also construct an alternative instrument with the exogenous shift being ΔN_g^{-l}, the increase in migrant employment in other provinces but itself. The estimate appears to be stable, as reported in Column (5).

[18]The Card-type instrument, while widely used, is subject to criticism. One concern is that it may be invalid if regional labor demand shocks are persistent (Borjas, Freeman and Katz, 1997). Helpfully, we find that our instrument $\Delta\widetilde{N}_{l,s}^m$ is uncorrelated with output per worker in 1990 and the growth in output per worker between 1990 and 2005 across provinces and sectors.

[19]We do not control province fixed effects because changes in the migrant share mainly came from between-province variation, as a result of different *Hukou* policies (Kinnan, Wang and Wang, 2018).

A final concern arises because provinces that have a similar initial industrial composition tend to have similar values in the residuals. As pointed out by Adao, Kolesár and Morales (2019), this spatial dependence in the residuals is not addressed by traditional methods. To this end, we report 95% confidence intervals for the coefficients using the inference method developed by Adao, Kolesár and Morales (2019). We find that the AKM 95% confidence intervals do not contain zero for any of the regressions.

2.4.2 Import Tariffs and Firms' Export-Regime Choices

We estimate the impact of import tariff changes on the number of ordinary exporters and processing exporters separately. Because imported materials for processing exports are duty-free, import tariff reductions benefit ordinary exporters more. In a previous study, Brandt and Morrow (2017) find that the share of ordinary exports increases as tariffs fall. We show that a similar relationship holds for differential responses in the number of ordinary exporters relative to processing exporters.

We estimate the following reduced-form regression:

$$\Delta M_{l(m),s} = b_0 + (b_1 + b_2 \mathbf{1}_{\mathcal{O}}) \sum_k \lambda_{l,s}^k IP_{l,k} \left(\frac{1 + t_{k,2005}}{1 + t_{k,2000}} - 1 \right) + \gamma x_{l,s} + \epsilon_{l,s}, \tag{4}$$

where the dependent variable is changes in the number of exporters in province l and sector s between 2000 and 2005, constructed as $(M_{l(m),s,2005} - M_{l(m),s,2000}) / \left(\frac{1}{2} M_{l(m),s,2005} + \frac{1}{2} M_{l(m),s,2000}\right)$, separately for ordinary and processing regimes $m \in \{\mathcal{O}, \mathcal{P}\}$. The independent variable measures province-sector-level changes in production costs resulting from import tariff reductions. $IP_{l,k}$ is the share of imports in the total expenditure of sector k in province l. t_k is China's tariff rate imposed on imports in sector k, therefore $\left(\frac{1+t_{k,2005}}{1+t_{k,2000}} - 1\right) < 0$ captures changes in import costs due to tariff reductions. $\lambda_{l,s}^k$ is the share of sector s's production costs spent on materials from sector k, obtained from the input-output tables in 2005.

The production costs reduced more if the province intensively used foreign inputs (high $IP_{l,k}$) or that sector intensively used materials that had large tariff reductions (high $\lambda_{l,s}^k$ or low $\frac{1+t_{k,2005}}{1+t_{k,2000}}$). $\mathbf{1}_{\mathcal{O}}$ is a dummy variable for ordinary exporters. The parameter of interest is b_2, which captures differential responses in the number of ordinary exporters relative to processing exporters.

Tariff changes between 2000 and 2005 may have been endogenous, as policymakers could change import tariffs selectively in favor of less competitive domestic industries. We construct an instrument for changes in applied tariffs by using the maximum tariff levels under

Table 2: The Impact of WTO on the Number of Ordinary and Processing Exporters

	OLS (1)	**2SLS** (2)	**2SLS** (3)	**2SLS** (4)
	Dep Var: Growth in Num of Firms, 00–05			
b_1	-1.122	-1.873	3.079	-8.368**
	(8.504)	(8.626)	(8.774)	(3.570)
b_2	-11.827	-11.265	-17.383**	-18.692**
	(9.041)	(8.740)	(7.096)	(8.866)
Controls	No	No	Yes	Yes
Province Fixed Effects	No	No	No	Yes
First-stage F		8653.43	6839.21	2485.28
Obs	751	751	751	751
R-squared	0.354	0.354	0.426	0.668

Notes: This table presents the results from estimating regression (4) across provinces, sectors and export regimes. All regressions include a dummy variable for export regimes. The instruments are the change in maximum tariffs (as specified in the main text) and its interaction with the ordinary regime. The controls include: 1) changes in non-tariff barriers, FDI restrictions, and output tariffs between 2000 and 2005, from Brandt et al. (2017); and 2) initial openness levels measured by the ratio of exports to output in 2000. Regressions are weighted by firm numbers in each province-sector-regime pair in 2000. We report first-stage Kleibergen-Paap F-statistic on the excluded instrument. Standard errors are in parenthesis and clustered by province. Significance levels: 10% * 5% ** 1% ***.

the WTO agreement, following Brandt et al. (2017),

$$x^*_{l,s} = \sum_k \lambda^k_{l,s} IP_{l,k} \left(\frac{1 + t^{WTO}_{k,2005}}{1 + t^{WTO}_{k,2000}} - 1 \right), \tag{5}$$

where $t^{WTO}_{k,2000}$ and $t^{WTO}_{k,2005}$ refer to specified maximum tariff levels in the WTO agreement, which were mostly agreed in 1999.

The exclusion restrictions of this instrument require two premises: (1) the actual tariffs deviate from the agreed rates which we do observe in the data, and (2) the agreed maximum tariff rates are uncorrelated with $\epsilon_{l,s}$, the unobserved future factors that affect the relative provincial-sector number of ordinary and processing firms. The justification for (2) is that because of many local policy and economic uncertainties, policymakers' anticipation on $\epsilon_{l,s}$ is not formed by the agreed maximum tariff rates.[20]

Column (1) of Table 1 reports a negative and insignificant OLS estimate. Columns (2)–(4) report the IV estimates under different specifications. All IV estimates show negative values of b_2, where the parameters are precisely estimated when adding local controls in Column (3) and province fixed effects in Column (4). We also find that the instrument strongly predicts the independent variable, with a linear coefficient of 1.161 (standard error of 0.038) and

[20] As mentioned in Brandt et al. (2017), this instrument cannot address the endogeneity problem if the policymakers can correctly anticipate $\epsilon_{l,s}$. Moreover, in line with Brandt et al. (2017), we also find suggestive evidence that the WTO tariff cut was less likely to be driven by the past firm or industry performance: Our instrument is uncorrelated with the number of processing and ordinary exporters across provinces and sectors in the past.

sizable first-stage F values. The evidence shows that provinces and sectors, in which production cost reduced more after China's WTO accession, faced faster growth in the number of ordinary exporters relative to processing exporters.

3 A Spatial Equilibrium Model with Firms' Location Choices

We extend ARRY to a multi-sector spatial general equilibrium model with heterogeneous firms' and workers' location choices, and input-output linkages. We treat each foreign country as a single region. In China, we consider provinces as regions. Firms decide in which country to produce and whether to export; if located in China, firms also choose a combination of province and export regime. The world has a total number M_s of potential firms in each sector s. We take M_s as exogenous in our benchmark model, but provide a model extension that endogenizes M_s in Appendix D.3.

In China, workers are imperfectly mobile across provinces and sectors, but are perfectly mobile between processing and ordinary firms within each province-sector pair. In foreign countries, we assume workers are perfectly mobile across sectors. We use index $l(m)$ to denote a combination of province l and export regime $m \in \{\mathcal{O}, \mathcal{P}\}$, where $\mathcal{O}$ and $\mathcal{P}$ denote ordinary and processing regimes respectively. We use j or n to index foreign countries. For ease of description, we present our model based on China's provinces and export regimes. We discuss the setup for foreign countries when a distinction arises. Math derivations are provided in Appendix A.

3.1 Final-good Producers

In province l and regime m, non-tradable final goods are produced using a Dixit-Stiglitz production function,

$$Q_{l(m),s} = \left(\sum_j \int q_{j,l(m),s}(\omega)^{\frac{\sigma-1}{\sigma}} \mathrm{d}\omega + \sum_{l'} \int q_{l'(\mathcal{O}),l(m),s}(\omega)^{\frac{\sigma-1}{\sigma}} \mathrm{d}\omega \right)^{\frac{\sigma}{\sigma-1}},$$

where $q_{j,l(m),s}(\omega)$ is the quantity of intermediate goods ω shipped from foreign country j to $l(m)$, and $q_{l'(\mathcal{O}),l(m),s}(\omega)$ is the quantity sourced from domestic ordinary producers in province l'. Since processing producers must sell their output overseas, the summation combines intermediate goods sourced from all foreign countries and domestic ordinary producers in all China's provinces. $\sigma > 1$ is the elasticity of substitution across varieties. The final good can be either consumed by households or used as raw materials to produce intermediate goods. The price index of the final good in $l(m)$ and sector s is

$$P_{l(m),s} = \left(\sum_j \int p_{j,l(m),s}(\omega)^{1-\sigma} \mathrm{d}\omega + \sum_{l'} \int p_{l'(\mathcal{O}),l(m),s}(\omega)^{1-\sigma} \mathrm{d}\omega \right)^{\frac{1}{1-\sigma}}.$$

Foreign producers can source from processing and ordinary regimes of China. The production function in foreign country n and sector s is

$$Q_{n,s} = \left(\sum_j \int q_{j,n,s}(\omega)^{\frac{\sigma-1}{\sigma}} \mathrm{d}\omega + \sum_{l'} \sum_{m'} \int q_{l'(m'),n,s}(\omega)^{\frac{\sigma-1}{\sigma}} \mathrm{d}\omega \right)^{\frac{\sigma}{\sigma-1}}.$$

The price index in foreign country n and sector s is

$$P_{n,s} = \left(\sum_j \int p_{j,n,s}(\omega)^{1-\sigma} \mathrm{d}\omega + \sum_{l'} \sum_{m'} \int p_{l'(m'),n,s}(\omega)^{1-\sigma} \mathrm{d}\omega \right)^{\frac{1}{1-\sigma}}.$$

3.2 Intermediate-good Producers

3.2.1 Production Technology

Firms with productivity $\phi_{l(m),s}$ employ $L_{l(m),s}$ efficiency units of labor and $Q_{l(m),s,k}$ units of raw materials (final goods) from sector k to produce $q_{l(m),s}$ units of output, according to the following production function

$$q_{l(m),s} = \phi_{l(m),s} L_{l(m),s}^{\lambda^L_{l(m),s}} \prod_k Q_{l(m),s,k}^{\lambda^k_{l(m),s}}, \tag{6}$$

where $\lambda^L_{l(m),s}$ is the share of workers' value added, and $\lambda^k_{l(m),s}$ is the share of expenses on raw materials from sector k. We assume $\lambda^L_{l(m),s} + \sum_k \lambda^k_{l(m),s} = 1$. The implied unit cost of the input bundle is

$$c_{l(m),s} = \left(\frac{w_{l(m),s}}{\lambda^L_{l(m),s}} \right)^{\lambda^L_{l(m),s}} \prod_k \left(\frac{P_{l(m),k}}{\lambda^k_{l(m),s}} \right)^{\lambda^k_{l(m),s}}.$$ [21]

Two of the three policies we analyze would affect exports directly through the unit cost at provincial and sectoral levels. The reduction in migration costs increases labor supply and lowers wages $w_{l(m),s}$. The decline in import tariffs would change the price $P_{l(m),k}$ for ordinary producers. However, it has no direct impact on the price for processing producers who have faced zero import tariffs since 1987.

Each firm draws a vector of productivities, $\left\{ \vec{\phi}_{l(m),s}, \vec{\phi}_{j,s} \right\}$, across China's provinces and regimes, and across foreign countries from a multivariate Pareto distribution with the fol-

[21] The unit cost of the input bundle is common to all firms in province l and export regime m.

lowing cumulative distribution function (CDF) (Arkolakis et al., 2016):

$$F\left(\vec{\phi}_{l(m),s}, \vec{\phi}_{j,s}\right) = 1 - \left[\sum_l \left(\sum_m A_{l(m),s}\phi_{l(m),s}^{-\frac{\theta}{1-\rho}}\right)^{\frac{1-\rho}{1-\gamma}} + \sum_j A_{j,s}\phi_{j,s}^{-\frac{\theta}{1-\gamma}}\right]^{1-\gamma}, \quad \theta > \sigma - 1 \tag{7}$$

with support defined on values greater than $\left[\sum_l \left(\sum_m A_{l(m),s}\right)^{\frac{1-\rho}{1-\gamma}} + \sum_j A_{j,s}\right]^{\frac{1-\gamma}{\theta}}$.

The parameter ρ captures the correlation of productivity draws between processing and ordinary regimes, while the parameter γ captures the correlation across locations. Each correlation parameter takes a value between 0 and 1, with values closer to 1 indicating a stronger correlation. These two correlation parameters govern the aggregate trade elasticity resulting from firms' location and regime switching. A larger value of the parameter θ corresponds to a smaller productivity dispersion across firms.

In Appendix B.2, we show that the massive migration to coastal provinces started no later than the surge in Chinese exports, where the timing suggests that agglomeration economies in coastal provinces arose from internal migration. To this end, we model agglomeration forces as external economies of scale (Ethier, 1982). Specifically, we assume $A_{l(m),s} = \bar{A}_{l(m),s}L_{l(m),s}^{\alpha}$ with α governing the agglomeration externality.

3.2.2 Firm's Problem

Firms face fixed marketing costs of exporting and two types of variable trade costs—iceberg trade costs and *ad valorem* tariffs, following Costinot and Rodríguez-Clare (2014). Firms solve a sequential optimization problem. In the first stage, for each destination market n, firms choose where to locate by minimizing the unit cost of exporting to destination n. In the second stage, given location and regime choices, firms decide whether to export to destination n and the optimal price if exporting. We solve the firm's optimization problem through backward induction.

Optimal Price: Under monopolistic competition, firms choose the optimal price to maximize profits if they were to produce in $l(m)$ and export to foreign country n,

$$\pi(\phi_{l(m),s}) = \max_{p_{l(m),n,s}} \left\{ \frac{p_{l(m),n,s}q_{l(m),n,s}}{\tilde{t}_{i,n,s}} - q_{l(m),n,s}\frac{c_{l(m),s}d_{l(m),n,s}}{\phi_{l(m),s}} - c_{n,s}f_{n,s} \right\},$$

subject to the quantity demanded, $q_{l(m),n,s} = \left[p_{l(m),n,s}\right]^{-\sigma} E_{n,s}P_{n,s}^{\sigma-1}$, where $E_{n,s}$ is destination n's total expenditure in sector s. The expression, $\tilde{t}_{i,n,s} = 1 + t_{i,n,s}$, incorporates the export tariff levied by foreign country n on Chinese goods and is constant across all provinces and regimes. $d_{l(m),n,s}$ denotes the non-tariff trade barriers. Firms also need to pay fixed marketing costs in terms of input bundles of destination n, denoted as $c_{n,s} f_{n,s} > 0$.[22] The optimal price is set with a markup $\frac{\sigma}{\sigma-1}$ over the marginal cost of selling to country n

$$p_{l(m),n,s} = \frac{\sigma}{\sigma - 1} \tilde{t}_{i,n,s} \frac{c_{l(m),s} d_{l(m),n,s}}{\phi_{l(m),s}}.^{23} \tag{8}$$

Exporting Decisions: Firms will only export to destination n if the profit is positive. Given the demand and the optimal price in equation (8), the zero-profit productivity cutoff above which the firm would export from $l(m)$ to destination n is

$$\phi^*_{l(m),n,s} = \frac{\sigma}{\sigma - 1} c_{l(m),s} d_{l(m),n,s} \tilde{t}_{i,n,s}^{\frac{\sigma}{\sigma-1}} \left(\frac{\sigma c_{n,s} f_{n,s}}{E_{n,s}} \right)^{\frac{1}{\sigma-1}} \frac{1}{P_{n,s}}. \tag{9}$$

In related papers that model firms' location choices in the spatial equilibrium, Suárez Serrato and Zidar (2016) and Fajgelbaum, Morales, Suárez Serrato and Zidar (2018) assume zero fixed costs. Here, we allow for positive fixed costs, and therefore our model incorporates the *extensive margin* of trade (Chaney, 2008).[24] Another point to note from equation (9) is that by modeling revenue tariffs, the zero-profit productivity cutoff is more responsive to tariff changes than to changes in iceberg costs.

Firm's Location and Regime Choices: In each sector s, firms choose a location among Chinese province-regimes and foreign countries to serve destination n where the unit cost of export is the lowest

$$\min_{l(m),j} \left\{ \frac{c_{l(m),s} d_{l(m),n,s} \tilde{t}_{i,n,s}}{\phi_{l(m),s}}, \frac{c_{j,s} d_{j,n,s} \tilde{t}_{j,n,s}}{\phi_{j,s}} \right\}.$$

In equilibrium, the number of firms that set up production in Chinese province-regime $l(m)$ is

$$M_{l(m),n,s} = \frac{\psi_{l(m),n,s}}{\sum_m \psi_{l(m),n,s}} \times \frac{\Psi_{l,n,s}}{\sum_l \Psi_{l,n,s} + \sum_j \psi_{j,n,s}} \times M_s, \tag{10}$$

and the number of firms that set up production in a foreign country j is

$$M_{j,n,s} = \frac{\psi_{j,n,s}}{\sum_l \Psi_{l,n,s} + \sum_j \psi_{j,n,s}} \times M_s, \tag{11}$$

where $\psi_{l(m),n,s} = A_{l(m),s} \left(c_{l(m),s} d_{l(m),n,s} \tilde{t}_{i,n,s} \right)^{-\frac{\theta}{1-\rho}}$, $\psi_{j,n,s} = A_{j,s} \left(c_{j,s} d_{j,n,s} \tilde{t}_{j,n,s} \right)^{-\frac{\theta}{1-\gamma}}$, and $\Psi_{l,n,s} =$

[22] $f_{n,s}$ is the fixed cost in units of input bundles in destination n. Although our model remains tractable by considering $f_{n,s}$ to be specific to l and m, we assume that $f_{n,s}$ is the same across l and m.

[23] Alternatively, we can also quantify the impact of China's elimination of trading rights on export growth by incorporating a commission rate charged by export intermediaries into $\tilde{t}_{i,n,s}$. See Bai, Krishna and Ma (2017) for the analysis of direct trading rights. However, this exercise is out of the scope of our paper.

[24] Without fixed marketing costs, the *extensive margin* of trade is absent because every firm makes positive profits and exports to every market under monopolistic competition.

$\left[\sum_m \psi_{l(m),n,s}\right]^{\frac{1-\rho}{1-\gamma}}$. $\tilde{t}_{i,n,s}$ and $\tilde{t}_{j,n,s}$ are the tariffs levied by destination n on China's and country j's exports, respectively. Firm location and regime choices are determined by local TFP $A_{l(m),s}$, trade costs, and production costs. The structural parameters, θ, ρ, and γ, govern the elasticity of firm responses to trade or production costs.

3.3 Aggregate Trade Flows and Prices

The aggregate trade flow from $l(m)$ to n in sector s is

$$X_{l(m),n,s} = M_{l(m),n,s} \times \left[\int_{\phi^*}^{+\infty} x_{l(m),n,s}(\phi) \, \mathrm{d}G_{\phi|l(m)} \right], \tag{12}$$

where $x_{l(m),n,s}(\phi)$ denotes the sales from $l(m)$ to n in sector s by firms with productivity level ϕ.[25] ϕ^* is the zero-profit productivity cutoff defined in equation (9), and $G_{\phi|l(m)}$ is the equilibrium productivity distribution among firms that choose $l(m)$.[26]

Equation (12) speaks to the key factors that determine China's export growth resulting from changes in $c_{l(m),s}$ or $\tilde{t}_{i,n,s}$. A reduction in $c_{l(m),s}$ would not only promote exports through the intensive and the extensive margin (Chaney, 2008), but also change the number of firms by affecting $M_{l(m),n,s}$. The aggregate trade elasticity also depends on γ and ρ, which govern firm location and regime responses to policy shocks, respectively.

Country n's expenditure share in sector s on goods produced by $l(m)$ is

$$\Pi_{l(m),n,s} = \frac{M_{l(m),n,s}\tilde{t}^{\vartheta}_{i,n,s}}{\sum_{l,m} M_{l(m),n,s}\tilde{t}^{\vartheta}_{i,n,s} + \sum_j M_{j,n,s}\tilde{t}^{\vartheta}_{j,n,s}}. \tag{14}$$

Equation (14) points out the *macro-level* consequence of modeling revenue tariffs, the changes in export tariffs have an additional impact on aggregate trade, which is captured by $\vartheta = \frac{\sigma-1-\theta}{\sigma-1}$, rather than entering symmetrically into iceberg trade costs. Similarly, the share of country n's expenditure in sector s that is spent on goods produced by foreign country j is

$$\Pi_{j,n,s} = \frac{M_{j,n,s}\tilde{t}^{\vartheta}_{j,n,s}}{\sum_{l,m} M_{l(m),n,s}\tilde{t}^{\vartheta}_{i,n,s} + \sum_j M_{j,n,s}\tilde{t}^{\vartheta}_{j,n,s}}. \tag{15}$$

[25] $x_{l(m),n,s}(\phi)$ is firm's sales to n, and we write it as

$$x_{l(m),n,s}(\phi) = \left(\frac{\sigma}{\sigma-1}\right)^{1-\sigma} \left(c_{l(m),s} d_{l(m),n,s} \tilde{t}_{i,n,s}\right)^{1-\sigma} \left(\phi_{l(m),s}\right)^{\sigma-1} E_{n,s} P^{\sigma-1}_{n,s}. \tag{13}$$

[26] As we showed in an early version of this paper, the equilibrium productivity distribution $G_{\phi|l(m)}$ also follows a Pareto distribution. The proof is available upon request.

The aggregate price index in country n and sector s is

$$P_{n,s} = \left[\Theta M_s \left(\frac{c_{n,s} f_{n,s}}{E_{n,s}}\right)^{\vartheta} \left(\sum_l \Psi_{l,n,s} + \sum_j \psi_{j,n,s}\right)^{-\gamma} \left(\left[\sum_l \Psi_{l,n,s}\right] \tilde{t}_{i,n,s}^{\vartheta} + \sum_j \psi_{j,n,s} \tilde{t}_{j,n,s}^{\vartheta}\right)\right]^{-\frac{1}{\theta}}, \quad (16)$$

where $\Theta = \sigma^{\frac{\sigma-\theta-1}{\sigma-1}} \left(\frac{\theta}{\theta-\sigma+1}\right) \left(\frac{\sigma}{\sigma-1}\right)^{-\theta}$.

3.4 Workers' Preferences and Labor Markets

Preferences. Workers' preferences over final goods are $U = \prod_s C_s^{\beta_s}$, with β_s being the expenditure share on the final good produced by sector s and $\sum_s \beta_s = 1$.

Chinese Labor Markets: Chinese workers are grouped by province of *Hukou* registration. We index group by g. Workers choose provinces and sectors by maximizing $\tau_{g,l,s} \times a_{g,l,s} \times V_{l,s}$. $\tau_{g,l,s}$ is the migration frictions which act as proportional adjustments to real income. In our baseline model, we assume migration frictions are group-destination-sector-specific, but consider alternative specifications in Appendix G.

$V_{l,s} = \frac{w_{l,s}}{P_l}$ is the real wage per efficiency unit in l and s, where P_l is the aggregate price index in province l.[27] $a_{g,l,s}$ is the idiosyncratic preferences, drawn independently across l and s from a Fréchet distribution with CDF $G(a) = \exp\big(-a_{g,l,s}^{-\kappa}\big)$. A larger κ corresponds to a smaller degree of heterogeneity in location preferences across workers.

Each worker supplies one unit of labor, and is perfectly mobile between processing and ordinary firms, $w_{l,s} = w_{l(\mathcal{P}),s} = w_{l(\mathcal{O}),s}$ within a province-sector pair. The Fréchet-distributed location preferences imply the fraction of group g workers in province l and sector s is

$$\Lambda_{g,l,s} = \frac{\tau_{g,l,s}^{\kappa} V_{l,s}^{\kappa}}{\sum_{l',s'} \tau_{g,l',s'}^{\kappa} V_{l',s'}^{\kappa}}. \quad (17)$$

Parameter κ governs the elasticity of labor supply with respect to real wages. We denote $L_{g,l,s} = L_g \Lambda_{g,l,s}$ as total efficiency units supplied by group g to province l and sector s.

Foreign Labor Markets: Each foreign country n has a fixed population L_n. We consider a single labor market in each foreign country, where labor is perfectly mobile across sectors, and w_n denotes the wage rate in country n.

[27] As workers only consume the final goods from ordinary production, $P_l = \prod_s \left(P_{l(\mathcal{O}),s}/\beta_s\right)^{\beta_s}$.

3.5 Market Clearing Conditions

Assuming that profits are spent on input bundles,[28] and tariff revenues are rebated to local workers, the market clearing condition for final goods in Chinese provinces is:

$$E_{l(m),s} = \beta_s I_{l(m)} + \sum_k \lambda^s_{l(m),k} \left((1-\eta) \sum_r \frac{\Pi_{l(m),r,k} E_{r,k}}{\tilde{t}_{l(m),r,k}} + \eta \sum_r \frac{\Pi_{r,l(m),k} E_{l(m),k}}{\tilde{t}_{r,l(m),k}} \right), \tag{18}$$

where $\eta = \frac{\theta - \sigma + 1}{\sigma\theta}$ is the ratio of marketing costs to net-of-tariff trade flows. The left-hand side is the value of the final good produced in $l(m)$ and sector s.[29] The first term on the right-hand side is workers' consumption. Because processing goods cannot be consumed domestically, workers spend wages and tariff revenues on ordinary goods: $I_{l(\mathcal{O})} = \sum_g \sum_s w_{l,s} L_{g,l,s} + \sum_s \sum_r \frac{t_{r,l(\mathcal{O}),s}}{\tilde{t}_{r,l(\mathcal{O}),s}} \Pi_{r,l(\mathcal{O}),s} E_{l(\mathcal{O}),s}$ and $I_{l(\mathcal{P})} = 0$. The second term sums up the material costs spent by local establishments and the marketing costs incurred by firms selling to the local market.

The labor market clears for each China's province l and sector s separately:

$$\sum_m \lambda^L_{l(m),s} \left((1-\eta) \sum_r \frac{\Pi_{l(m),r,s} E_{r,s}}{\tilde{t}_{l(m),r,s}} + \eta \sum_r \frac{\Pi_{r,l(m),s} E_{l(m),s}}{\tilde{t}_{r,l(m),s}} \right) = \sum_g w_{l,s} L_{g,l,s}. \tag{19}$$

The left-hand side represents both ordinary and processing producers' expenses on labor. The right-hand side is the labor income in province l and sector s earned by workers from all labor groups.

In summary, given model fundamentals and parameters, the endogenous variables for Chinese provinces and sectors $\{\Pi_{l(m),n,s}, P_{l(m),s}, \Lambda_{g,l,s}, E_{l(m),s}, w_{l,s}\}$ satisfy conditions (14), (16), and (17)–(19). The equilibrium conditions for foreign countries can be obtained analogously. We solve the model following the iterative algorithm developed in Alvarez and Lucas (2007).

4 Calibration

We calibrate our model to 29 sectors, 30 Chinese provinces, 35 foreign countries and a constructed rest of the world. We express the equilibrium system in proportional changes (see Appendix A.4) and solve the model using the "Exact Hat Algebra" approach (Dekle, Eaton and Kortum, 2008). We match our model to the year 2005, for which we have better quality data to measure provincial imports and exports. Our counterfactual results inform what the level of China's exports in 2005 would be if the tariffs and migration frictions were to stay at

[28] This assumption allows us to directly use input-output tables to calibrate input-output parameters $\{\lambda^L_{l(m),s}, \lambda^k_{l(m),s}\}$.

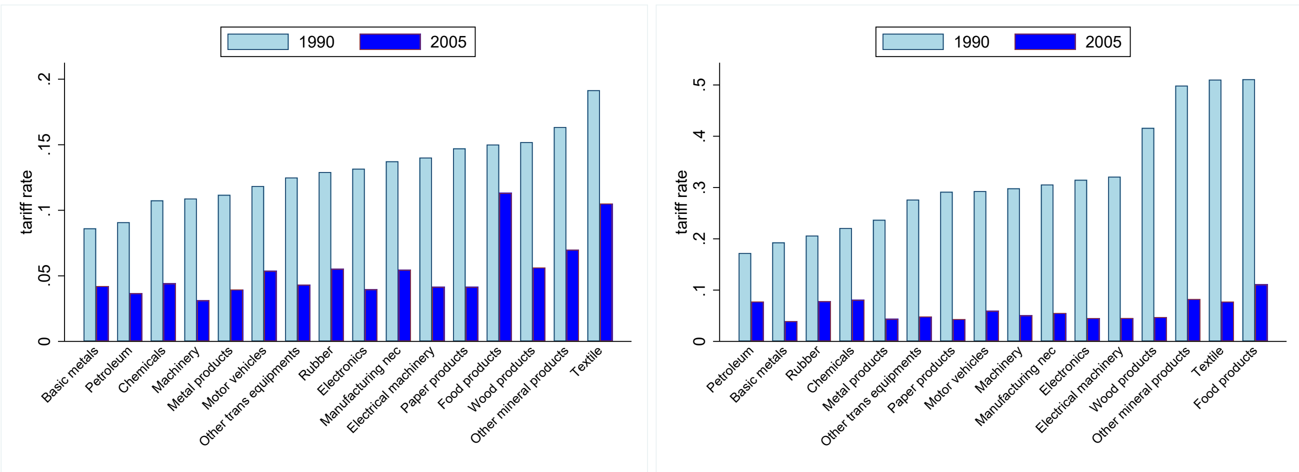
[29] Since the final good is produced using only intermediate goods (either produced domestically or imported), the value of the final good equals its total expenditure on intermediate goods, $E_{l(m),s} = P_{l(m),s} Q_{l(m),s}$.

the level in 1990.[30]

Solving the model requires data on intranational and international trade flows $\{\Pi_{l(m),n,s}\}$; firms' location choice $\{\frac{M_{l(m),s}}{M_s}\}$; inter-provincial migration rates $\{\Lambda_{g,l,s}\}$; sectoral output $\{X_{l(m),s}, X_{j,s}\}$; and labor income in both China $\{w_{l,s}L_{g,l,s}\}$ and foreign countries $\{w_n L_n\}$. We detail the data sources used to construct these variables in Appendix C. The rest of the section discusses the measurement of policy shocks, the calibration of model parameters, and the model fit.

4.1 Measuring Policy Shocks

Import and Export Tariff Changes. We draw tariffs from the UNCTAD Trade Analysis and Information System (TRAINS). We use trade volume as weights to aggregate the reported tariffs of 6-digit HS products into 16 tradable sectors. As China joined the WTO and gained the Most-Favored-Nation (MFN) status, the tariff levied by foreign countries on China's exports, on average, declined from 13% to 5% between 1990 and 2005. The changes also varied across sectors, see Figure 4 (left), and applied to both processing and ordinary firms. The decline in China's import tariffs was even more prominent, which on average declined from over 30% to less than 10%, and varied systematically across sectors, see Figure 4 (right). However, these changes only applied to ordinary firms.



(a) Export Tariffs

(b) Import Tariffs

Figure 4: China's Average Export Tariffs by Sectors (left); China's Import Tariffs by Sectors, in 1990 and 2005 (right)

Migration Cost Changes. Our baseline allows the migration cost changes to be specific to 29 sectors. Specifically, we calibrate changes in migration costs, $\hat{\tau}_{g,l,s}$, that match the observed

[30] Some previous papers calibrate models to the initial year (e.g., Caliendo and Parro, 2015, among others), while others match the model to the final year (Adao, Costinot and Donaldson, 2017). The choice of the initial equilibrium matters for the state of the economy the counterfactual exercise is conditional on, and thus the counterfactual interpretation differs.

changes in sectoral wages and migrant employment relative to home province l_g

$$\widehat{\tau}_{g,l,s} = \frac{\widehat{V}_{l_g,s}}{\widehat{V}_{l,s}} \left(\frac{\widehat{\Lambda}_{g,l,s}}{\widehat{\Lambda}_{g,l_g,s}} \right)^{\frac{1}{\kappa}}. \tag{20}$$

We measure $\widehat{V}_{l,s}$ as changes in province-sector-level real wages from the China Labor Statistical Yearbook. Calibrating migration costs requires a value of migration elasticity, for which we set $\kappa = 1.5$ following Tombe and Zhu (2019). While our baseline results are based on destination-origin-sector-specific migration costs, Appendix D.1 shows the results are similar when using alternative migration costs.

Column (1) in Table 3.A reports the aggregate and provincial changes in log τ between 1990 and 2005, obtained as the migrant population-weighted averages across origin provinces and all sectors. A larger value means a larger increase in the take-home wage rate over time, which is equivalent to a larger decline in migration costs. Not surprisingly, migration costs were reduced more in coastal provinces relative to other provinces, and the reduction was more prominent in Guangdong and Zhejiang. It also appears that the reduction in migration costs was more substantial in manufacturing than non-manufacturing sectors, as shown in Columns (2) and (3). Within manufacturing sectors, migration costs were reduced more in sectors with higher export-output ratios (see Appendix Figure G.1).

To summarize how the estimates vary across provinces, we regress $\log \frac{\tau_{l,s,2005}}{\tau_{l,s,1990}}$ on local observable characteristics. See Table 3.B. First, the estimated log changes were uncorrelated (or weakly correlated) with bilateral distance, and the results are similar when we use all or only manufacturing sectors. Second, we regress $\log \frac{\tau_{l,s,2005}}{\tau_{l,s,1990}}$ on the export-output ratio for each destination province and sector. Migration costs were reduced more in provinces and sectors that were more export oriented. Finally, we regress $\log \frac{\tau_{l,s,2005}}{\tau_{l,s,1990}}$ on the Hukou openness scores collected by Fan (2019).[31] Our estimated migration costs are generally consistent with these Hukou scores: Provinces that had larger reductions in migration costs also became less restrictive (more open) in terms of Hukou policies.

[31] Fan (2019) collected Hukou-related official news articles, laws, and regulations and then rated the stringency of the Hukou policy based on a set of criteria (e.g., whether a migrant is required to purchase an apartment or work for a certain amount of years to obtain local Hukou).

Table 3: Changes in Migration Frictions

A. Summary Statistics of Log Changes in Migration Frictions ($\log \frac{\tau_{l,s,2005}}{\tau_{l,s,1990}}$)

	(1) Overall	(2) Manufacturing	(3) Non-manufacturing
China	1.80	2.45	1.00
By destination:			
Guangdong	2.22	2.55	1.29
Jiangsu	1.70	2.15	1.12
Shanghai	1.29	1.56	1.09
Zhejiang	2.49	2.99	1.42
Fujian	2.62	3.37	1.21
Other provinces	0.85	1.37	0.70

B. Changes in Migration Frictions and Destination Characteristics

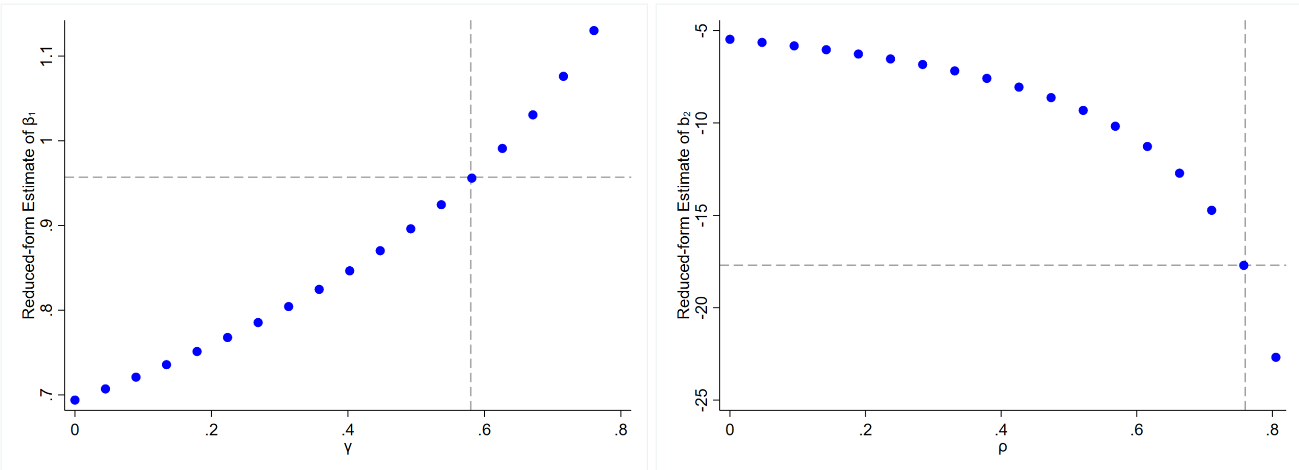
	All Sectors			Manufacturing Sectors		
	(1)	(2)	(3)	(4)	(5)	(6)
	Dep Var: Log Change in Migration Costs ($\log \frac{\tau_{l,s,2005}}{\tau_{l,s,1990}}$)					
Log(distance)	0.010			-0.020		
	(0.023)			(0.032)		
Export-output ratio		1.560***			1.036***	
(destination-sector-specific)		(0.067)			(0.072)	
ΔHukou openness score			0.060***			0.095***
(destination-specific)			(0.012)			(0.016)
Origin Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Obs	25,230	25,230	25,230	13,920	13,920	13,920
R-squared	0.005	0.084	0.011	0.008	0.059	0.023

Notes: In Panel A, the changes in migration costs by destination province are the migrant-population weighted averages across origin provinces and sectors. Other provinces include all the provinces other than Guangdong, Jiangsu, Shanghai, Zhejiang and Fujian. Panel B presents the regressions of changes in migration costs on destination characteristics. The distance refers to the physical distance between capitals of provinces. The export-output ratio is drawn for each destination-sector in 2005. As the Hukou openness scores (drawn from Fan (2019)) are only available after 1997, we use the change in Hukou openness scores between 1997 and 2005 in the regressions. In Columns (1)–(3), we use all our 29 sectors in the regression, and in Columns (4)–(6), we use 16 manufacturing sectors. Standard errors are in parenthesis and clustered by origin-destination pairs of provinces. Significance levels: 10% * 5% ** 1% ***.

4.2 Using Reduced-Form Estimates to Calibrate Structural Parameters

The credibility of our quantitative results depends crucially on the values of γ and ρ. We use an indirect inference approach (Gouriéroux and Monfort, 1996) to jointly search these structural parameters by targeting the reduced-form estimates in Section 2.4. Specifically, we solve the model for $20 \times 20 = 400$ times, where each time we set parameter values of γ and ρ as the pairwise combination in $[0, 0.9] \times [0, 0.9]$, with equally sized bins for each. We use the model-generated data of $\Delta M_{l,s}$ and $\Delta M_{l(m),s}$ to re-estimate equations (2) and (4), and search parameter values of γ and ρ under which the model-generated data can replicate the reduced-form estimates of $\beta_1 = 0.957$ (Column (3) of Table 1) and $b_2 = -17.38$ (Column (3) of Table 2). We provide details on the search algorithm in Appendix F.

Figure 5 (left) plots the reduced-form estimates of β_1 using the model-generated data against the associated value of γ, and Figure 5 (right) plots the reduced-form estimates of b_2 using the model-generated data against the associated value of ρ. We see a higher γ corresponds to a greater response of firms' location adjustments to internal migrants. We also find that a higher ρ indicates that lower import tariffs lead to larger responses of firms' switching toward ordinary regime, which corresponds to a more negative value of b_2. Our indirect inference approach yields estimates of $\gamma = 0.58$ and $\rho = 0.76$, both of which are comparable to those in the previous literature.[32]



(a) Estimate of β_1 in in Regression (2)

(b) Estimate of b_2 in Regression (4)

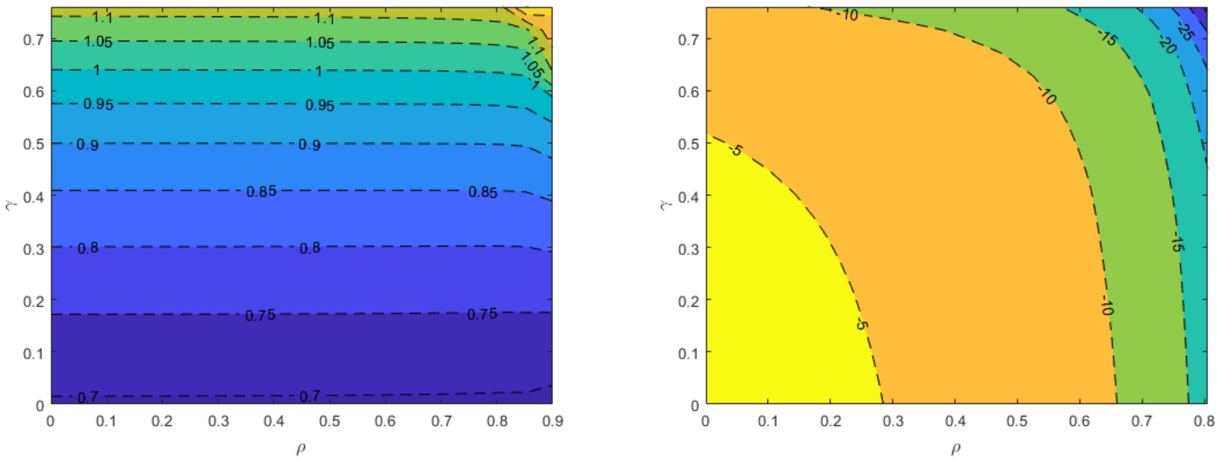
Figure 5: Reduced-form Estimates of β_1 against γ (left); Reduced-form Estimates of b_2 against ρ (right)

The left-hand figure varies γ in the counterfactual exercise with changes in migration barriers, holding all other parameters at their baseline levels. The vertical line represents the value of $\gamma = 0.58$, which matches the estimate in Column (3) of Table 1. The right-hand figure varies ρ in the counterfactual exercise with changes in import tariffs, holding all other parameters at their baseline levels. The vertical line represents the baseline value of $\rho = 0.76$, which matches the estimate in Column (3) of Table 2.

To confirm that our approach indeed identifies each structural parameter from its associated firm adjustments, Figure 6 plots the structural parameters ρ and γ on the horizontal and vertical axes, respectively. Given a pair of structural parameter values ρ and γ, the value of each contour line is the reduced-form estimates of β_1 using the model-generated data

[32] ARRY find the correlation of productivity draws across countries to be 0.55. Brandt et al. (2019) find the correlation of productivity draws between export regimes to be 0.71.

(left), and the reduced-form estimates of b_2 (right). Figure 6 (left) shows that the reduced-form estimate of β_1 is only responsive to γ but not to ρ, and similarly, Figure 6 (right) shows the reduced-form estimate of b_2 is mostly responsive to ρ but not to γ. These pieces of evidence confirm that γ is identified from the firm location response, and ρ from the firm regime switching.



(a) Estimate of β_1 in Regression (2)   (b) Estimate of b_2 in Regression (4)

Figure 6: Reduced-form Estimates of β_1 (contour line) against γ (y-axis) and ρ (x-axis), Left-hand Panel; Reduced-form Estimates of b_2 (contour line) against γ (y-axis) and ρ (x-axis), Right-hand Panel

4.3 Other Parameter Values

Table 4: Other Parameter Values

Parameter	Definition	Source	Value
σ	Elasticity of substitution across varieties	Head and Mayer (2014)	4
θ	Trade elasticity	Simonovska and Waugh (2014)	4
$\lambda^L_{l(m),s}$	Value added share (China)	ASIF, Customs, China I/O Table	
$\lambda^k_{l(m),s}$	Intermediate input share (China)	ASIF, Customs, China I/O Table	
$\lambda^L_{n,s}$	Value added share (foreign)	OECD I/O Table	
$\lambda^k_{n,s}$	Intermediate input share (foreign)	OECD I/O Table	
β_s	Sector consumption share	OECD I/O Table	
α	Agglomeration elasticity	Combes and Gobillon (2015)	0.05
κ	Labor supply elasticity	Tombe and Zhu (2019)	1.5

We also need nine additional sets of parameter values to solve the model, for which we summarize the values and data sources in Table 4. Briefly, we calculate β_s, the share of income spent on sector s, as the ratio of total consumption on sectoral goods to the world total income. We compute sectoral value added shares $\lambda^L_{l(m),s}$ for processing and ordinary firms by matching the 2005 China's Annual Survey of Industrial Firms (ASIF) with the 2005 Customs Database. We draw cost shares of inputs $\lambda^k_{l(m),s}$ from China's input-output tables, and rescale the value added shares for processing and ordinary firms such that the export-weighted average of value added shares in each sector matches the one in the input-output tables. We obtain foreign countries' value added shares $\lambda^L_{n,s}$ and cost shares of intermediate inputs $\lambda^k_{n,s}$ from OECD input-output tables.[33]

4.4 Model Fit

As we solve the model in changes, it is difficult to compare the model fit to the data in levels. For model validation, we compare employment responses to tariff changes between the model and the data. Specifically, we introduce changes in China's export and import tariffs between 2000 and 2005 into our model, to obtain model-predicted changes in province-sector-level employment of processing and ordinary firms. We also measure the actual province-sector-level employment changes by processing and ordinary firms from the merged ASIF-Customs data for the same period.[34] We regress the model-generated and actual province-sector-level employment changes, respectively, on tariff changes measured as $\frac{1+t_{k,2005}}{1+t_{k,2000}}$, where $t_{k,t}$ is the tariff rate at time t for sector k.

Panel A of Table 5 reports the coefficients for import tariff changes, by ordinary and processing exporters. Although all coefficients only reflect the raw correlation between tariff and employment changes, the model and the data show a similarity in the coefficient estimates. In Panel B, we again find a relatively similar magnitude of coefficients for export tariff changes. We take these as suggestive evidence that our model is able to capture heterogeneity in province-sector-level employment changes.

[33] We calculate $\lambda^k_{n,s}$ as the ratio of intermediate inputs from sector k to total output in sector s for each country, and then take the average over all countries. We calculate the value added share as $\lambda^L_{n,s} = 1 - \sum_k \lambda^k_{n,s}$.

[34] We compute firms' ordinary (processing) employment using their total employment multiplied by the share of ordinary (processing) exports in its total sales.

Table 5: Province-Sector-Level Employment and Tariff Changes between 2000 and 2005

Dependent variable	Changes in employment ordinary exporters		Changes in employment processing exporters	
	data	model	data	model
Panel A: import tariff changes between 2000–2005				
import tariff changes	-3.212**	-2.956***	-8.154***	-3.885***
	(1.225)	(0.193)	(2.423)	(0.548)
Obs	382	380	306	299
R-squared	0.008	0.237	0.039	0.116
Panel B: export tariff changes between 2000–2005				
export tariff changes	-6.753***	-8.677***	-11.236**	-11.785***
	(2.547)	(0.401)	(4.463)	(1.041)
Obs	382	380	306	299
R-squared	0.010	0.570	0.021	0.297

Notes: Changes in employment are defined following Davis and Haltiwanger (1992). We perform the regressions across 30 provinces and 16 manufacturing sectors. The changes in export tariffs are calculated as the average of export tariffs changes across all destinations. Standard errors are in parenthesis and clustered by province. Significance levels: 10% * 5% ** 1% ***.

5 Quantitative Results

China's manufacturing exports increased by a factor of 11.8 in real terms between 1990 and 2005, equaling an annual growth rate of 17.8%. The export growth was more concentrated among coastal provinces (see Appendix Figure G.2). We begin by accounting for the observed export growth by each individual policy, and the residual growth unexplained by tariff and migration policies. The residual includes the potential interaction of tariff and migration policies, as well as other factors such as firm-level TFP growth and reductions in non-tariff trade barriers. These non-tariff barriers are captured in iceberg and fixed trade costs which potentially absorb factors such as the elimination of direct trading rights (Bai et al., 2017), the falling in trade uncertainty (Handley and Limão, 2017), and the elimination of export quotas (Khandelwal et al., 2013). We keep the tariff structure between foreign countries unchanged in counterfactual exercises. Appendix D presents additional quantitative results using alternative migration costs or an alternative model with firm entry.

5.1 The Effects of Individual Policy

National Export Growth. We first evaluate the export impact of each individual policy shock. We do so by taking each shock into the model, one at a time. Panel A of Table 6 shows that the reduction in migration costs led to a 1.29 p.p. increase in annual export growth rate, accounting for $\frac{1.29}{17.8} \approx 7.2\%$ of the overall export growth during this period. Because foreign countries differed in their sourcing patterns from China's provinces, the reduction in migration costs favored exports to the US and European countries more than to Asian trade partners (see Appendix D.4).

The reduction in import tariffs caused a 2.25 p.p. increase in annual export growth rate and accounted for $\frac{2.25}{17.8} \approx 12.6\%$ of the overall export growth. We elaborate in Section 5.3 that the equilibrium wage and labor adjustments both played an important role, particularly in promoting the growth of processing exports. The changes in export tariffs resulted in a 1.37 p.p. increase in annual export growth and accounted for $\frac{1.37}{17.8} \approx 7.7\%$ of the overall export growth.

Table 6: The Overall Impact on China's Export Growth (in percentage points), 1990–2005

Migration Costs		**Import Tariff**		**Export Tariff**	
Panel A: Impact on the overall national exports					
1.29		2.25		1.37	
Panel B: Impact on ordinary and processing exports					
Ordinary	Processing	Ordinary	Processing	Ordinary	Processing
0.89	1.61	2.66	1.95	0.66	1.99

Each shock had differential impacts on processing and ordinary exports, reported in Panel B. Although the share of labor value added was higher in ordinary production than in processing production (Kee and Tang, 2016), we find the reduction in migration costs had a larger impact on processing exports than on ordinary exports at the national level, causing a 1.61 p.p. increase in annual growth for processing exports and a 0.89 p.p. increase for ordinary exports. This result was unexpected and was primarily driven by the fact that migrants' employment shares were large in processing-oriented sectors.

Reductions in import tariffs caused a 2.66 p.p increase in annual growth for ordinary exports, which was larger than the impact on processing exports. The results are driven by that the imported materials for processing exporters were duty-free and thus unaffected by these reductions in nominal tariffs. However, differing from the partial equilibrium analysis in Brandt and Morrow (2017), our general equilibrium approach also predicts a 1.95 p.p increase in annual growth of processing exports, which is a result of input-output linkages and equilibrium wage adjustments (similar to Ossa, 2014). Finally, because processing producers were more concentrated in sectors that experienced large export tariff reductions than ordinary producers, the impacts are larger on processing than on ordinary exports.

Provincial Export Growth. The export growth of internal migration took place primarily among coastal provinces. Panel A of Table 7 shows that 95% of the growth was contributed by three provinces (Guangdong, Jiangsu and Shanghai), with Guangdong itself accounting for 68.6% of the total. Panel B breaks down the contributions by processing and ordinary exports. In line with the large migrant employment in processing-oriented sectors, Guangdong accounted for 77.8% of processing export growth from the reduced migration costs, but 48.4% for ordinary exports. In contrast, driven by industrial composition, Jiangsu and Shanghai both contributed higher percentages to China's ordinary export growth than to processing exports.

In Section 2.3, we decomposed the effect of migration on export growth into an aggregate productivity gain and an increase in aggregate export intensity. One of the several factors overlooked there was the general equilibrium wage adjustments. As reported in Appendix Table G.1, these wage adjustments appear to be large: On average, internal migration caused the manufacturing wages to fall by 7% in Guangdong, with the largest wage decline of 11.4% in electronic and optical equipment sector. Revisiting the decomposition in equation (1) in our equilibrium model, we find migration cost reductions led to a 0.54 p.p. increase of China's annual output growth, accounting for $\frac{0.54}{1.29} = 42\%$ of the impact of migration cost reductions on national export growth.[35] The remaining $1 - 42\% = 58\%$ was due to the increase in the national export intensity.

The effects of tariff reductions were less concentrated among coastal provinces. On the aggregate, the three listed provinces accounted for $26\% + 15.2\% + 11.9\% = 53.1\%$ of national export growth from import tariff reductions and $31.8\% + 20.0\% + 12.6\% = 64.4\%$ from export tariff reductions. Because export processing activities were more concentrated in Guangdong and Jiangsu, import and export tariff reductions both had larger impacts on their processing than ordinary export growth. We find the opposite pattern for Shanghai.

Table 7: The Provincial Share in National Export Growth, 1990–2005

	Migration Costs		**Import Tariff**		**Export Tariff**	
	Panel A: Provincial Share in National Export Growth					
Guangdong	68.6%		26.0%		31.8%	
Jiangsu	6.9%		15.2%		20.0%	
Shanghai	19.9%		11.9%		12.6%	
	Panel B: Provincial Share in National Export Growth by Regime					
	Ordinary	Processing	Ordinary	Processing	Ordinary	Processing
Guangdong	48.4%	77.8%	17.0%	35.2%	14.4%	36.8%
Jiangsu	8.0%	6.5%	13.7%	16.7%	11.4%	22.5%
Shanghai	24.7%	17.7%	16.3%	7.4%	12.8%	12.6%

[35]Here, the result is nearly half of that calculated in Section 2.3, because the calculation in Section 2.3 holds the sectoral labor force of local Hukou residents unchanged.

5.2 The Policy Interactions

Because the reductions in migration costs caused China to be more export oriented, China is able to enjoy faster export growth from opening to trade. This suggests a potential positive interaction effect of migration and trade policies. We quantify the policy interaction effect in this section.

Table 8: The Interaction of Migration and Trade Policies

The Joint Effects of Tariffs and Migration		**Aggregating Individual Effects of Tariffs and Migration**	
5.27		4.91	
Ordinary	Processing	Ordinary	Processing
4.22	6.21	4.21	5.55

To this end, we evaluate the joint effects of three policies, in which we simultaneously incorporate the three policy changes in the model. Table 8 reports a joint effect of 5.27 p.p., which accounted for $\frac{5.27}{17.8} = 30\%$ of China's export surge between 1990 and 2005. The remaining 70% of China's export surge was unexplained by migration and tariff policy changes, which reflects the fact that other factors also matter for China's export surge, such as firm-level TFP growth and reductions in non-tariff trade barriers. Interestingly, the joint effect is larger than the aggregation of individual effects, which total 4.91 p.p. The latter is computed based on Table 6. The comparison indicates a positive interaction of tariff and migration policy, which contributed to $5.27 - 4.91 = 0.36$ p.p. annual export growth. This interaction effect would have been missing if we analyzed migration and tariffs separately.

The positive interaction is driven by the covariance between migration and trade policies: The movement of labor increased the employment size in export-intensive provinces and processing-oriented industries so that when tariffs fell, aggregate exports tended to rise more. This association, however, can be generated through three possible mechanisms in our model.[36] The first is comparative advantage: Even if the decrease in migration costs were similar across provinces and sectors, the same change in migration costs would have led to a larger change in the relative supply of workers in export-oriented provinces and sectors, because migrants accounted for a higher employment share in these provinces and sectors (due to geographic proximity or comparative advantage). The second is that migration costs decreased more in export-oriented provinces (similarly across sectors). Third, migration costs were reduced more in export-oriented industries.

To evaluate the strength of each mechanism, we first quantify the interaction effects by

[36] We thank an anonymous referee for this suggestion.

considering constant migration cost changes $\widehat{\tau}_{g,l,s} = \bar{\zeta}$. We search for $\bar{\zeta}$ such that the predicted changes in aggregate migrant employment between 1990 and 2005 match the data. We find a positive interaction effect of 0.24 p.p. (0.36 p.p in the baseline). In this setting, the positive interaction effect arises because migrants accounted for a higher employment share in export-oriented provinces and sectors.

Second, we quantify the interaction effects by considering two other scenarios for migration cost changes: (1) destination-specific $\widehat{\tau}_{g,l,s} = \zeta_l$, in which we search for ζ_l such that the predicted provincial migration changes match the data, and (2) origin-destination-specific $\widehat{\tau}_{g,l,s} = \zeta_{g,l}$, in which we search for $\zeta_{g,l}$ such that the predicted bilateral migration changes match the data. In contrast to the baseline model, these exercises eliminate origin-sector or sectoral heterogeneity in migration cost reductions. The first two mechanisms are both in play. We find an interaction effect of 0.28 p.p for both settings.

Third, we calibrate migration cost changes to be specific to one broad manufacturing sector and 13 non-tradable sectors. Here, for each origin-destination pair, the migration cost changes are identical across 16 manufacturing sectors and match exactly the changes in migrants' employment shares and wages in broad manufacturing. This exercise eliminates heterogeneity in migration cost reductions across detailed manufacturing sectors. We find an interaction effect of 0.34 p.p, which is comparable to the baseline model (0.36 p.p).

Overall, we interpret these results as evidence that the first mechanism—the observed higher employment share in export-oriented provinces and sectors (due to comparative advantage or geographic proximity)—is the main driver of the positive interaction effect.

Breaking down the results by processing and ordinary exports, we find that, consistent with migrants' sectoral sorting, the interaction effects of tariff and migration policies arose only for processing exports but were absent for ordinary exports. Specifically, the joint effects caused a 6.21 p.p. annual growth rate for processing exports, which was $6.21 - 5.55 = 0.66$ p.p. larger than the aggregation of individual effects. The results are because migrants accounted for a much larger employment share in processing-oriented sectors than the other sectors (see Figure 2). The mechanism would have been missing if processing and ordinary exports were not distinguished in the model.

5.3 The Firm and Worker Adjustments

Our model departs from ARRY by allowing labor adjustments across locations and sectors, and differs from Tombe and Zhu (2019) and Fan (2019) by allowing firm adjustments across locations and regimes. This section analyzes the impact of firm and worker adjustments on China's exports.

First, we study what the effects of (import and export) tariffs would have been if workers' location and sectoral adjustments were absent. We carry out this exercise by directly applying ARRY to multiple sectors and regions in China's context with fixed labor force in each province and sector. Using this model, we find tariff reductions caused export growth to increase by 3.34 p.p. annually, as reported in Panel A of Table 9. Using our benchmark model, however, the effect of tariffs became 3.75 p.p. and the difference reflected the role of labor adjustments in driving the overall export growth. Moreover, because migration was prominent in processing-oriented sectors, the impact of labor adjustments was substantial for processing exports but was negligible for ordinary exports: The effect of tariffs on processing export growth was 21% higher with labor adjustments than without, increasing from 3.51 p.p. to 4.24 p.p..

Table 9: The Export Effects of Firm and Labor Adjustments

Impact of Tariffs No Labor Adjustments		**Impact of Tariffs Benchmark Model**	
Panel A: The Role of Labor Adjustments			
The Aggregate Export Effects			
3.34		3.75	
Ordinary	Processing	Ordinary	Processing
3.14	3.51	3.18	4.24
The Joint Effects of Tariffs and Migration $\gamma = \rho = 0$		**The Joint Effects of Tariffs and Migration** **Benchmark Model**	
Panel B: The Role of Firm Adjustments			
The Aggregate Export Effects			
2.94		5.27	
Ordinary	Processing	Ordinary	Processing
2.86	3.00	4.22	6.21

Next, we analyze the role of firm adjustments in affecting exports. Note that our model-implied (partial) trade elasticity to trade costs is

$$\frac{\partial X_{l(m),n,s}}{\partial d_{l(m),n,s}} = \underbrace{\Big(\sigma - 1\Big)}_{\text{Intensive Margin}} + \underbrace{\Big(\theta - \sigma + 1\Big)}_{\text{Extensive Margin}} + \underbrace{\frac{\theta\gamma}{1-\gamma}\left(1 - \frac{M_{l,n,s}}{M_s}\right)\frac{M_{l(m),n,s}}{M_{l,n,s}}}_{\text{Firm-location}} + \underbrace{\frac{\theta\rho}{1-\rho}\left(1 - \frac{M_{l(m),n,s}}{M_{l,n,s}}\right)}_{\text{Export-regime}}. \tag{21}$$

The first two terms in equation (21) measure the *intensive* and *extensive margins* that follow the same formula as in Chaney (2008). The third and the fourth terms capture the aggregate export response resulting from firm location and regime changes. As a special case when $\rho = \gamma = 0$, the number of processing and ordinary firms is fixed in each province and sector, and our model turns off firm location and regime adjustments. We then re-evaluate the joint effects of three policies in a model that sets $\rho = \gamma = 0$, and compare the effects with our benchmark results. Unsurprisingly, Panel B of Table 9 shows the effects drop by nearly half, from 5.27 p.p. to 2.94 p.p. The effects of firm adjustments on exports appear to be stronger for processing exports, with a larger percentage drop of $\frac{6.21-3}{6.21} = 52\%$ for processing exports, than for ordinary exports, $\frac{4.22-2.86}{4.22} = 32\%$.

We conclude that firm and worker adjustments are both quantitatively important for evaluating China's export growth.

6 Conclusion

A large number of studies have examined the economic consequences of China's export surge on advanced economies: for example, see Autor, Dorn and Hanson (2013) and Pierce and Schott (2016) on the US; and Bloom, Draca and Van Reenen (2016) and Dippel, Gold, Heblich and Pinto (2022) on European countries, among others. However, the causes of China's export growth are relatively understudied. This paper builds a spatial equilibrium model to quantify how reductions in tariffs and migration costs affected Chinese exports between 1990 and 2005. The model incorporates heterogeneous firms' location and regime choices, and workers' location and sectoral choices. Using reduced-form estimates to discipline the key structural parameters, our results show the tariff and migration policies jointly accounted for 30% of China's export growth. Importantly, we find a positive interaction of migration and trade policies, which arose entirely from processing export growth. We also find evidence suggesting the quantitative importance of firm and worker adjustments for evaluating China's export growth. Our analysis highlights the importance of jointly analyzing migration and tariff policies, as well as the importance of distinguishing processing and ordinary exports in China's context.

China has experienced spectacular economic growth over the past three decades. The policy interaction in China's context suggests that internal market integration can potentially prepare a country to better enjoy the economic gain from globalization, offering a lesson for developing countries.

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Online Appendix

A Derivation

A.1 Firm Location and Regime Choices

The proof follows closely from ARRY, while the only difference is that we allow the productivity correlation across regimes (ρ) to differ from the productivity correlation across locations (γ). To ease the argument, we define the following two random variables Y and Z as follows

$$Y = \arg\max_{l(m),j} \left\{ \vec{\tilde{\phi}}_{l(m),n,s}, \vec{\tilde{\phi}}_{j,n,s} \right\},$$

where Y is a discrete random variable denoting firms' location and regime choices. $\tilde{\phi}_{l(m),n,s} = \frac{\phi_{l(m),s}}{c_{l(m),s} d_{l(m),n,s} \tilde{t}_{i,n,s}}$ and $\tilde{\phi}_{j,n,s} = \frac{\phi_{j,n,s}}{c_{j,s} d_{j,n,s} \tilde{t}_{j,n,s}}$

We omit subscript n and s, but we are aware that Y is destination- and sector-specific.

$$Z = \max_{l(m),j} \left\{ \vec{\tilde{\phi}}_{l(m),n,s}, \vec{\tilde{\phi}}_{j,n,s} \right\}.$$

For ease of notations, we also omit n and s in the proof and denote $\xi = cd\tilde{t}$.

$$\begin{aligned} P\Big(\tilde{\phi}_{l(m)} \leqslant x_{l(m)}, \tilde{\phi}_j \leqslant x_j, \forall l, m, j\Big) &= P\Big(\phi_{l(m)} \leqslant \xi_{l(m)} x_{l(m)}, \phi_j \leqslant \xi_j x_j, \ \ \forall l, m, j\Big) \\ &= 1 - \left[\sum_l \left(\sum_m A_{l(m)} \xi_{l(m)}^{-\frac{\theta}{1-\rho}} x_{l(m)}^{-\frac{\theta}{1-\rho}} \right)^{\frac{1-\rho}{1-\gamma}} + \sum_j A_{j,s} \xi_j^{-\frac{\theta}{1-\gamma}} x_j^{-\frac{\theta}{1-\gamma}} \right]^{1-\gamma}. \end{aligned}$$

The first equality holds since by definition, $\tilde{\phi} = \frac{\phi}{\xi}$. The derivative of the CDF with respect to an arbitrary element $x_{k(o)}$ is

$$P\Big(\tilde{\phi}_1 \leqslant x_1, ..., \tilde{\phi}_{k(o)} = x_{k(o)}, ..., \tilde{\phi}_N \leqslant x_N\Big) = \frac{\partial P\Big(\tilde{\phi}_1 \leqslant x_1, ..., \tilde{\phi}_{k(o)} = x_{k(o)}, ..., \tilde{\phi}_N \leqslant x_N\Big)}{\partial x_{k(o)}}.$$

Using our multivariate Pareto CDF function, this derivative further equals

$$\theta \left[\sum_l \left(\sum_m A_{l(m)} \xi_{l(m)}^{-\frac{\theta}{1-\rho}} x_{l(m)}^{-\frac{\theta}{1-\rho}} \right)^{\frac{1-\rho}{1-\gamma}} + \sum_j A_j \xi_j^{-\frac{\theta}{1-\gamma}} x_j^{-\frac{\theta}{1-\gamma}} \right]^{-\gamma} \left(\sum_m A_{l(m)} \xi_{l(m)}^{-\frac{\theta}{1-\rho}} x_{l(m)}^{-\frac{\theta}{1-\rho}} \right)^{\frac{1-\rho}{1-\gamma}-1} \frac{A_{k(o)} \xi_{k(o)}^{-\frac{\theta}{1-\rho}} x_{k(o)}^{-\frac{\theta}{1-\rho}}}{x_{k(o)}}. \tag{22}$$

Evaluating the derivative of the CDF at a common productivity level z gives the joint probability for firms to choose k and n at that productivity level, which equals

$$\begin{aligned} P\Big(Y = k(o) \ \& \ Z = z\Big) &= P\Big(\tilde{\phi}_1 \leqslant z, ..., \tilde{\phi}_{k(o)} = z, ..., \tilde{\phi}_{l(m)} \leqslant z\Big) \\ &= \frac{\psi_{k(o),n,s}}{\sum_m \psi_{k(m),n,s}} \times \Psi_{k,n,s} \times \Big[\sum_l \Psi_{l,n,s} + \sum_j \psi_{j,n,s} \Big]^{-\gamma} \theta z^{-\theta-1}. \end{aligned}$$

The second equality holds by plugging z into formula (22).

$$\psi_{k(o),n,s} = A_{k(o),s} \Big(c_{k(o),s} d_{k(o),n,s} \tilde{t}_{i,n,s} \Big)^{-\frac{\theta}{1-\rho}}, \qquad \psi_{j,n,s} = A_{j,s} \Big(c_{j,s} d_{j,n,s} \tilde{t}_{j,n,s} \Big)^{-\frac{\theta}{1-\gamma}},$$

and $\Psi_{k,n,s} = \left[\sum_m \psi_{k(m),n,s}\right]^{\frac{1-\rho}{1-\gamma}}$. Analogously, the derivative of the CDF with respect to an arbitrary element x_j is

$$\theta\left[\sum_l \left(\sum_m A_{l(m)}\xi_{l(m)}^{-\frac{\theta}{1-\rho}} x_{l(m)}^{-\frac{\theta}{1-\rho}}\right)^{\frac{1-\rho}{1-\gamma}} + \sum_j A_j \xi_j^{-\frac{\theta}{1-\gamma}} x_j^{-\frac{\theta}{1-\gamma}}\right]^{-\gamma} \frac{A_j \xi_j^{-\frac{\theta}{1-\gamma}} x_j^{-\frac{\theta}{1-\gamma}}}{x_j}.$$

Evaluating the derivative of CDF at a common productivity level z, we have

$$P\Big(Y = j \,\&\, Z = z\Big) = \psi_{j,n,s} \times \Big[\sum_l \Psi_{l,n,s} + \sum_j \psi_{j,n,s}\Big]^{-\gamma} \theta z^{-\theta-1}.$$

The probability density function of Z is

$$\begin{aligned} P\Big(Z = z\Big) &= \sum_{l,m} P\Big(Y = k(o) \,\&\, Z = z\Big) + \sum_j P\Big(Y = j \,\&\, Z = z\Big) \\ &= \Big[\sum_l \Psi_{l,n,s} + \sum_j \psi_{j,n,s}\Big]^{1-\gamma} \theta z^{-\theta-1}. \end{aligned}$$

By the definition of conditional probability,

$$P\Big(Y = l(m)|Z = z\Big) = \frac{P\Big(Y = l(m) \,\&\, Z = z\Big)}{P\Big(Z = z\Big)} = \frac{\psi_{l(m),n,s}}{\sum_m \psi_{l(m),n,s}} \times \frac{\Psi_{l,n,s}}{\sum_l \Psi_{l,n,s} + \sum_j \psi_{j,n,s}}. \tag{23}$$

Note that $P(Y = l(m)|Z = z)$ is not a function of z, this means $P(Y = l(m)|Z = z) = P(Y = l(m))$. We have

$$M_{l(m),n,s} = \frac{\psi_{l(m),n,s}}{\sum_m \psi_{l(m),n,s}} \times \frac{\Psi_{l,n,s}}{\sum_l \Psi_{l,n,s} + \sum_j \psi_{j,n,s}} \times M_s.$$

A.2 Aggregate Price and Trade Shares

The trade flows from $l(m)$ to n can be written as (we drop subscripts n and s for most variables to simplify the notation). Again, let $\widetilde{\phi}_{l(m),n,s} = \frac{\phi_{l(m),s}}{c_{l(m),s} d_{l(m),n,s} \tilde{t}_{i,n,s}}$ and $\widetilde{\phi}_{j,n,s} = \frac{\phi_{j,n,s}}{c_{j,s} d_{j,n,s} \tilde{t}_{j,n,s}}$.

$$\begin{aligned} X_{l(m),n,s} &= M_{l(m),n,s} \int_{\widetilde{\phi}*}^{+\infty} x_{l(m),n,s}(\widetilde{\phi}) P\Big(Z = \widetilde{\phi} \mid Y = \{l,m\}\Big) \mathrm{d}\widetilde{\phi} \\ &= \theta M_s \frac{\psi_{l(m)}}{\sum_m \psi_{l(m)}} \Psi_l \Big[\sum_l \Psi_l + \sum_j \psi_j\Big]^{-\gamma} \Big(\frac{\sigma}{\sigma-1}\Big)^{1-\sigma} \Bigg[\int_{\widetilde{\phi}*}^{+\infty} \Big(\widetilde{\phi}\Big)^{\sigma-\theta-2} \mathrm{d}\widetilde{\phi}\Bigg] E_{n,s} P_{n,s}^{\sigma-1} \\ &= \frac{\theta\big(\frac{\sigma}{\sigma-1}\big)^{1-\sigma}}{\theta-\sigma+1} M_s \frac{\psi_{l(m)}}{\sum_m \psi_{l(m)}} \Psi_l \Big[\sum_l \Psi_l + \sum_j \psi_j\Big]^{-\gamma} \Big(\widetilde{\phi}^*\Big)^{\sigma-\theta-1} E_{n,s} P_{n,s}^{\sigma-1} \\ &= \Theta M_s \frac{\psi_{l(m)}}{\sum_m \psi_{l(m)}} \Psi_l \Big[\sum_l \Psi_l + \sum_j \psi_j\Big]^{-\gamma} \tilde{t}_i^{\vartheta} \Big(c_{n,s} f_{n,s}\Big)^{\vartheta} E_{n,s}^{\frac{\theta}{\sigma-1}} P_{n,s}^{\theta}, \end{aligned}$$

where $\Theta = \sigma^{\frac{\sigma-\theta-1}{\sigma-1}} \left(\frac{\theta}{\theta-\sigma+1}\right) \left(\frac{\sigma}{\sigma-1}\right)^{-\theta}$, and $\vartheta = \frac{\sigma-1-\theta}{\sigma-1}$. The second equality holds by plugging in $M_{l(m),n,s}$ as in equation (10), $x_{l(m),n,s}(\widetilde{\phi})$ as in equation (13), and $P\Big(Z = \widetilde{\phi} \mid Y = \{l,m\}\Big)$ as in equation (23). Analogously, one can derive the trade flows from country j to n as

$$X_{j,n,s} = M_{j,n,s} \int_{\widetilde{\phi}*}^{+\infty} x_{j,n,s}(\widetilde{\phi}) P\Big(Z = \widetilde{\phi} \mid Y = \{j\}\Big) \mathrm{d}\widetilde{\phi}$$

$$= \Theta M_s \psi_j \Big[\sum_l \Psi_l + \sum_j \psi_j \Big]^{-\gamma} \tilde{t}_j^{\vartheta} \Big(c_{n,s} f_{n,s} \Big)^{\vartheta} E_{n,s}^{\frac{\theta}{\sigma-1}} P_{n,s}^{\theta}.$$

We can obtain the aggregate price index as

$$P_{n,s} = \Bigg[M_{l(m),n,s} \sum_{l,m} \int_{\widetilde{\phi}^*_{i,n,s}}^{+\infty} p(\widetilde{\phi})^{1-\sigma} P\Big(Z = \widetilde{\phi} \mid Y = \{l,m\}\Big) \mathrm{d}\widetilde{\phi}$$

$$+ M_{j,n,s} \sum_j \int_{\widetilde{\phi}^*_{j,n,s}}^{+\infty} p(\widetilde{\phi})^{1-\sigma} P\Big(Z = \widetilde{\phi} \mid Y = \{j\}\Big) \mathrm{d}\widetilde{\phi} \Bigg]^{\frac{1}{1-\sigma}}$$

$$= \Bigg[M_s \theta \sum_{l,m} \frac{\psi_{l(m)}}{\sum_m \psi_{l(m)}} \Psi_l \Big[\sum_l \Psi_l + \sum_j \psi_j \Big]^{-\gamma} \Big(\frac{\sigma}{\sigma-1} \Big)^{1-\sigma} \Big[\int_{\widetilde{\phi}^*_{i,n,s}}^{+\infty} \widetilde{\phi}^{\sigma-\theta-2} \mathrm{d}\widetilde{\phi} \Big]$$

$$+ M_s \theta \sum_j \psi_j \Big[\sum_l \Psi_l + \sum_j \psi_j \Big]^{-\gamma} \Big(\frac{\sigma}{\sigma-1} \Big)^{1-\sigma} \Big[\int_{\widetilde{\phi}^*_{j,n,s}}^{+\infty} \widetilde{\phi}^{\sigma-\theta-2} \mathrm{d}\widetilde{\phi} \Big] \Bigg]^{\frac{1}{1-\sigma}}$$

$$= \Bigg[\Theta M_s \Big(\frac{c_{n,s} f_{n,s}}{E_{n,s}} \Big)^{\vartheta} P_{n,s}^{\theta-\sigma+1} \Big[\sum_l \Psi_{l,n,s} + \sum_j \psi_{j,n,s} \Big]^{-\gamma} \Bigg(\sum_l \Psi_l \tilde{t}_{i,n,s}^{\vartheta} + \sum_j \psi_j \tilde{t}_{j,n,s}^{\vartheta} \Bigg) \Bigg]^{\frac{1}{1-\sigma}}$$

$\iff$

$$P_{n,s}^{\theta} = \Bigg[\Theta M_s \Big(\frac{c_{n,s} f_{n,s}}{E_{n,s}} \Big)^{\vartheta} \Big[\sum_l \Psi_{l,n,s} + \sum_j \psi_{j,n,s} \Big]^{-\gamma} \Bigg(\sum_l \Psi_l \tilde{t}_{i,n,s}^{\vartheta} + \sum_j \psi_j \tilde{t}_{j,n,s}^{\vartheta} \Bigg) \Bigg]^{-1},$$

where the second equality holds because $p(\widetilde{\phi})^{1-\sigma} = \widetilde{\phi}^{\sigma-1} \Big(\frac{\sigma}{\sigma-1} \Big)^{1-\sigma}$. The third equality is obtained by noting that $\widetilde{\phi}^* = \frac{\sigma}{\sigma-1} \Big(\tilde{t}_{i,n,s} \Big)^{\frac{1}{\sigma-1}} \Big(\frac{\sigma c_{n,s} f_{n,s}}{E_{n,s}} \Big)^{\frac{1}{\sigma-1}} \frac{1}{P_{n,s}}$ and $\sum_m \frac{\psi_{l(m)}}{\sum_m \psi_{l(m)}} = 1$.

Plugging the price index into trade flows, we have the trade share from $l(m)$ to n as

$$\Pi_{l(m),n,s} = \frac{\psi_{l(m),n,s}}{\sum_m \psi_{l(m),n,s}} \times \frac{\Psi_{l,n,s}}{\sum_l \Psi_{l,n,s}} \times \frac{\Big[\sum_l \Psi_{l,n,s} \Big] \tilde{t}_{i,n,s}^{\vartheta}}{\Big[\sum_l \Psi_{l,n,s} \Big] \tilde{t}_{i,n,s}^{\vartheta} + \sum_j \psi_{j,n,s} \tilde{t}_{j,n,s}^{\vartheta}}.$$

The price index is

$$P_{n,s} = \Bigg[\Theta M_s \Big(\frac{c_{n,s} f_{n,s}}{E_{n,s}} \Big)^{\vartheta} \Big[\sum_l \Psi_{l,n,s} + \sum_j \psi_{j,n,s} \Big]^{-\gamma} \Bigg(\sum_l \Psi_l \tilde{t}_{i,n,s}^{\vartheta} + \sum_j \psi_j \tilde{t}_{j,n,s}^{\vartheta} \Bigg) \Bigg]^{-\frac{1}{\theta}}.$$

where $\Theta = \sigma^{\frac{\sigma-\theta-1}{\sigma-1}} \Big(\frac{\theta}{\theta-\sigma+1} \Big) \Big(\frac{\sigma}{\sigma-1} \Big)^{-\theta}$, and $\vartheta = \frac{\sigma-1-\theta}{\sigma-1}$. Using the aggregate price just obtained, we express trade shares as the following

$$\begin{aligned}
\Pi_{l(m),n,s} &= \frac{\psi_{l(m),n,s}}{\sum_m \psi_{l(m),n,s}} \times \frac{\Psi_{l,n,s}\tilde{t}^{\vartheta}_{i,n,s}}{\left[\sum_l \Psi_{l,n,s}\right]\tilde{t}^{\vartheta}_{i,n,s} + \sum_j \psi_{j,n,s}\tilde{t}^{\vartheta}_{j,n,s}} \\
&= \frac{\psi_{l(m),n,s}}{\sum_m \psi_{l(m),n,s}} \times \frac{\Psi_{l,n,s}}{\sum_l \Psi_{l,n,s} + \sum_j \psi_{j,n,s}} \times \frac{\tilde{t}^{\vartheta}_{i,n,s}}{\frac{\sum_l \Psi_{l,n,s}}{\sum_l \Psi_{l,n,s}+\sum_j \psi_{j,n,s}}\tilde{t}^{\vartheta}_{i,n,s} + \frac{\sum_j \psi_{j,n,s}}{\sum_l \Psi_{l,n,s}+\sum_j \psi_{j,n,s}}\tilde{t}^{\vartheta}_{j,n,s}} \\
&= \frac{P\big(Y=\{l,m\}\big)\tilde{t}^{\vartheta}_{i,n,s}}{\sum_{l,m} P\big(Y=\{l,m\}\big)\tilde{t}^{\vartheta}_{i,n,s} + \sum_j P\big(Y=\{j\}\big)\tilde{t}^{\vartheta}_{j,n,s}} \\
&= \frac{M_{l(m)}\tilde{t}_{i,n,s}^{\frac{\sigma-1-\theta}{\sigma-1}}}{\sum_{l,m} M_{l(m)}\tilde{t}_{i,n,s}^{\frac{\sigma-1-\theta}{\sigma-1}} + \sum_j M_j\tilde{t}_{j,n,s}^{\frac{\sigma-1-\theta}{\sigma-1}}},
\end{aligned}$$

and

$$\Pi_{j,n,s} = \frac{M_j\tilde{t}^{\vartheta}_{j,n,s}}{\sum_{l,m} M_{l(m)}\tilde{t}^{\vartheta}_{i,n,s} + \sum_j M_j\tilde{t}^{\vartheta}_{j,n,s}}.$$

A.3 The Derivation of Labor Market Variables

Migration Share: Workers choose to work in the region-sector pair that brings them the highest utility. If a worker from labor group g chooses to work in province l and sector s, it implies $x_{g,l,s} \geqslant \frac{\tau_{g,l',s'}x_{g,l',s'}V_{l',s'}}{\tau_{g,l,s}V_{l,s}}$. Note that $x_{g,l,s}$ is drawn from $G_{g,l,s}(x) = \exp(-x^{-\kappa})$ independently across all regions and sectors. Denote $g_{g,l,s}$ as the probability density function of the location preference distribution. Then we have:

$$\begin{aligned}
\Lambda_{g,l,s} &= \int_0^{\infty} \prod_{l'\neq l \text{ or } s'\neq s} G_{g,l',s'}\left(\frac{\tau_{g,l,s}V_{l,s}x}{\tau_{g,l',s'}V_{l',s'}}\right) g_{g,l,s}(x)dx \\
&= \int_0^{\infty} \kappa x^{-\kappa-1}\exp\left(-\sum_{l',s'}(\tau_{g,l',s'}V_{l',s'}/\tau_{g,l,s}V_{l,s})^{\kappa}x^{-\kappa}\right)dx \\
&= \frac{(\tau_{g,l,s}V_{l,s})^{\kappa}}{\sum_{l',s'}(\tau_{g,l',s'}V_{l',s'})^{\kappa}}.
\end{aligned}$$

The second equality is obtained by using the functional form of $G_{g,l,s}(x)$. The third equality is derived by taking the integral.

A.4 Variables in Proportional Changes

Denote the proportional change for variable x as $\widehat{x} = \frac{x'}{x}$, where x' represents variables in the counterfactual equilibrium, and x refers to variables in the observed equilibrium. The proportional changes of the equilibrium system can be expressed as

$$\widehat{\Pi}_{r,n,s} = \frac{\widehat{M}_{r,n,s}\widehat{\tilde{t}}^{\vartheta}_{r,n,s}}{\sum_{r'} \widehat{M}_{r',n,s}\widehat{\tilde{t}}^{\vartheta}_{r',n,s}\Pi_{r',n,s}}. \tag{24}$$

When r refers to a province-regime combination in China, then

$$\frac{\widehat{M}_{l(m),n,s}}{\widehat{M}_{l,n,s}} = \frac{\widehat{\psi}_{l(m),n,s}}{\sum_m \widehat{\psi}_{l(m),n,s}\frac{M_{l(m),n,s}}{M_{l,n,s}}}, \qquad \widehat{M}_{l,n,s} = \frac{\widehat{\Psi}_{l,n,s}}{\sum_l \widehat{\Psi}_{l,n,s}\frac{M_{l,n,s}}{M_s} + \sum_j \widehat{\psi}_{j,n,s}\frac{M_{j,n,s}}{M_s}}.$$

Analogously, when r refers to a foreign country j, then

$$\widehat{M}_{j,n,s} = \frac{\widehat{\psi}_{j,n,s}}{\sum_l \widehat{\Psi}_{l,n,s}\frac{M_{l,n,s}}{M_s} + \sum_j \widehat{\psi}_{j,n,s}\frac{M_{j,n,s}}{M_s}},$$

where $\widehat{\psi}_{l(m),n,s} = \widehat{A}_{l(m),s}\left(\widehat{c}_{l(m),s}\widehat{d}_{l(m),n,s}\widehat{\tilde{t}}_{i,n,s}\right)^{-\frac{\theta}{1-\rho}}$, $\widehat{\psi}_{j,n,s} = \widehat{A}_{j,s}\left(\widehat{c}_{j,s}\widehat{d}_{j,n,s}\widehat{\tilde{t}}_{j,n,s}\right)^{-\frac{\theta}{1-\gamma}}$, and $\widehat{\Psi}_{l,n,s} = \left[\sum_m \widehat{\psi}_{l(m),n,s}\frac{M_{l(m),n,s}}{M_{l,n,s}}\right]^{\frac{1-\rho}{1-\gamma}}$.[37]

We also have the proportional change of the aggregate price index as

$$\widehat{P}_{n,s} = \left[\left(\frac{\widehat{c}_{n,s}\widehat{f}_{n,s}}{\widehat{E}_{n,s}}\right)^{\vartheta}\frac{\left[\sum_l \widehat{\Psi}_{l,n,s}\frac{M_{l,n,s}}{\sum_l M_{l,n,s}}\right]\widehat{\tilde{t}}^{\vartheta}_{i,n,s}\Pi_{i,n,s} + \sum_j \widehat{\psi}_{j,n,s}\widehat{\tilde{t}}^{\vartheta}_{j,n,s}\Pi_{j,n,s}}{\left(\sum_l \widehat{\Psi}_{l,n,s}\frac{M_{l,n,s}}{M_s} + \sum_j \widehat{\psi}_{j,n,s}\frac{M_{j,n,s}}{M_s}\right)^{\gamma}}\right]^{-\frac{1}{\vartheta}}. \tag{25}$$

The proportional changes of migration flows are

$$\widehat{\Lambda}_{g,l,s} = \frac{\widehat{\tau}^{\kappa}_{g,l,s}\widehat{V}^{\kappa}_{l,s}}{\sum_{l',s'}\widehat{\tau}^{\kappa}_{g,l',s'}\widehat{V}^{\kappa}_{l',s'}\Lambda_{g,l',s'}}. \tag{26}$$

The final-good market clearing conditions can be written in proportional changes as

$$E_{r,s}\widehat{E}_{r,s} = \beta_s I_r \widehat{I}_r + \sum_k \lambda^s_{r,k}\left((1-\eta)\sum_u \frac{\Pi_{r,u,k}E_{u,k}\widehat{\Pi}_{r,u,k}\widehat{E}_{u,k}}{\tilde{t}_{r,u,k}\widehat{\tilde{t}}_{r,u,k}} + \eta\sum_u \frac{\Pi_{u,r,k}E_{r,k}\widehat{\Pi}_{u,r,k}\widehat{E}_{r,k}}{\tilde{t}_{u,r,k}\widehat{\tilde{t}}_{u,r,k}}\right), \tag{27}$$

where $\widehat{\tilde{t}}_{r,u,s} = \frac{1+t'_{r,u,s}}{1+t_{r,u,s}}$.

The labor market equilibrium for China can be written in proportional changes as:

$$\begin{aligned}&\sum_m \lambda^L_{l(m),s}\left((1-\eta)\sum_u \frac{\Pi_{l(m),u,s}E_{u,s}\widehat{\Pi}_{l(m),u,s}\widehat{E}_{u,s}}{\tilde{t}_{l(m),u,s}\widehat{\tilde{t}}_{l(m),u,s}} + \eta\sum_u \frac{\Pi_{u,l(m),s}E_{l(m),s}\widehat{\Pi}_{u,l(m),s}\widehat{E}_{l(m),s}}{\tilde{t}_{u,l(m),s}\widehat{\tilde{t}}_{u,l(m),s}}\right)\\ &= \sum_g w_{l,s}\widehat{w}_{l,s}L_{g,l,s}\widehat{L}_{g,l,s}\end{aligned} \tag{28}$$

And the labor market equilibrium for foreign countries is written similarly as:

$$\sum_s \lambda^L_{n,s}\left((1-\eta)\sum_u \frac{\Pi_{n,u,s}E_{u,s}\widehat{\Pi}_{n,u,s}\widehat{E}_{u,s}}{\tilde{t}_{n,u,s}\widehat{\tilde{t}}_{n,u,s}} + \eta\sum_u \frac{\Pi_{u,n,s}E_{n,s}\widehat{\Pi}_{u,n,s}\widehat{E}_{n,s}}{\tilde{t}_{u,n,s}\widehat{\tilde{t}}_{u,n,s}}\right) = w_n\widehat{w}_n L_n\widehat{L}_n. \tag{29}$$

[37]The proportional change of unit costs is given by $\widehat{c}_{l(m),s} = \widehat{w}^{\lambda^L_{l(m),s}}_{l(m),s}\prod_k \widehat{P}^{\lambda^k_{l(m),s}}_{l(m),k}$. $\widehat{A}_{l(m),s} = \widehat{\bar{A}}_{l(m),s}\widehat{L}^{\alpha}_{l(m),s}$ contains both changes in fundamental productivity $\bar{A}_{l(m),s}$ and agglomeration effects that are induced through $L_{l(m),s}$.

B Additional Evidence on Internal Migrants

B.1 The Sector Sorting of Internal Migration

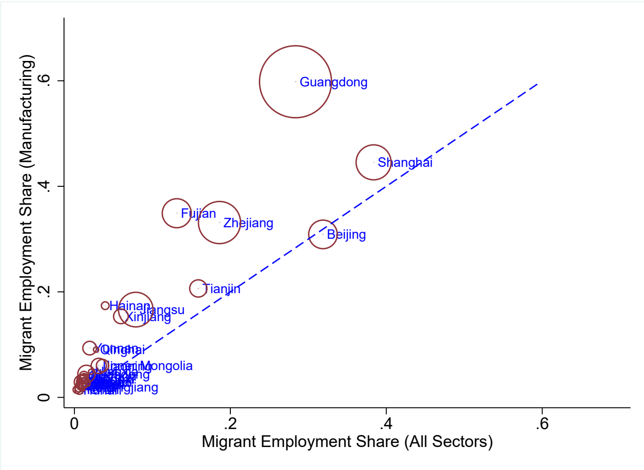
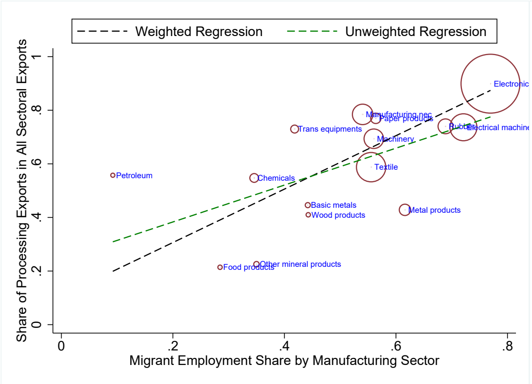


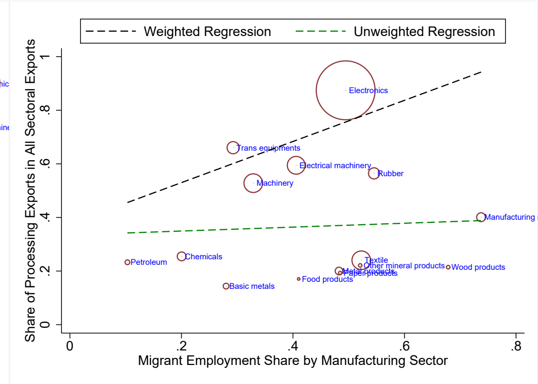
Figure B.1: Manufacturing vs. Overall Migrant Shares of Employment. The circle size is based on the number of migrants each province received.

Internal migration overpresents in the broad manufacturing sector in destination provinces, which confirms that migration expanded employment more so in manufacturing sectors. Figure B.1 plots the migrant share of provincial overall employment against the migrant share of provincial manufacturing employment, with an auxiliary 45-degree line (blue dashed line). We see most provinces lie above the 45-degree line.

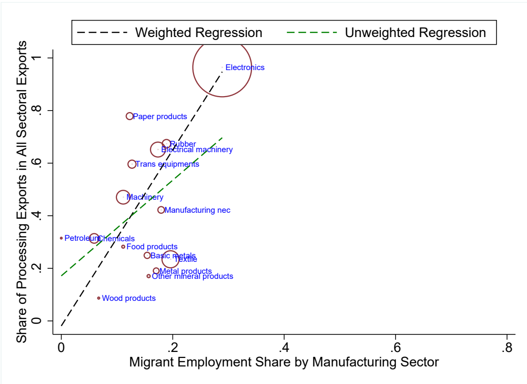
Figure B.2 plots the share of processing exports against migrant employment shares across manufacturing sectors, separately by four coastal provinces. We find a strong positive association in Guangdong province. There are also positive associations in Zhejiang and Jiangsu provinces, despite their migrant employment shares were smaller compared to Guangdong. The positive association holds for Shanghai when weighting industries by export volumes.



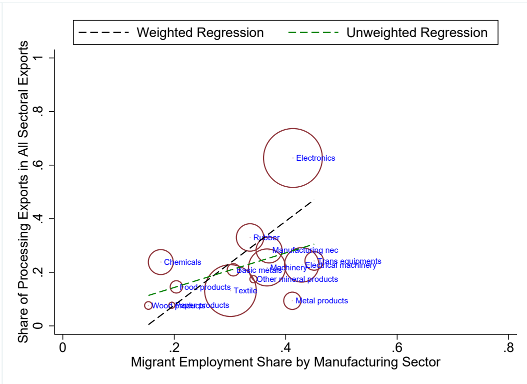
(a) Guangdong



(b) Shanghai



(c) Jiangsu



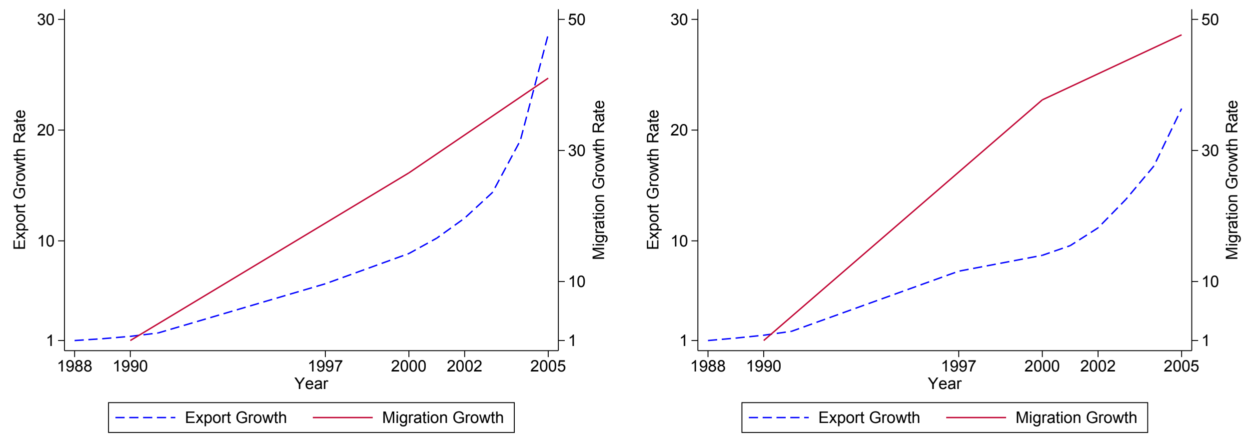
(d) Zhejiang

Figure B.2: Provincial and Sectoral Migrant Employment Share vs. Share of Processing Exports. The black dashed line is the linear fit weighted by province-sector-level processing export volumes (reflected by the circle size).

B.2 The Timing of Migration and Trade

We compare the timing of migration and trade surges. Our migration data have three time points drawn from China's Population Survey (1990, 2000, and 2005). Our export data are based on China's Customs Transactions Database in the years 1988-1991, 1997, 2000, and 2005. Figure B.3 (left) is for five coastal provinces including Guangdong, Shanghai, Fujian, Zhejiang, and Jiangsu, and Figure B.3 (right) is for Guangdong Province only. We normalize both variables by their initial year values. Exports are plotted in blue dashed lines and migration in red solid lines.

Among the coastal provinces considered in Figure B.3 (left), manufacturing migrant employment grew steadily in both the period of 1990–2000 and the period of 2000–2005. Figure B.3 (right) shows that in Guangdong Province, the epic rise in migrant employment of manufacturing took place prior to 2000, and migrant employment grew relatively slowly after 2000. The time-series evidence of migration and export growth suggests that migrants to coastal provinces started, prior to, the surge in Chinese exports to the global market. The trend suggests internal migrants promoted industrial agglomeration in coastal provinces.



(a) Five Coastal Provinces

(b) Guangdong

Figure B.3: Growth in Exports and Manufacturing Migrant Employment for Coastal Provinces, 1990–2005

C Data Appendix

Provincial Gross Output by Sectors and Regimes. Since processing production is not allowed to be sold domestically, we use the total amount of processing exports from China's Customs Transactions Database to measure processing output. We measure province-sector-level gross output from input-output tables in the year 2007 (the closest available year to 2005), and deflate output using the growth rate of China's sectoral output between 2005 to 2007. The difference between gross output and the overall processing exports (which also equal processing output) reflects the gross output in ordinary production.[38]

Inter-provincial Trade Flows by Sectors and Regimes. Again, since processing production is not allowed to be sold domestically, sectoral inter-provincial trade flows from regional input-output tables reflect domestic sales from ordinary producers. We compute the amount of domestic sales to processing producers in each destination and sector, by using data from input-output tables, processing exports, and processing imports. The rest of domestic sales are sold to ordinary final-good producers. We further assume that processing and ordinary final-good producers in each destination and sector have identical expenditure shares on goods from each domestic origin. This assumption allows us to construct trade flows between province-regime-sectors. We measure China's inter-provincial bilateral trade flows and provincial sectoral output using China's regional input-output table. China's National Bureau of Statistics collected its first regional input-output survey in the year 1987. After 1987, the survey has been collected for every five years. We use China's input-output table of the year 2007, which is the closest available year to the year 2005. We deflate these trade flows and output to the year 2005 by the growth rate of China's sectoral output between 2005 to 2007. China's input-output table reports industries using 2-digit China's Standard Industrial Classification Code (CSIC), and contains 42 industries. We discuss the crosswalk of CSIC industries to our 29 industries below.

Trade Flows Between Foreign Countries. We measure bilateral trade flows between foreign countries using

[38]China's regional input-output tables in 2007 are obtained from Liu et al. (2012). We match the 2-digit Chinese Standard Industrial Classification Code (CSIC) used in China's regional input-output tables with the 2-digit ISIC code, using the concordance in Dean and Lovely (2010).

the STAN Bilateral Trade Database and measure sectoral gross output of each foreign country using OECD Input-Output Database. We also measure imports from the rest of the world by subtracting the imports from each country that we consider from the total import volume from the world.[39]

Measuring the Location Choice Probability of Firms. For the distribution of firms, we first use equilibrium conditions (10) and (11) to pin down the relative probability between any two locations (including any foreign country and China's provinces). Second, we divide provincial firms into processing and ordinary regimes using equilibrium conditions which imply the provincial share of firms in each regime equals the share of exports. Combining equations (10) and (11), one can have

$$\frac{M_{l,n,s}}{M_{j,n,s}} = \frac{\left[\sum_m \Pi_{l(m),n,s}\right]\tilde{t}_{i,n,s}^{-\vartheta}}{\Pi_{j,n,s}\tilde{t}_{j,n,s}^{-\vartheta}}, \tag{30}$$

where $\tilde{t}_{i,n,s}$ denotes China's export tariff. $\Pi_{l(m),n,s}$ and $\Pi_{j,n,s}$ are n's expenditure share in sector s on goods produced by $l(m)$ and j respectively. We also know that

$$\sum_l M_{l,n,s} + \sum_j M_{j,n,s} = M_s. \tag{31}$$

We solve $M_{l,n,s}$ and $M_{j,n,s}$ for all l and j from the system of equations (30) and (31). Finally, we obtain the share of provincial firms in each regime m by equaling to the share of exports

$$\frac{M_{l(m),n,s}}{M_{l,n,s}} = \frac{\Pi_{l(m),u,s}}{\sum_m \Pi_{l(m),u,s}}.$$

Labor Market Variables. We use the 2005 Chinese Population Survey to measure China's internal migration flows, wages, and sectoral employment. For the year 2005, we define China's internal migrants as those who work in a province other than the place of their *Hukou* registration. The set of migrant population we measure reflects the effect of China's *Hukou* reform on the "floating population."[40] Since the variable on the province of *Hukou* registration is unavailable in the 1990 data, we define a worker as a migrant if their province of residence 5 years ago differs from their current province of residence.[41] We have a total of 30 groups defined by province of origin and measure the migration stock for each origin-destination-sector pair.

We consider one aggregate labor group for each foreign country. We measure the shares of sectoral employment and sectoral average wages using data from IPUMS–International and Luxembourg income study (LIS) to construct these variables. The ISIC code is available in both datasets, however manufacturing industries are reported as a single aggregation. For each country, we thus divide the share of manufacturing employment into 16 detailed (tradable) manufacturing sectors by using proportions of countries' sectoral output. Details of the data sources used for foreign countries are provided by the table below.

[39]Similarly, we measure exports to the rest of the world by subtracting the exports to each country that we consider from the total export volume to the world.

[40]Our measure slightly differs from the previous literature. Tombe and Zhu (2019) consider both inter-provincial migrants and rural-urban migrants during 2000–2005; they define rural-urban migrants as those whose *Hukou* is in rural agriculture sector but work in industrial sectors. Fan (2019) examines pre-2000 internal migrants who are defined as the mismatch between workers' place of residence and birthplace.

[41]Given that internal migration was under strict control before 1990, respondents' province of residence in 1985 tended to be their home province. Moving out of the *Hukou* area was initially tightly controlled by the government. According to China's 1982 Population Census, only 0.6% of China's total population in 1982 resided out of their *Hukou* county.

Table C.1: Data Sources to Measure Foreign Labor Markets

Data Source	Sectoral Wages	Sectoral Employment Shares
IPUMS-International	Brazil, Canada, India, Mexico, South Africa, Spain, United States	Argentina, Austria, Brazil, Canada, Chile, Denmark, Greece, Hungary, India, Indonesia, Ireland, Malaysia, Mexico, Philippines, Portugal, South Africa, Spain, Thailand, Turkey, United Kingdom, United States, Vietnam
Luxembourg Income Study	Austria, Chile, Denmark, Finland, Greece, Germany, Hong Kong, Italy, Ireland, Japan, Korea, Malaysia, Norway, Philippines, Portugal, United Kingdom	Finland, Germany, Hong Kong, Italy, Japan, Korea, Norway, Singapore
Occupational Wages around the World (OWW)	Thailand, Turkey, Vietnam	

Linking China's Annual Survey of Industrial Firms with China's Customs Transactions Database. China's Customs Transactions Database has information on whether a firm is engaged in exporting processing activities. Following Yu (2015) and Dai et al. (2016), we link these two dataset based on variables including firm name, telephone number, and zip code. Overall, the match between two databases is good: In 2005, around 70% of manufacturing exports reported in Annual Survey of Industrial Firms can be matched with customs data. We compute the number of ordinary (processing) exporters as the total number of firms that perform ordinary (processing) exports, weighted by the share of ordinary (processing) exports in their sales.

Industrial Aggregation and Crosswalks. China's Customs Transactions Database reports product types using 8-digit Harmonized System (HS) classification, China's input-output table reports industries using 2-digit China's Standard Industrial Classification Code (CSIC) for 42 industries, and China's Population Census uses China's Standard Industrial Classification Code (CSIC) for 96 industries. In addition, we extract bilateral trade flows between foreign countries using STAN Bilateral Trade Database and draw tariff data from the TRAINS data. The former one uses ISIC industry codes, whereas the latter one uses 6-digit HS product codes. The OECD database provides input-output tables for 48 countries for the years 1995, 2000, and 2005, and contains information for 37 ISIC Rev 3 industries.

Table C.2: Tradable and Non-tradable Industries by International Standard Industrial Classification (ISIC) Revision 3

Industry	ISIC, Rev 3
Panel A: 16 Tradable Industries	
Food products, beverages and tobacco	C15T16
Textiles, textile products, leather and footwear	C17T19
Wood and products of wood and cork	C20
Pulp, paper, paper products, printing and publishing	C21T22
Coke, refined petroleum products and nuclear fuel	C23
Chemicals and chemical products	C24
Rubber and plastics products	C25
Other non-metallic mineral products	C26
Basic metals	C27
Fabricated metal products	C28
Machinery and equipment, nec	C29
Computer, Electronic and optical equipment	C30T33X
Electrical machinery and apparatus, nec	C31
Motor vehicles, trailers and semi-trailers	C34
Other transport equipment	C35
Manufacturing nec; recycling	C36T37
Panel B: 13 Non-tradable Industries	
Agriculture	C01T05
Mining	C10T14
Utility supply	C40T41
Construction	C45
Retail	C50T52
Hotels and restaurants	C55
Transportation and communications	C60T64
Financial intermediation	C65T67
Real estate and business services	C70T74
Public administration and defence; compulsory social security	C75
Education	C80
Health and social work	C85
Other services	C90T95

Our strategy is to map HS codes or CSIC industry codes to the 2-digit ISIC code, and after that we group the 2-digit ISIC code to our 29 industry aggregations as shown by Table C.2. Specifically, we map 8-digit and 6-digit HS codes to the 4-digit ISIC Rev 3 code based on the concordance which is provided by the World Integrated Trade Solution (WITS). The concordance is available on the WITS website.[42] The 4-digit ISIC code has 292 unique industries. We aggregate the 4-digit ISIC code to the 2-digit ISIC code where the cluster can be simply done based on the first two digits of the 4-digits ISIC code. The map of CSIC code to the 2-digit ISIC code follows the concordance in Dean and Lovely (2010).

[42]See https://wits.worldbank.org/product_concordance.html.

D Additional Quantitative Results

We present quantitative evidence using alternative models or calibration strategies.

D.1 Alternative Migration Costs

Our baseline results compute $\hat{\tau}_{g,l,s}$ specific to 29 sectors. Below, we report quantitative results based on calibrated migration costs specific to one broad manufacturing sector and 13 non-tradable sectors.

Table D.1: The Impact on China's Export Growth (in percentage points), 1990–2005 (Calibrating Migration Costs for One Broad Manufacturing Sector + 13 Non-tradable Sectors)

Migration Costs		**Import Tariff**		**Export Tariff**	
Panel A: Impact on the overall national exports					
1.24		2.25		1.37	
Panel B: Impact on ordinary and processing exports					
Ordinary	Processing	Ordinary	Processing	Ordinary	Processing
1.02	1.41	2.66	1.95	0.66	1.99

Table D.2: The Provincial Share in National Export Growth, 1990–2005 (Calibrating Migration Costs for One Broad Manufacturing Sector + 13 Non-tradable Sectors)

	Migration Costs		**Import Tariff**		**Export Tariff**	
	Panel A: Provincial Share in National Export Growth					
Guangdong	70.8%		26.0%		31.8%	
Jiangsu	6.9%		15.2%		20.0%	
Shanghai	18.5%		11.9%		12.6%	
	Panel B: Provincial Share in National Export Growth by Regime					
	Ordinary	Processing	Ordinary	Processing	Ordinary	Processing
Guangdong	44.2%	86.4%	17.0%	35.2%	14.4%	36.8%
Jiangsu	7.4%	6.6%	13.7%	16.7%	11.4%	22.5%
Shanghai	27.5%	13.3%	16.3%	7.4%	12.8%	12.6%

Table D.3: The Interaction of Migration and Trade Policies (Calibrating Migration Costs for One Broad Manufacturing Sector + 13 Non-tradable Sectors)

The Joint Effects of Tariffs and Migration		**Aggregating Individual Effects of Tariffs and Migration**	
5.20		4.86	
Ordinary	Processing	Ordinary	Processing
4.37	5.92	4.34	5.35

D.2 A Model with Firm Entry

We now compare our baseline result with that predicted by an alternative model of firm entry. We model firm entry similar to Krugman (1980) and Melitz (2003) and extend it with export regime choice. Specifically, we assume that in region r and sector s, entrepreneurs can hire $f^e_{r,s}$ units of labor to create a firm. Firms will produce in the location where they are created. For a firm in Chinese province l to serve destination n, the firm first draws the productivity levels under two export regimes, then chooses the export regime with the lowest unit cost of export, and finally will only export if the profit is positive after paying marketing costs.

Our settings of productivity distributions at the level of the region are consistent with the baseline model. For a Chinese firm in province l and sector s, its productivity is Pareto-distributed with substitution between two export regimes:

$$F\left(\vec{\phi}_{l(m),s}\right) = 1 - \left(\sum_m A_{l(m),s}\phi_{l(m),s}^{-\frac{\theta}{1-\rho}}\right)^{1-\rho}. \tag{32}$$

For destination n, the firm will choose regime m which minimizes the unit cost of export $\min_m \frac{c_{l(m),s}d_{l(m),n,s}\tilde{t}_{i,n,s}}{\phi_{l(m),s}}$ and export if the profit is positive after paying marketing costs $c_{n,s}f_{n,s}$. We abstract from export regime choices for foreign firms similar to the baseline model. The foreign firm's productivity is Pareto-distributed as $F\left(\phi_{j,s}\right) = 1 - A_{j,s}\phi_{j,s}^{-\theta}$, and a foreign firm will export to destination n if the profit is positive after paying $c_{n,s}f_{n,s}$. With these changes, following similar procedures as in Section 3.2, the share of destination n's expenditure spent on goods produced by province l and regime m becomes:

$$\Pi_{l(m),n,s} = \frac{\psi_{l(m),n,s}}{\sum_m \psi_{l(m),n,s}} \times \frac{M_{l,s}\Psi_{l,n,s}\tilde{t}^{\vartheta}_{i,n,s}}{\left[\sum_l M_{l,s}\Psi_{l,n,s}\right]\tilde{t}^{\vartheta}_{i,n,s} + \sum_j M_{j,s}\psi_{j,n,s}\tilde{t}^{\vartheta}_{j,n,s}}, \tag{33}$$

where $M_{l,s}$ is the number of firms in province l and sector s, $\frac{\psi_{l(m),n,s}}{\sum_m \psi_{l(m),n,s}}$ is the share of firms that choose export regime m to export to destination n. And $M_{j,s}$ is the number of firms in country j and sector s. $\psi_{l(m),n,s}$, $\Psi_{l,n,s}$, and $\Psi_{j,s}$ are still identically defined as in the baseline model except for $\gamma = 0$. In the equilibrium, the number of firms in a province-sector, $M_{l,s}$, is determined by the free-entry condition, which requires firms' average profits to equal entry costs,

$$M_{l,s}f^e_{l,s}w_{l,s} = \frac{\sigma-1}{\sigma\theta}\sum_m\sum_r \frac{\Pi_{l(m),r,s}E_{r,s}}{\tilde{t}_{l(m),r,s}}. \tag{34}$$

The left-hand side is the total costs of entry, whereas the right-hand side represents the total profits, where $\frac{\sigma-1}{\sigma\theta} = \frac{1}{\sigma} - \eta$ is the profit ratio after deducting marketing costs. Because entrepreneurs' profits now accrue to workers that they hire for entry, the market clearing condition for final goods in Chinese provinces is

$$E_{l(m),s} = \beta_s I_{l(m)} + \sum_k \lambda^s_{l(m),k}\left(\frac{\sigma-1}{\sigma}\sum_r \frac{\Pi_{l(m),r,k}E_{r,k}}{\tilde{t}_{l(m),r,k}} + \eta\sum_r \frac{\Pi_{r,l(m),k}E_{l(m),k}}{\tilde{t}_{r,l(m),k}}\right). \tag{35}$$

Workers' income is $I_{l(\mathcal{O})} = \sum_g\sum_s w_{l,s}L_{g,l,s} + \sum_s\sum_r \frac{t_{r,l(\mathcal{O}),s}}{\tilde{t}_{r,l(\mathcal{O}),s}}\Pi_{r,l(\mathcal{O}),s}E_{l(\mathcal{O}),s}$ and $I_{l(\mathcal{P})} = 0$.

Finally, because a portion of labor is used for entry, the labor-market clearing condition for each China's province l and sector s can be obtained as:

$$w_{l,s}M_{l,s}f^e_{l,s} + \sum_m \lambda^L_{l(m),s}\left(\frac{\sigma-1}{\sigma}\sum_r \frac{\Pi_{l(m),r,s}E_{r,s}}{\tilde{t}_{l(m),r,s}} + \eta\sum_r \frac{\Pi_{r,l(m),s}E_{l(m),s}}{\tilde{t}_{r,l(m),s}}\right) = \sum_g w_{l,s}L_{g,l,s}. \tag{36}$$

The left-hand side now includes entry costs.

With trade shares in equation (33), migration share in equation (17), free entry condition in equation (34), and market clearing conditions in (35)–(36), we can solve Chinese provinces and sectors' endogenous variables $\{M_{l,s}, \Pi_{l(m),n,s}, \Lambda_{g,l,s}, E_{l(m),s}, w_{l,s}\}$. The conditions for foreign markets are determined similarly. We calibrate the model with firm entry to the observed economy in 2005 and still apply the "Exact Hat Algebra" to perform counterfactual exercises without needing the estimates of entry costs. For ease of comparison, we use the same parameter values in the model with firm entry as in our baseline model, except for the absence of relocation parameter γ.

Table D.4: Annual Export Growth (1990–2005) in Baseline and Alternative Model Settings

Policy Shock	(1) Baseline	(2) Firm Entry	(3) Endogenizing M_s
Migration Cost Reductions	1.29	1.50	1.25
Import Tariff Reductions	2.25	1.33	1.82
Export Tariff Reductions	1.37	0.94	1.30

Notes: We calculate percentage points as $(\widehat{\text{export}}^{\frac{1}{15}} - 1) \times 100$, where $\widehat{\text{export}}$ is the proportional changes of export volume between the observed equilibrium and the counterfactual.

Columns (1)–(2) of Table D.4 present the effects of policy changes on export growth, for our baseline model and the model with firm entry. We highlight two findings. First, export effects of migration cost reductions were much stronger in the model with firm entry than in our model. In the model with firm entry, the large export effect of migration is because the free-entry condition implies the number of firms is proportional to employment size. In contrast, in our model, local employment growth indirectly affects firms' location choices through lowering labor costs. Second, the effects of tariff reductions were smaller in the model with firm entry than in our model. In the model with firm entry, the total measure of firms in a region-sector is determined by firms' total revenues. Because exports only account for a small fraction of firms' revenues, changes in firm entry tend to be small or even negative in the face of import competition, and therefore exports are mainly driven by the intensive and extensive margins of exports. In contrast, in our model, for each foreign destination, firms choose production locations by minimizing the unit cost of exports, and thus the measure of firms that choose to locate in China is directly affected by import and export tariff reductions.

D.3 Endogenizing the Potential Firm Mass

Our benchmark model assumes M_s, the amount of potential firms in each sector, is fixed. We discuss two versions of our model's extension to endogenize M_s. First, we assume that the change in the amount of potential firms is proportional to changes in total sectoral profit π_s, $\widehat{M_s} = \widehat{\pi}_s$, a known feature in models with firm entry (Krugman, 1980; Melitz, 2003).[43] In this case, the effect of tariff and migration policies on exports is identical to that of our baseline model, because changes in M_s affect the firm count in all regions proportionally and thus do not affect relative trade shares within sector s.

[43] $\pi_s = \frac{\sigma-1}{\sigma\theta}\left[\sum_l \sum_m \sum_r \frac{\Pi_{l(m),r,s} E_{r,s}}{\tilde{t}_{l(m),r,s}} + \sum_j \sum_r \frac{\Pi_{j,r,s} E_{r,s}}{\tilde{t}_{j,r,s}}\right]$ is the total sectoral profit for firms in sector s, where $\frac{\sigma-1}{\sigma\theta} = \frac{1}{\sigma} - \eta$ is the profit ratio after deducting marketing costs.

Second, we distinguish the potential firms by two countries of origin, China and the Rest of World, denoted by M_s^C and M_s^R. Superscript $\{C, R\}$ denotes firm origin. Firms originated from China and the Rest of the World separately draw productivities from the distribution in equation (7) with productivity parameters $\{A^C_{l(m),s}, A^C_{j,s}\}$ and $\{A^R_{l(m),s}, A^R_{j,s}\}$, respectively. Following similar derivations in ARRY and Appendix A, equations (37)–(38) characterize the share of destination n's expenditure that is spent on goods produced by province l conditional on the origin of production firms,

$$\frac{\Pi^C_{l,n,s}}{\sum_l \Pi^C_{l,n,s} + \sum_j \Pi^C_{j,n,s}} = \frac{M^C_{l,n,s}\tilde{t}^{\vartheta}_{i,n,s}}{\sum_l M^C_{l,n,s}\tilde{t}^{\vartheta}_{i,n,s} + \sum_j M^C_{j,n,s}\tilde{t}^{\vartheta}_{j,n,s}}, \tag{37}$$

$$\frac{\Pi^R_{l,n,s}}{\sum_l \Pi^R_{l,n,s} + \sum_j \Pi^R_{j,n,s}} = \frac{M^R_{l,n,s}\tilde{t}^{\vartheta}_{i,n,s}}{\sum_l M^R_{l,n,s}\tilde{t}^{\vartheta}_{i,n,s} + \sum_j M^R_{j,n,s}\tilde{t}^{\vartheta}_{j,n,s}}. \tag{38}$$

By definition of trade shares, for each destination n, $\sum_l(\Pi^C_{l,n,s} + \Pi^R_{l,n,s}) + \sum_j(\Pi^C_{j,n,s} + \Pi^R_{j,n,s}) = 1$. The share of destination n's expenditure spent on China-originated firms relative to firms originated from the Rest of the World is

$$\frac{\sum_l \Pi^C_{l,n,s} + \sum_j \Pi^C_{j,n,s}}{\sum_l \Pi^R_{l,n,s} + \sum_j \Pi^R_{j,n,s}} = \frac{\left[\sum_l \Psi^C_{l,n,s} + \sum_j \psi^C_{j,n,s}\right]^{-\gamma}\left(\sum_l \Psi^C_l \tilde{t}^{\vartheta}_{i,n,s} + \sum_j \psi^C_j \tilde{t}^{\vartheta}_{j,n,s}\right)}{\left[\sum_l \Psi^R_{l,n,s} + \sum_j \psi^R_{j,n,s}\right]^{-\gamma}\left(\sum_l \Psi^R_l \tilde{t}^{\vartheta}_{i,n,s} + \sum_j \psi^R_j \tilde{t}^{\vartheta}_{j,n,s}\right)}. \tag{39}$$

$\{M^C_{l,n,s}, M^C_{j,n,s}, \Psi^C_{l,n,s}, \psi^C_{j,n,s}\}$ and $\{M^R_{l,n,s}, M^R_{j,n,s}, \Psi^R_{l,n,s}, \psi^R_{j,n,s}\}$ are determined similarly as in our baseline model except for firm-origin-specific firm counts (M_s^C and M_s^R), productivity levels ($\{A^C_{l(m),s}, A^C_{j,s}\}$ and $\{A^R_{l(m),s}, A^R_{j,s}\}$) and iceberg trade costs. $\Pi_{l,n,s} = \Pi^C_{l,n,s} + \Pi^R_{l,n,s}$ is the share of destination n's expenditure that is spent on goods produced by province l (aggregated over firm origins).

As shown by ARRY, solving the equilibrium requires data on the trade shares for firms originated from each region. We measure $\Pi^C_{j,n,s}$ and $\Pi^R_{j,n,s}$ as follows: (1) because there is little outward FDI from China before 2005, we set $\Pi^C_{j,n,s} = 0$ for any foreign country j; (2) for each destination n and Chinese province l, we choose $\Pi^R_{l,n,s} = 0.6\Pi_{l,n,s}$, according to the observation that in 2005, 60% of Chinese exports were produced by foreign-invested firms in China. With these two assumptions and the observed aggregated trade shares $\{\Pi_{j,n,s}, \Pi_{l,n,s}\}$, we obtain all the trade shares by firm origin $\{\Pi^C_{j,n,s}, \Pi^C_{l,n,s}, \Pi^R_{j,n,s}, \Pi^R_{l,n,s}\}$. Finally, we consider the amount of firms originated from each region scales with their respective profits, $\widehat{M}_s^C = \hat{\pi}_s^C$ and $\widehat{M}_s^R = \hat{\pi}_s^R$. We solve the counterfactual exercises of policy changes using the "Exact Hat Algebra" and with all our baseline parameters.

Column (3) of Table D.4 presents the counterfactual results for this second check. We find that introducing firm entry in China and the Rest of the World slightly reduces the combined effects of migration and tariff policies on export growth by 10% (from 4.91 p.p. to 4.41 p.p.). The slight reduction is because firms originated from China do not produce in foreign countries, which decreases the overall magnitude of firm relocation from overseas to China after policy changes. This decrease in the strength of firm relocation outweighs the increasing entry of firms originated from China after migration and trade policy changes.

D.4 The Export Growth By Foreign Destinations

A large number of studies have examined the economic consequences of China's export surge on advanced economies: for example, see Autor et al. (2013) and Pierce and Schott (2016) on the US; and Bloom et al. (2016) and Dippel et al. (2022) on European countries, among others. We show that the export impact of reducing migration costs varied across destination countries. Figure D.1 plots the effect of migration on annual export growth against the migrant employment intensity of exports across destination countries. The migrant employment intensity of exports is computed as the average of province-sector-level migrant employment shares, weighted by provincial-sector export volumes to that foreign destination. China's reduction in migration costs favored exports to the US and European countries more than to Asian trade partners such as Japan and Korea. For example, the impact of migration policy on annual export growth rate was 1.64 p.p. for the US, but was only 0.38 p.p. for Korea. These findings reflect countries' differences in sourcing patterns from China's provinces: the US's top sourcing province was Guangdong in 2005, where migrant employment was prominent; in contrast, Korea's top sourcing province was Shandong, where migrant employment was low.

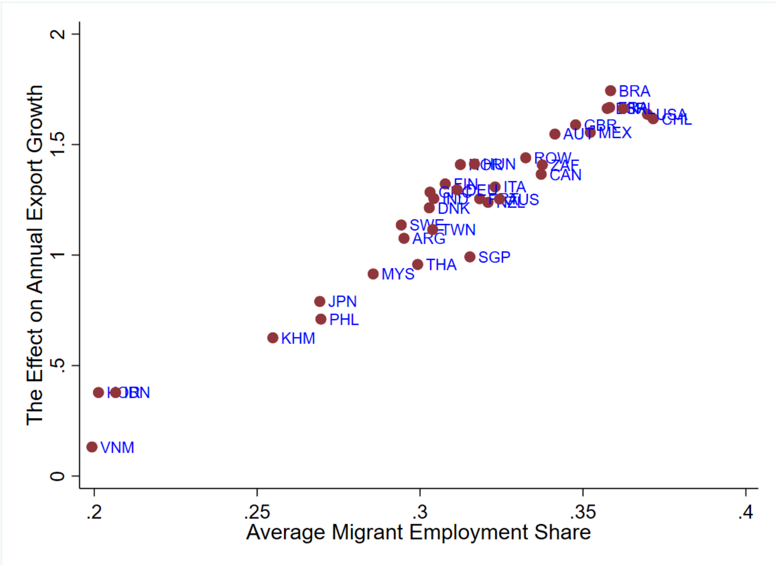


Figure D.1: The Export Impact of Reducing Migration Costs across Destinations

E Additional Validation Exercises

E.1 Model Fit to Employment Responses

We compare the predictions on province-sector employment changes across different models and with the data, and show our baseline model does relatively better in matching the observed changes. For each of the three models we compared (baseline, firm entry, baseline model with $\gamma = \rho = 0$), we introduce changes in tariffs (export and import tariffs separately) between 2000 and 2005 and solve the province-sector employment changes. We regress the model-generated employment changes on tariff changes, as discussed in Section 4.4. Columns (1) and (5) present the data estimates separately using changes in employment at ordinary and processing exporters as dependent variables, respectively. Columns (2) and (6) present the results using the model-generated data from our baseline model. Columns (3) and (7) present the results for the model with firm entry. Finally, Columns (4) and (8) show the results of our baseline model with standard gravity ($\gamma = \rho = 0$). We present the results for import tariffs in Panel A, and for export tariffs in Panel B.

Table E.1: Province-Sector-Level Employment and Tariff Changes between 2000 and 2005

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dependent variable	Changes in employment ordinary exporters				Changes in employment processing exporters			
	data	baseline model	model with firm entry	baseline model ($\gamma = \rho = 0$)	data	baseline model	model with firm entry	baseline model ($\gamma = \rho = 0$)
Panel A: import tariff changes between 2000–2005								
import tariff changes	-3.212**	-2.956***	-1.494***	-1.689***	-8.154***	-3.885***	-2.467***	-1.937***
	(1.225)	(0.193)	(0.110)	(0.109)	(2.423)	(0.548)	(0.457)	(0.279)
Obs	382	380	380	380	306	299	299	299
R-squared	0.008	0.237	0.197	0.273	0.039	0.116	0.163	0.225
Panel B: export tariff changes between 2000–2005								
export tariff changes	-6.753**	-8.677***	-4.171***	-4.884***	-11.236**	-11.785***	-7.021***	-5.746***
	(2.547)	(0.401)	(0.231)	(0.203)	(4.463)	(1.041)	(0.897)	(0.601)
Obs	382	380	380	380	306	299	299	299
R-squared	0.010	0.570	0.427	0.636	0.021	0.297	0.369	0.553

Notes: We present the OLS estimates by regressing the employment changes on tariff changes. Changes in tariffs are defined as $\frac{1+t_{k,2005}}{1+t_{k,2000}}$, where $t_{k,t}$ is the tariff rate at time t for sector k. As changes in export tariffs are destination-specific, we use the average change of export tariffs across all destination markets as independent variables in the regression. Changes in employment are defined following Davis and Haltiwanger (1992). We perform the regressions across 30 provinces and 16 manufacturing sectors. Standard errors are in parenthesis and clustered by province. Significance levels: 10% * 5% ** 1% ***.

For all cases, we find our baseline model is more capable to capture the magnitude of province-sector-level employment responses as firms decide locations for each destination. As a result of little firm entry after tariff changes, the model with firm entry predicts much smaller responses of province-sector-level employment by export regime to tariff changes than the data. Columns (4) and (8) show that when we abstract from firms' location and regime choices in our baseline model, our model falls short of capturing the magnitude of province-sector-level employment responses to tariff changes. These pieces of evidence support the use of our baseline model.

E.2 Model Fit to the Origin of Foreign Firms

In our analysis, firm mobility plays an important role in driving China's aggregate trade impact of policy changes. In this final exercise, we provide suggestive evidence to show that our model can capture variation in the origin of new firms in the data.

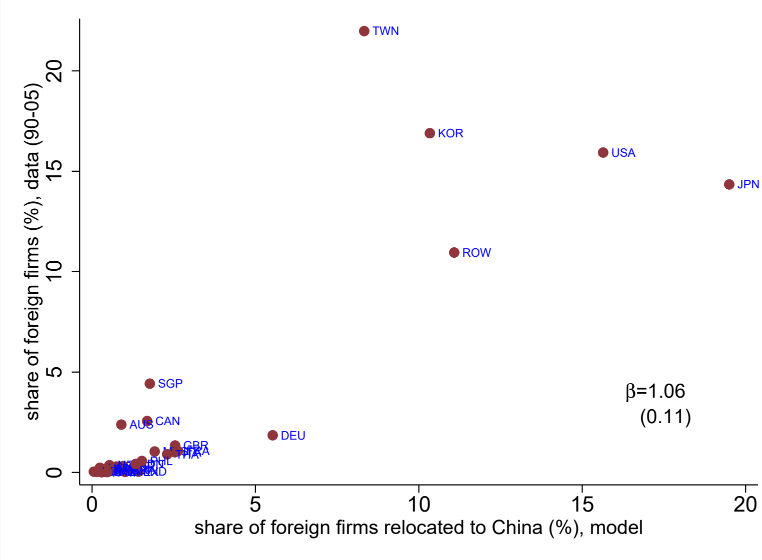


Figure E.1: Comparison of Model Predictions with Data on Foreign-invested Firms

We draw data from Chinese Ministry of Commerce to measure the number of new foreign-invested firms. Before 2016, all foreign-invested firms in China were required to obtain approval for registry and changes of business, and these requests were then publicized on the website. We collect all these raw data and use text analysis to identify information on firms' name, industry, and ownership structure.[44] Between 1990 and 2005, there were 102,072 new registrations of foreign-invested firms, which is similar to the 91,047 existing manufacturing foreign-invested firms in the Firm Census 2004.[45] We identify the places of origin by the nationality of firms' majority owner and omit Hong Kong because it invested hugely in mainland China due to its well-developed financial markets and shared border.

Figure E.1 plots the model-predicted origins of new firms in China against the actual share of foreign-invested firms across origins obtained from Chinese Ministry of Commerce. Our model-predicted origins of new firms are calculated as the amount of firms relocated from each foreign origin as a share of the overall increase in the amount of firms in China, resulting from changes in China's tariffs and migration costs between 1990 and 2005.[46] It appears that our model-predicted origins of new firms match the data reasonably well. For instance, in the data, 15.9% of foreign-invested firms came from the US between 1990 and 2005, whereas our model predicts that the US accounted for 15.6% of foreign firms relocated to China after changes in China's migration costs and tariffs. This evidence suggests that our model can capture a reasonable amount of variation

[44] We keep manufacturing firms registered between 1990 and 2005 and define foreign-invested firms as firms with at least 30% foreign ownership. Our results are robust if we use thresholds of 0% or 50% to define foreign ownership.

[45] Across our 16 manufacturing sectors, the correlation between the number of foreign-invested entrants between 1990 and 2005 and the number of existing foreign-invested firms in 2004 is 0.95.

[46] Using our model, for each destination and sector, we first compute the reduction in the firm's probability to produce in each foreign origin as a share of the total increase in the firm's probability to produce in China, after changes in China's trade and migration costs. We then take a weighted average of these shares, where the weights are the output sold to each destination and sector from China.

in the origin of foreign-invested firms in China.

F Indirect Inference of Structural Parameters

Below we describe the procedure we used to jointly search for the values of $\{\gamma, \rho\}$:

1. We start with an initial guess of $\{\gamma_0, \rho_0\}$.
2. Given ρ_0, we choose γ to target the extent to which the number of firms responded to migration shocks, targeting the estimate of Columns (3) in Table 1. We introduce changes in migration costs between 1990 and 2005 to our quantitative model which is calibrated to the year 2005. We search for a value of γ such that the model-generated data can produce the same estimate of β_1 as in Column (3) of Table 1. We compute the model-generated changes in the number of firms in a province-sector as the weighted average of changes in firms' location probability (in that province-sector) across destination markets. The weights are the output sold to each destination market. We use the same instrument and controls as in Table 1.
3. Given γ_0, we choose ρ to target the extent to which the number of ordinary exporters responded to import tariff reductions, targeting the estimate of Columns (3) in Table 2. We introduce China's import tariff reductions between 2000 and 2005 to our model. Again, we calibrate our model to the year 2005 and search for a value of ρ such that the model-generated data can produce the same estimate of b_2 as in Column (3) in Table 2. Again, we compute the model-generated changes in the number of firms for a province-sector-regime as the weighted average of changes in firms' location probability (in that province-sector-regime) across destination markets. The weights are the output sold to each destination market. We use the same instrument and controls as in Table 2.
4. We update $\{\gamma_0, \rho_0\}$ with $\{\gamma_1, \rho_1\}$ and iterate Steps 1–3 until the convergence of $\{\gamma, \rho\}$.

G Additional Tables and Figures

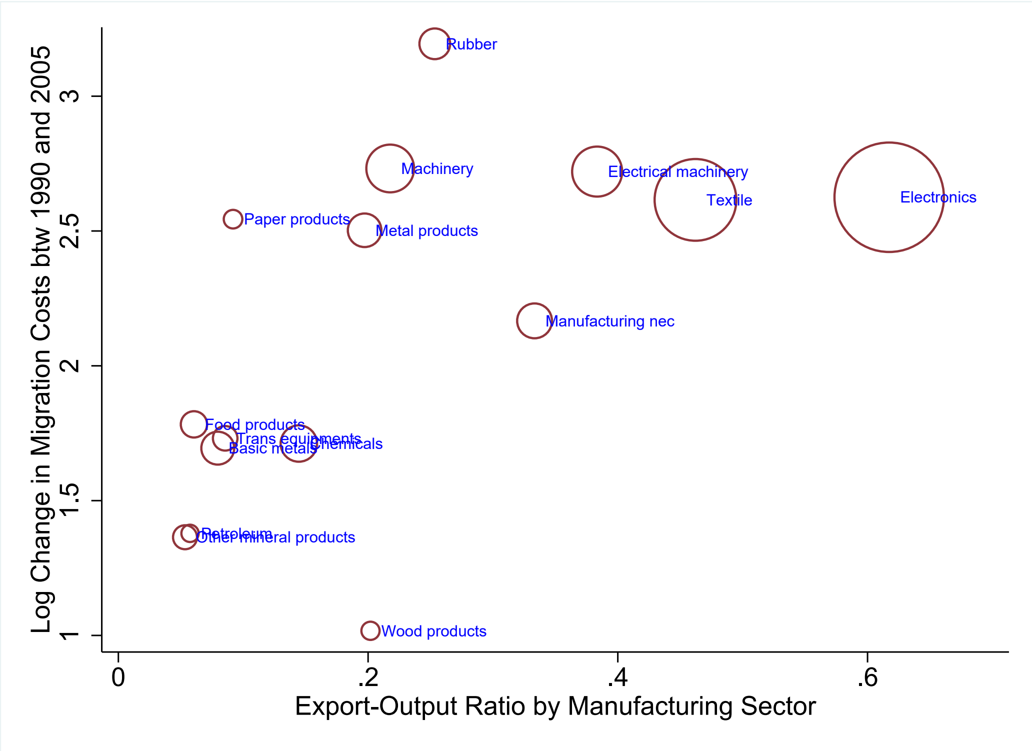


Figure G.1: Changes in Migration Frictions ($\log \frac{\sum_s \tau_{l,s,2005}}{\sum_s \tau_{l,s,1990}}$) across Manufacturing Sectors

Notes: Here we show the changes in migration costs for manufacturing sectors, which are the migrant-population weighted average across origin provinces and destination provinces. The circle size reflects the export volume in 2005.

Figure G.2: Provincial Annual Export Growth Rate Between 1990 and 2005

Notes: The black dots are four Special Economic Zones (SEZs) in 1980; the red dots are 14 national Economic and Technological Development Zones (ETDZs) in 1984; and the pink dots are 18 national ETDZs added in the year 1992.

Table G.1: Overall Impacts on Wages Per Efficiency Unit

	Migration Costs		**Import Tariff**		**Export Tariff**	
	Average	Most Affected	Average	Most Affected	Average	Most Affected
Guangdong	-7.02%	-11.41%	-2.57%	-10.40%	5.94%	7.11%
Jiangsu	-2.16%	-3.41%	-1.56%	-10.61%	6.10%	8.60%
Shanghai	-0.86%	-4.14%	-0.13%	-8.86%	5.82%	8.33%

Notes: Panel A reports counterfactual changes in wages per efficiency unit for tradable sectors as a whole and for the most affected tradable sector.

Table G.2: The Interaction Effects in Different Scenarios of Migration Cost Calibration

	The Joint Effects of Tariffs and Migration	**Aggregating Individual Effects of Tariffs and Migration**	**Interaction**
(1) Baseline Model	5.27	4.91	0.36
(2) Broad Manufacturing Sector	5.20	4.86	0.34
(3) Constant Migration Cost Change	4.71	4.47	0.24
(4) Destination-specific Cost Change	4.90	4.62	0.28
(5) Origin-destination-specific Cost Change	4.89	4.61	0.28

Notes: In Row (2), we compute $\hat{\tau}_{g,l,s}$ using equation (20), but aggregate the 16 manufacturing sectors into one broad manufacturing sector. Here, for each origin-destination pair, the migration cost changes are identical across 16 manufacturing sectors and match exactly the changes in migrants' employment shares and wages in the broad manufacturing sector. In Row (3), we consider constant migration cost changes $\hat{\tau}_{g,l,s} = \bar{\zeta}$. We obtain the value of $\bar{\zeta}$ to match changes in China's migration flows (aggregated over origins and destinations) between 1990 and 2005 observed in our baseline result. In Row (4), we consider destination-specific migration cost changes $\hat{\tau}_{g,l,s} = \bar{\zeta}_l$. We obtain the value of $\bar{\zeta}_l$ to match changes in destination-specific migration flows (aggregated over origins) between 1990 and 2005 observed in our baseline result. In Row (5), we consider migration cost changes to be origin-destination-specific $\hat{\tau}_{g,l,s} = \zeta_{g,l}$. We obtain $\zeta_{g,l}$ by matching exactly the aggregate migrant employment changes for each origin-destination pair between 1990 and 2005 observed in our baseline result.