International Trade and Wage Inequality: Evidence from Brazil*

Lucas Squarize Chagas† — *Intuit, Inc.*

Vinicios P. Sant'Anna‡ — *MIT*

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Abstract

We study the effect of the bilateral trade integration with China on wage inequality in Brazil. Previous studies have documented the contribution of trade opening to the decline in inequality since the 1990s, driven primarily by cross-firm pay differences. We find a sharper reduction in wage inequality over the 2000s, parallel to China's accession to the WTO. Our analysis of the China shock suggests that some firms are harmed by import competition, especially those in the High-Tech Manufacturing sector, while others profit from increased exports and cheaper inputs. We rationalize these patterns by extending the theoretical framework of Helpman et al. (2017) to include sector heterogeneity in trade exposure and firm-level selection into imports. Our model indicates that the rise of China led to a reduction in cross-firm wage inequality in Brazil by about 5%.

Keywords: Trade, Wage Inequality, Labor Markets, China, Brazil

JEL Classification: F16, J21, J31

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†Intuit, Inc. Email: **lsquarize@gmail.com**. Website: **https://sites.google.com/view/lucassquarizechagas**

‡Corresponding Author. Massachusetts Institute of Technology, Center for Real Estate. 105 Massachusetts Avenue. Samuel Tak Lee Bldg. 9-343. Cambridge, MA 02139. Email: **vsantann@mit.edu**. Website: **vpsantanna.com**.

1. Introduction

Studying the effects of international trade on labor markets has been a central topic in the theoretical and empirical international trade literature. Most recent literature has focused on the direct impacts of global trade liberalization, international demand, or supply shocks on labor market outcomes within trade partners, such as earnings and employment (Autor et al., 2013; Dix-Carneiro and Kovak, 2017). Nevertheless, due to its industry-specific nature, international trade shocks have heterogeneous effects on firms and workers within a country. In particular, international trade shocks tend to affect some sectors more significantly than others. Consequently, international trade shocks can lead to important changes in the income distributions within countries (Muendler, 2017; Adao et al., 2022).

This paper investigates the relationship between international trade exposure and wage inequality in Brazil over the 2000s. During this period, bilateral trade between Brazil and China increased dramatically, driven by the rise of China as a prominent participant in global trade. Throughout the same period, Brazil (and other Latin American countries) experienced a significant decline in wage inequality (Messina and Silva, 2017; Ferreira et al., 2017), suggesting that trade integration could have played an important role in this phenomenon.

To assess the impact of trade shocks on wage inequality, we exploit detailed information from the matched employer-employee Brazilian administrative data, which contains the universe of formal employment in the country. The data allows us to observe workers' earnings, occupations, and other characteristics while identifying the key features of their employers, such as their location, size, and industry. Leveraging the detailed dataset, our empirical strategy filters out all potential worker-specific characteristics that could affect wages to isolate the firm-specific component of the wage distribution. Our primary measure of industry-level trade exposure follows the standard approach in the literature and uses the change in imports (exports) from (to) China between 2000 and 2008 per worker of 2000. We contribute to the literature by incorporating input-output linkages across industries to account for the effects of trade shocks via production chains.

Using an instrumental variable approach inspired by Costa et al. (2016), we find a positive and significant impact of export exposure on wages and a negative effect of import exposure on wages. More specifically, we find that the net effect of the China shock on the Agriculture/Mining sector is about a 1 percent increase in wages.[1] The Low-Tech manufacturing sector suffers a net decrease in wages of about 0.6 percent on wages, primarily due to the downstream decline in demand through import exposure (about 1.6 percent, which more than offsets the positive effect of upstream exposure of around 0.5 percent). Finally, High-Tech manufacturing industries suffered a large 6 percent reduction in wages due to the China shock. Despite the cheaper and higher-quality inputs, which partially increment wages by 1.3 percent, the decline in demand from downstream import exposure implied larger negative effects on wages by almost 8 percent.

In sum, our results highlight the importance of indirect (or production chain) exposure to trade shocks through industries' production networks. The downstream export (import) exposure leads to an increase (decrease) in wages. Furthermore, upstream import exposure tends to increase wages, but upstream export exposure tends to reduce wages. These results indicate that firms tend to prosper when greater import exposure occurs in their input markets. In contrast, increases in upstream export exposure imply that firms will compete with the external demand for input supply, leading to a decline in wages.

In more detailed analysis, we do not find differential effects of trade exposure between importer/non-importer and exporter/non-exporter firms. Nonetheless, upstream import exposure positively impacts the firms' probability of importing, suggesting that firms benefit from cheaper imported inputs. In contrast, the positive shocks downstream of production (i.e., export exposure) increase firms' probabilities of exporting. Thus, the positive shift in demand causes firms to begin supplying their output in the external market.

To rationalize our reduced-form findings, we extend the model proposed in Helpman et al. (2017) (henceforth HIMR) and Helpman et al. (2010) (henceforth HIR) to account for sector heterogeneity. We also incorporate within-sector firm selection into export and import markets as alternative mechanisms for trade shocks to affect wage distribution. This model offers possibilities for firms to self-select into exporting and importing markets through market access and selection effects. The former establishes that exporter and importer firms pay higher wages and hire more workers, while the latter implies that high-productivity firms are more likely to engage in international trade by becoming exporters or importers. Moreover, sector heterogeneity means that firms in distinct sectors will pay different wages and be subject to different forces to become exporters and importers. Estimating the model parameters using maximum likelihood (ML), we

[1] We must highlight that the RAIS dataset only contains information about formal employment. This means that we are not accounting for wages in the informal sector, which can be significant, especially for the Agriculture sector, which has a relatively higher informality rate and experienced higher export growth.

show that the estimated model provides a good fit for the empirical joint distribution of employment and wages and various measures of wage inequality. In particular, the model matches the observed trend in the fall of wage variance over time. Nonetheless, the model's predictions underestimate the share of employees and firms operating in the export and import markets.

The model presents two channels through which trade shocks may affect wages and employment, import competition and export exposure. Import competition represents a negative shock on a firm's output demand, which leads to lower wages and lower demand for workers. Nonetheless, upstream import exposure represents a positive shock for firms by making inputs cheaper, which leads to higher labor demand and higher wages. Export exposure causes a positive shock on firms' output and enables firms to export. Moreover, due to downstream domestic increases in output demand, even non-exporter firms may benefit highly. Thus, direct and downstream export exposure leads to higher labor demand and wages. As a result, wage inequality arises within-sector firms taking advantage of trade shocks and selecting into imports or exports. Across sectors, import or export exposure changes the average wages for all firms and the composition of workers, which leads to between-sector changes in wage variance.

We use the model to perform counterfactual analyses. First, we construct two counterfactual scenarios in which we shut down one "side" of the trade integration shock, i.e., the import or export exposure. Then, using a strategy similar to Caliendo et al. (2019), we calibrate the model's parameters to identify the partial effects of import and export exposure that we encountered in the reduced-form analysis for each sector. Our findings suggest that the China shock is responsible for a 5 percent decrease in the overall wage variance in Brazil between 2000 and 2008, mainly driven by the import exposure across sectors. In other words, the cross-sector effect tends to harm high-paying sectors relative to low-paying sectors, thus generating a decline in inequality and dominating the within-sector effect, which favors firms that select into imports or exports, thus increasing inequality.

We also consider counterfactual scenarios that combine the China shock with tariff reductions. We study whether trade liberalization can limit or amplify the effects on wage variance stemming from the China shock. We find that trade openness reduces the magnitude (in absolute terms) of the decline in wage variance. For instance, in the scenario of a 40% tariff reduction, the wage variance would have decreased by a little over 2.5%.

This paper contributes to the extensive literature on the consequences of international trade on income inequality and labor market outcomes (Stolper and Samuelson, 1941; Galle et al., 2023;

Adao et al., 2022). Our analysis is most closely related to recent studies based on heterogeneous exposure to trade shocks and their consequences on labor market outcomes, especially to the literature exploring the effects of the so-called China shock (Autor et al., 2013, 2014; Caliendo et al., 2019; Bloom et al., 2016; Autor et al., 2016; Bloom et al., 2019). Overall, these studies focus primarily on the impact of import penetration on labor market outcomes, especially in manufacturing industries, for the United States and other developed economies. We mainly contribute to this literature by studying the effects of both import and export shocks (Feenstra et al., 2019) on wage inequality in a developing country, Brazil. Accounting for both trade flows allows us to provide a more balanced way to study the impact of the China shock on its trade partners. Our analysis is also closely related to Costa et al. (2016); Pessoa and Costa (2019), which studies the effects of China's rise on Brazil's local labor market outcomes, uncovering the existence of winners (where export exposure was high) and losers (where import exposure was high) from trade. To the best of our knowledge, we are the first to study which extent the China shock has influenced Brazil's (formal) wage inequality. We also contribute to these studies by incorporating input-output linkages into the trade shock measures, which Acemoglu et al. (2016) and Adao et al. (2022) have shown to play a significant role in the general equilibrium effects of trade.

By extending the model proposed by Helpman et al. (2010) and Helpman et al. (2017), our paper also contributes to the literature that incorporates firm and worker heterogeneity when rationalizing wage variation across firms. Those differences may arise from assortative matching (Abowd et al., 1999; Card et al., 2018) or from labor market frictions (Burdett and Mortensen, 1998). In both settings, workers with the same characteristics can be paid different wages, and those differences are sustained in equilibrium. The empirical facts commonly stated in this type of model explain how firms sort into the exporting market and how larger firms pay higher wages than smaller firms (Melitz, 2003; Amiti and Davis, 2012). By incorporating both firm and sector heterogeneity, we also contribute to the literature that investigates structural changes in the economy, either due to trade shocks (Dix-Carneiro, 2014; Cravino and Sotelo, 2019) or other factors (Bustos et al., 2016; Rodrik, 2013). Moreover, our sector-heterogeneity model is associated with firm heterogeneity, explaining the change in inequality between and within-sector after a double-sided trade integration shock.

Finally, this paper also relates to the literature that investigates the falling wage inequality in Latin America in recent decades (Messina and Silva, 2017). In the case of Brazil, many studies relate the sharp decline in wage inequality since the mid-1990s to changes in international trade, such as trade opening (Dix-Carneiro, 2014; Dix-Carneiro and Kovak, 2017; Helpman et al., 2017; Felix, 2021) and commodity price shocks (Adão, 2016). However, the current literature suggests that the decline in wage inequality in Brazil is mostly due to the minimum wage policy since 1995 (Engbom and Moser, 2022) and the gender, race, education, and experience wage gaps (Nopo, 2012; Messina and Silva, 2017; Ferreira et al., 2021).

2. Data and Descriptive Statistics

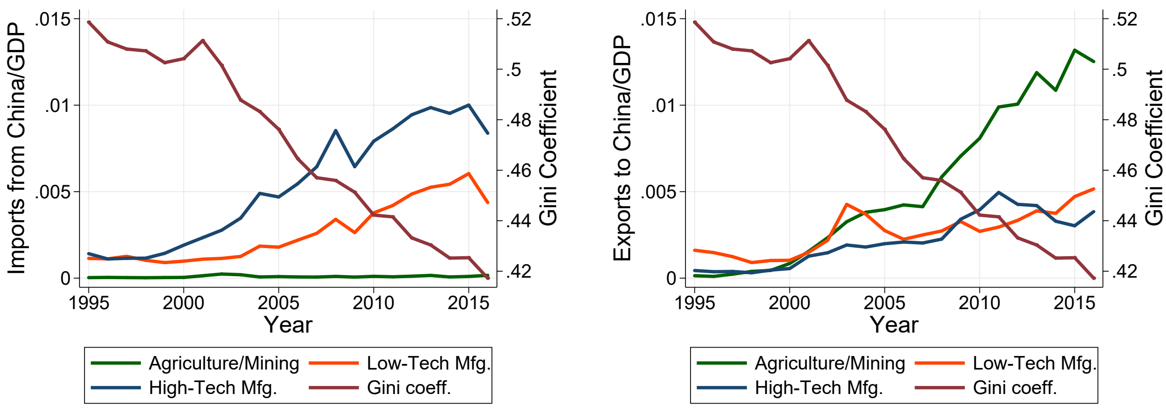
2.1 International Trade

We use data on bilateral trade flows of goods at the 4-digit Harmonized System between 1992 and 2016 from the U.N. Comtrade database United Nations (2018).[2] Using a comprehensive crosswalk algorithm, we convert the international bilateral flows from the 4-digit Harmonized System product codes to the Brazilian industry codes from Classificação Nacional de Atividades Econômicas (CNAE) version 2.0.

With this data at hand, we begin our analysis by assessing the evolution of the Brazil–China trade relationship. Before China became a member of the World Trade Organization (WTO), the international trade volume between Brazil and China was modest, and the Chinese participation in Brazilian trade was tiny. Data from United Nations (2018) indicate that in 1999, China was the destination of 1.5% of total Brazilian exports, while 1.7% of Brazilian imports came from China. In sharp contrast, by 2010, China had become one of Brazil's largest international trade partners, accounting for 15.3% of its exports and 13.4% of its imports.

While Brazil and China dramatically increased their overall bilateral trade volume, there was considerable heterogeneity across sectors. Figure 1 illustrates the increase in bilateral trade between Brazil and China and the decrease in the Brazilian Gini coefficient. Panel (A) shows that the share of Brazilian spending on Chinese manufactured goods soared after 2001, while imports of agricultural and mining goods remained low. Panel (B) highlights the sharp rise in Brazilian exports of agriculture and mining products.

[2]In compiling the data, we give preference to the trade flows reported by the exporting country recorded fob (free on board). We determine the import flows by mirroring the bilateral export flows. The data is complemented by the reported import bilateral flows when the exporter's report is unavailable.



(A) Brazilian imports from China

(B) Brazilian exports to China

Figure 1. Trends in Brazil-China trade (relative to the Brazilian GDP) and wage inequality in Brazil. Imports (Panel A) and Export (Panel B) for Brazilian trade with China as a percentage of the GDP (left scale) and Gini Coefficient for the Brazilian formal labor market (right scale). We plot the data for three sectors: agriculture and mining (green line), high-technology manufacturing (blue line), and low-technology manufacturing (orange line). Especially after the 2000s, the manufacturing industries showed the highest increase in imports as a percentage of the GDP. In contrast, the agriculture and mining industries showed a higher increase in exports as a percentage of the GDP. Wage inequality, measured by the Gini index, has a declining path, steeper after 2001.

To capture the exposure to international trade shocks, we use industry-level measures[3] calculated based on the change in trade with China in each industry per initial employment level in that industry. According to this measure, the shock is heterogeneous only at the industry level. Using a similar strategy as Autor et al. (2014), Acemoglu et al. (2016) and Feenstra et al. (2019), we measure the exposure of industry s to the trade shock by the change in the sector-level trade between Brazil and China as follows:

$$IPW_{jt} = \frac{M_{jt} - M_{j2000}}{L_{j,2000}} \tag{2.1}$$

$$EPW_{jt} = \frac{E_{jt} - E_{j2000}}{L_{j,2000}}, \tag{2.2}$$

where IPW_{jt} is the imports per worker, or import exposure in industry j and year t in Brazil from Chinese imports; EPW_{jt} is the Brazilian exports per worker, or export exposure of industry j in year t to China; The numerators represent the difference between imports (M) in eq. (2.1) or exports (E) eq. (2.2) in year t with the reference year, 2000. To normalize, we divide the differences in thousands of dollars by the total number of workers in

[3] Alternatively, one could assume that trade shocks are related to local labor market changes. More recent works use regional-level shift-share designs to study the impact of the international economy on Brazilian labor markets. (Dix-Carneiro and Kovak, 2017; Adão, 2016; Costa et al., 2016).

industry j in 2000. The information on workers comes from the Brazilian Census data, which accounts for both formal and informal employment.

The trade literature has extensively documented the various ways that trade shocks directly affect the firm's output demand. However, firms are not isolated in their production process. They also buy inputs and sell their products to other firms, so international trade shocks may also indirectly affect an industry through production chains. On the one hand, there is an *upstream effect* caused by *downstream exposure*: firms are indirectly affected if their customers are directly affected by the shocks. If firms face positive (negative) demand shocks for their products, they will likely increase (decrease) their demand for inputs through the intermediate consumption channels (input-output linkages). On the other hand, there is also a *downstream effect* caused by *upstream exposure*: firms are indirectly affected by trade shocks if their input suppliers are affected by those shocks. Having import exposure upstream in the production chain is likely to increase the supply of inputs (via price reductions or quality improvements), which reduces costs with potential transmission to increased wages. Conversely, export exposure upstream in production leads to greater competition for inputs, with a potential increase in input prices and a decrease in wages.[4]

Considering this potential propagation of shocks through the industries' production chains, we use an input-output matrix from Guilhoto and Sesso-Filho (2005, 2010) to measure industry linkages and account for them in our trade shocks measures.[5] Using the 1995 input-output matrix, we propose four measures for the production chain exposure of a sector to the import and export shocks:

$$\begin{aligned}
IPW_{jt}^{UP} &= \sum_{k \in J} \left(\omega_{kj,1995} IPW_{kt} \right) - IPW_{jt} \\
EPW_{jt}^{UP} &= \sum_{k \in J} \left(\omega_{kj,1995} EPW_{kt} \right) - EPW_{jt} \\
IPW_{jt}^{DOWN} &= \sum_{k \in J} \left(\omega_{jk,1995} IPW_{kt} \right) \\
EPW_{jt}^{DOWN} &= \sum_{k \in J} \left(\omega_{jk,1995} EPW_{kt} \right)
\end{aligned} \tag{2.3}$$

[4]Accounting for indirect effects of trade shocks are increasing in the literature. Acemoglu et al. (2016) documents that downstream exposure to import competition has a comparable effect on industry employment as the direct effect from import penetration. Other recent papers have focused on using firm-to-firm transaction data to study the role of production networks in the transmission of international trade shocks (Huneeus, 2018; Dhyne et al., 2021).

[5]The authors propose different methods to estimate yearly matrices using a flexible approach and preliminary data. Despite using a different methodology, their estimates do not differ from official input-output matrices from the Instituto Brasileiro de Geografia e Estatística - IBGE.

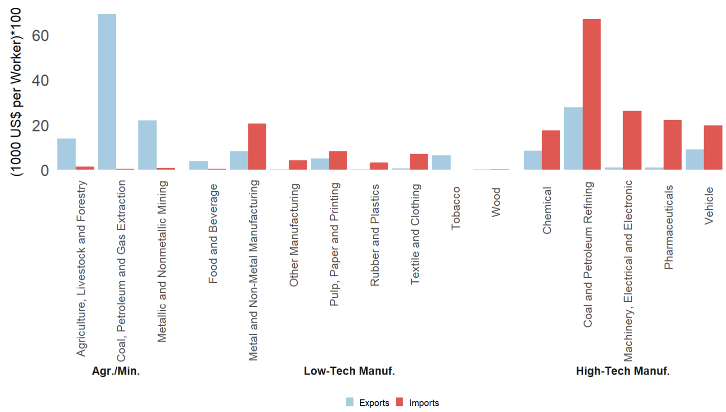
where $\omega_{jk,1995}$ is the $(j,k)^{th}$ entry in the Leontief-inverse matrix for the year 1995, normalized to sum 1 in the row or column depending on the direction from which we calculate the effect.[6] The superscripts *UP* and *DOWN* represent the upstream or downstream shock incidence on the production chain. The shocks with no superscripts represent direct shocks to each industry, as defined in eq. (2.1) and eq. (2.2). It is important to highlight that, by construction, our downstream exposure measure will include the direct trade exposure in each sector. In other words, our downstream exposure measure captures the incidence of trade shocks to firms in terms of their products as final goods and as inputs to other firms.

Figure 2 illustrates our exposure measures across industries: direct exposure (Panel A), downstream exposure (Panel B), and upstream exposure (Panel C). From panel (A), we note that the Agriculture/Mining industries are relatively more exposed to the export shock. On the other hand, manufacturing industries show the highest values for import competition, especially those classified as High-Tech manufacturing. In panels (B) and (C), we display the indirect exposure using the input-output linkages by measuring downstream and upstream exposure, respectively. Panel (B) represents demand shocks on each industry's output. Even though increased exports primarily benefited agriculture/Mining in the 2000s and the commodity boom, they are not free from being negatively impacted by import shocks in upstream industries. Panel (C) represents the shocks in the supply of inputs to industries on the graphs' horizontal axis. Note that manufacturing industries, especially High-Tech, are largely exposed to upstream and downstream shocks. That is caused by this sector's strong input-output linkages up and downstream. Low-tech manufacturing firms are also exposed to high up and downstream shocks, although with more variation across industries. Overall, upstream and downstream exposure show a high correlation.

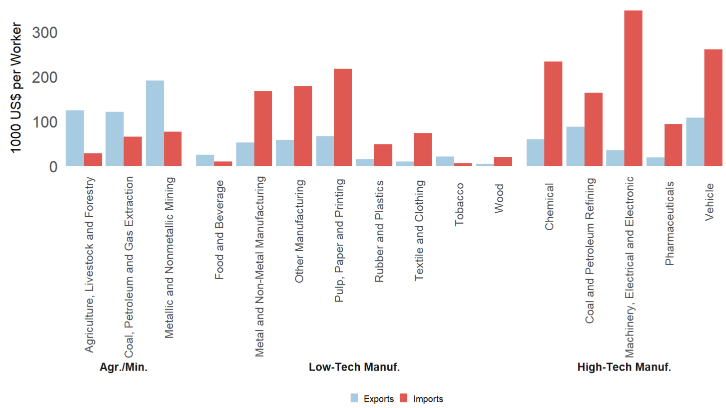
2.2 Labor Markets

One challenge in studying the consequences of international trade on wage inequality is the shortage of detailed micro-level data that allow us to track firms and workers over time. To address this challenge, we use labor market information from the Relação Anual de Informações Sociais (RAIS), the matched employer-employee administrative database collected by the Brazilian Ministry of Labor comprising the population of formal employment in Brazil from 1996 to 2012. It is a high-quality source of information regarding labor markets in Brazil because

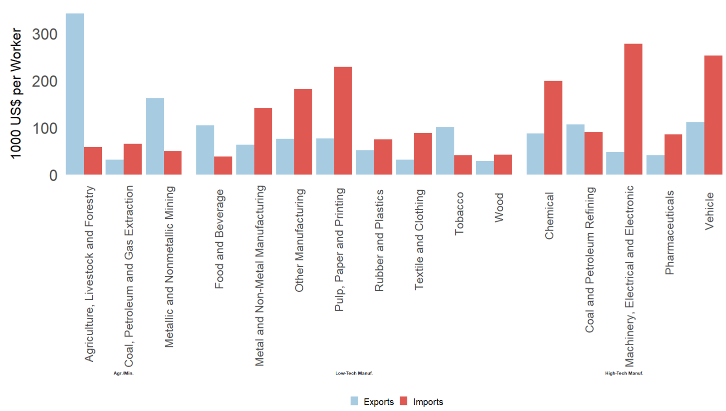
[6] We follow Acemoglu et al. (2016) in using the Leontief-inverse matrix to obtain indirect effects. This way, we also capture the full chain of supply and demand triggered by trade shocks.



(A) Direct Exposure



(B) Downstream Exposure



(C) Upstream Exposure

Figure 2. Import and Export exposure to Trade Shocks between 2000 and 2008. The figures display the measures of direct and indirect import and export exposure. Each bar averages the exposure measures from the 4-digit to the 2-digit industry classification. We sort the columns according to our broad classification of sectors. Down and Upstream exposure are estimated using the Input-Output matrix (Guilhoto and Sesso-Filho, 2005, 2010). Panel (A) displays the direct shocks. Agriculture and Mining industries face higher levels of export exposure. On the contrary, manufacturing industries are more highly exposed to import competition from China, especially the high-tech manufacturing industries. Panels (B) and (C) display the downstream and upstream exposure, respectively. Differently from the direct exposure, higher-order exposure to trade shocks is relatively more sparse across industries. We highlight the impact on manufacturing industries, coming from their high-up and downstream linkages.

it contains rich details on wages and workers' characteristics, such as educational attainment, gender, age, occupation, industry, and region.

Industries classification follows the Classificação Nacional de Atividades Econômicas (CNAE) version 2.0. We use the crosswalks provided by IBGE (Instituto Brasileiro de Geografia e Estatística) to match with previous versions. The primary definition of industry uses 4-digits, which comprises around 600 industries (304 in the tradable sector). We define a firm by a tuple firm-identifier-region.

Although RAIS is a rich administrative dataset for formal employment in Brazil, comprising a broad set of information about workers, it has limited information about firms. For instance, we cannot observe revenues, profits, and input expenditures, among other firm characteristics. However, using the firm identifier and data provided by SECEX (Secretaria de Comércio Exterior), we can establish whether a firm f is an exporter or an importer (or both) in each year t. Additional demographic data comes from the Brazilian Census data of 1991 and 2010.

RAIS has some relevant caveats: I) it only contains information about formal employment. This means that we are not accounting for wages in the informal sector, which can be significant, especially for the Agriculture sector, which has a relatively higher informality rate and experienced higher export growth; ii) RAIS does not register the number of hours the worker actually worked during a period or extra earnings (overtime payments, bonuses, benefits, etc.). Thus, the reported earnings and hours worked likely underestimate their true values.

2.3 Wage Trends

To study the relationship between trade shocks and wage inequality at the firm level, we must find a consistent measure for the firm average wage. Therefore, based on Helpman et al. (2017) and Alvarez et al. (2018), we estimate the following model separately for each year in the period 1996–2012.

$$log(wage_{it}) = X'_{it}\Lambda_t + \psi_{oft} + \varepsilon_{i,t}, \tag{2.4}$$

where $log(wage_{it})$ is the natural logarithm of the average hourly-wage of worker i in year t. X_{it} is a fully interacted set of workers' characteristics and sector-occupation-state pairs.[7]

[7] Observable worker's characteristics include a dummy variable for females; educational attainment in three categories: i) high-school dropouts; ii) high-school graduates; iii) at least some college; dummy variable for age in five categories: 18-25, 26-34, 35-42, 43-50, 51-64 (these breaks correspond to quintiles of the initial year of age distribution).

Sector-occupation-state pairs interact with seven sectors with five occupation classes, and 27 Brazilian states.[8] Λ_t is a vector of parameters that identifies the return to each category in X. Changes over time in the term $X'_{it}\Lambda_t$ represent the changes in the composition of the labor force in the economy. ψ_{oft} is an interaction of firm identifiers with sector-occupation categories. This term captures the between firm-occupation components. Thus, Eq. (2.4) decomposes wages into the labor market composition $X'_{it}\Lambda_t$ and between firm-occupation ψ_{oft} components. $\varepsilon_{i,t}$ is the idiosyncratic component.

Table 1 reports the variance decomposition of $log(wage_{it})$ estimated in Eq. (2.4).[9] The first line shows the change in overall wage variance between 2000 and 2008. As previously suggested, the wage variance fell almost 30 percent between 2000 and 2008. Similarly to the patterns documented by Helpman et al. (2017) and Alvarez et al. (2018), the between-firm fixed effects (ψ_{oft}) correspond to a large share of the total variance of log-wage, around 2/3. It also was the component with the highest decline over the period.

Table 1. Decomposition of Variance of Log-Wage per Hour

	2000		2008		Change (%)
	Level	(%)	Level	(%)	
$var(log(wage))$	0.663	100	0.489	100	–26.18
$var(\psi_{of})$	0.449	67.7	0.310	63.4	–30.82
$var(x'\beta)$	0.047	7.1	0.040	8.1	–15.09
$var(\varepsilon)$	0.105	15.9	0.089	18.1	–16.09
$2 \times cov$	0.062	9.3	0.051	10.3	–18.10

Results are based on estimates of Eq. (2.4). $log(wage)$ is the log of the wage per hour for every worker in our sample. ψ_{of} is a firm-occupation-sector component. $x'\beta$ as workers' observable characteristics. ε is the residual wage per hour. cov is the covariance between ψ_{of} and $x'\beta$.

The within-firm wage variance ($\varepsilon_{i,t}$) increased to a greater share of the overall wage variance. In particular, we note an increase in the share of the residual component by over two percentage points. As studied in Helpman et al. (2017) and Alvarez et al. (2018), trade and productivity gains may explain a significant part of the faster decrease in cross-firm wage inequality, with productivity gains being the main reason for the decreased inequality in the Brazilian formal labor market.

[8] Sectors are grouped into Agriculture/Mining, Low-Tech Manufacturing, High-Tech Manufacturing, Transportation/Communications, Construction, Trade, and Services; Occupations are grouped into blue-collar, skill-intensive blue-collar, white-collar, Technical and Supervisory, and Professional and Managerial

[9] The complete set of estimates are available upon request.

Our analysis complements the previous studies by focusing on the evolution of the between-firm wage component in response to the increased trade integration between Brazil and China.

We denote $\hat{\psi}_{ft}$ the estimated between-firm wage component in Eq. (2.4), and which we refer to as the firm wage component. We obtain this term by averaging $\hat{\psi}_{oft}$ for each firm, weighting by the firm's number of employees. Considering the large participation of the firm wage component in the total wage variance, and the fact that this measure is independent of compositional changes in the Brazilian labor force, we adopt this as our main measure of firm-level wages. Effectively, our analysis focuses on the impacts of international trade shocks on firm wage inequality.

3. Reduced-Form Results

3.1 Industry-Level

In this section, we study the effects of the China shock on employment, firm wages, firm size, and exporter and importer status. We begin by assessing the impacts of trade shocks on labor market outcomes at the industry level. Following the literature investigating the effect of the China shock (Autor et al., 2013, 2014; Acemoglu et al., 2016; Pierce and Schott, 2016), we first aggregate our data to the industry level and estimate the following equation:

$$\Delta y_{jt} = \alpha_I IPW_j^{DOWN} + \alpha_E EPW_j^{DOWN} + \beta_I IPW_j^{UP} + \beta_E EPW_j^{UP} + X_j'\delta + \eta_s + \varepsilon_j, \qquad (3.1)$$

where Δy_{jt} is our industry-level dependent variable, which takes the difference between the levels in year t and 2000. In this specification, we use two measures for y_{jt}: $log(employment_{jt})$ and the weighted average of firm component ψ_{ft} for industry j. An industry is a 4-digit CNAE classification consisting of 306 industries in total. IPW_j^{DOWN} and EPW_j^{DOWN} are the measures of downstream import and export exposure in industry j. IPW_j^{UP} and EPW_j^{UP} are the measures of upstream import and export exposure in industry j. X_j includes pre-2000 exposure to Chinese imports and exports and industry-level controls in 2000: (unconditional) average wages, formality rate, the share of high-educated workers, and the share of workers whose earnings are smaller than the minimum wage plus 10 percent. η_s are sector fixed effects. Thus, α_I and α_E capture the effect of import and export exposure within-sector. One common concern when estimating the effects of the China-shock in endogeneity. The main concern is that the shock measures might be driven by factors other than the rise of the Chinese economy correlated with the Brazilian labor market outcomes. To address this concern, we estimate eq. (3.1) using the instrumental variable as proposed in Costa et al. (2016), which is further discussed in the Online Appendix. ε_j is an idiosyncratic error. The results are reported in Table 2.

Table 2. The Effect of Import and Export exposure on Log Employment and Average Wages

	(1)	(2)	(3)	(4)	(5)	(6)
	Log Employment			Average Log Wage		
	2002	2008	2012	2002	2008	2012
Downstream Import Exposure	–0.934**	–0.591	–0.522	–0.11	–0.586***	–0.689***
	(0.369)	(0.502)	(0.529)	(0.073)	(0.169)	(0.172)
Downstream Export Exposure	0.753	2.043**	2.410***	–0.23	–0.267	–0.372
	(0.457)	(0.842)	(0.905)	(0.187)	(0.325)	(0.414)
Upstream Import Exposure	1.033**	0.629	0.447	0.303**	0.774***	0.921***
	(0.446)	(0.843)	(0.822)	(0.151)	(0.258)	(0.294)
Upstream Export Exposure	–0.125	–0.693	–0.889	–0.094	–0.049	–0.006
	(0.249)	(0.693)	(0.743)	(0.093)	(0.212)	(0.24)
Observations	306	306	306	306	306	306
R-squared	0.088	0.097	0.099	0.025	0.258	0.359
Controls	Yes	Yes	Yes	Yes	Yes	Yes
F-test	1.57	2.17	2.081	3.989	8.231	17.22
Weak instruments (F-stat)	25.5	25.5	25.5	25.5	25.5	25.5

The dependent variables: change in log-employment between the year in column and 2000 (columns 1-3); change in the weighted average wages (estimated firm-component, ψ_{ft}) between the year in column and 2000. The industry definition is a 4-digit of the CNAE classification, for tradable sectors (N=306). All equations include sector fixed effects and pre-200 controls: (unconditional) average wages, formality rate, and share of workers whose earnings are smaller than minimum wage plus 10 percent. Specifications are estimates using the instrumental variable approach from Costa et al. (2016). Regressions are weighted by the number of formal employees in 2000. Bootstrapped standard errors are reported in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

The results suggest that high downstream import exposure is associated with lower employment growth. That occurs mainly in the first periods after the shock and diminishes over time. The difference between the 90^{th} and 10^{th} percentile of downstream import exposure implies a reduction in employment by around 36 percent (-0.934×0.386) by 2012, with a lower 20 percent long-term impact percent (-0.5×0.386), although not statistically significant. One interpretation of this result is that downstream import exposure tends to decrease the demand for a firm's output.

The upstream import exposure also has effects but only in the short-term, with a difference of 3 percent by 12 (1.03×0.028) between the 90^{th} and 10^{th} percentile of exposure, becoming insignificant in the following years. This finding suggests that upstream import exposure increases the availability of inputs for firms, potentially decreasing input costs and increasing their production.

Downstream export exposure is related to an increase in aggregate employment over time. This suggests that downstream export exposure means a positive shock to a firm's output demand, leading to increased labor demand. The magnitudes of the point estimates are relatively stable over time, and we find more significant results starting around 2008. This pattern indicates that the employment adjustment tends to take more time in those sectors, but with a considerable increase in the longer term. On average, by 2008, the industries in the 90^{th} percentile of the downstream export exposure experienced increased employment levels by 28 percent (2.04×0.140). In contrast, upstream export exposure has a negative coefficient, suggesting that upstream export exposure tends to increase competition in the input markets, reflecting a negative shock to a firm's production. However, the point estimates are not statistically significant.

3.2 Firm-Level

We further analyze the effect of the China shock on firm-level labor market outcomes. We restrict the analysis to firms operating between 1997 and 1998, so we can explore pre-trends in outcome variables. Then, we use the following model to test the impact of import and export exposure on the firm's wage component, ψ_{ft}. Our main specification is below:

$$y_{ft} = \rho y_{f,0} + \alpha_I IPW_j^{DOWN} + \alpha_E EPW_j^{DOWN} + \beta_I IPW_j^{UP} + \beta_E EPW_j^{UP} + X'_f \delta + \hat{\lambda}_f + \eta_{sr} + \varepsilon_f, \quad (3.2)$$

where y_{ft} is the dependent variable for firm f in the post-shock period and $y_{f,0}$ is the dependent variable of firm f over 1997-2000. For firm-level wages, the dependent variable is $\Delta\psi_f$, i.e., the difference in the firm component between the average over the period 2006-2010 and the average over the period 1997-2000 (pre-shock). For firm-level employment, the dependent variable is the log of the average number of employers between 2006 and 2010. IPW_j^k and EPW_j^k, for $k = \{UP, DOWN\}$ are the measures of import and export exposure in industry j, respectively, described in Section 2. We estimate the equation above using Two Stages Least Squares with the instrumental variable approach as described in the Appendix. We include pre-2000 trends of each measure of import and export exposure in the estimation to identify those terms consistently. η_{sr} are state-by-sector fixed effects (27 States and 3 sectors). Therefore, the estimates for α_I and α_E refer to industry-level, downstream trade shocks, and β_I and β_E refer to industry-level, upstream trade shocks. X_f is a set of baseline (before 2000) controls that include firm characteristics, the share of college-educated workers, and white-collar employment share. Industry controls include (unconditional) average wages, the log of the number of employees, the industry formality rate, and the share of workers whose earnings are below the minimum wages plus 10 percent. ε_f is an idiosyncratic shock.

Since we only use active firms, we also control for selection.[10] Following Amiti and Davis (2012), we first round up the panel to include all the firms that appear in the sample at least once and create an indicator variable that assumes a value of 1 if the firm is active. Then, we apply the selection procedure as proposed in Heckman (1979). For that, we rely on three excluded variables that influence changes in firm wages only through the probability that a firm will operate in a given year: i) firm's age; ii) cost of opening a firm; and iii) indicator of belonging to a "priority" sector. With the predicted values of a Probit model proposed by Heckman (1979), we constructed the Inverse Mill's Ratio $(\hat{\lambda}_f)$ to be included as a control variable in our model. The specification of the selection model is further discussed in the Appendix.

Because upstream exposure may influence firm wages, we expect that $\beta_I > 0$, so that higher availability of imported inputs is beneficial to the firm. $\beta_E < 0$ reflects the increased external demand on a firm's input market, and so a potential negative impact on wages. On the other hand, we expect that $\alpha_E > 0$, so that firms improve their gains when exposed to a positive output demand shock. An import competition shock downstream in production should reduce the demand for a product, so we might expect that $\alpha_I < 0$.

The estimates of Eq. (3.2) are reported on Table 3. Column 1 displays the OLS regression of firm wages on the trade shocks. The other columns present the two stage least squares estimates. The OLS estimates show that the effects of import and export exposure are consistent with the findings in the literature: positive shocks in the output market lead to higher wages, while negative shocks lead to lower wages. In the input market, the logic is reversed: negative shocks are related to higher wages, and positive shocks are linked to lower wages. In Table 3, columns 2 to 9 present instrumental variable estimates with different assumptions over controls, dependent variables, and clustered standard errors. The IV procedure increased the magnitudes of most estimates (except for downstream export shocks). The inclusion of controls does not significantly change the direction and magnitude of our estimates, although it makes them more precise.

[10] As Olley and Pakes (1996) highlight, when estimating the production function parameters in firm-level data, the decision to exit the market is related to productivity: more productive firms are less likely to exit the market. Hence, selection may drive our estimates upward using only the observed firms. For instance, industries that are more affected by import competition shocks may lose more unproductive firms. As a result, the point estimates associated with trade shocks will be higher (or less negative for positive shocks).

Because we observe heterogeneous input demand and output supply across industries, the upstream and downstream exposure measures are also heterogeneous. Similar to the duality of import-export exposure, the identification of indirect exposure relies on this heterogeneity in the composition of input-output linkages to capture the partial causal impact.

The estimates suggest that upstream import exposure and downstream export exposure positively impact firm wages. Higher upstream import exposure in the production structure means a more extensive input variety at lower prices. Similarly, higher downstream export exposure in production leads to a positive shift in the demand for a firm's outputs and increased wages. These results are similar to those found by Acemoglu et al. (2016) and aligned our hypotheses $\beta_I > 0$ and $\alpha_E > 0$.

Table 3. Impact of Import and Export Shocks on Firm-Level Wages and Employment

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Average Firm Wage 2006-2010					Log-Employees	
	OLS	IV	IV	IV	IV	OLS	IV
Downstream Import Exposure	–0.08	–0.174	–0.190**	–0.259***	–0.280***	0.115	0.061
	(0.068)	(0.114)	(0.092)	(0.091)	(0.096)	(0.274)	(0.32)
Downstream Export Exposure	0.327***	0.187	0.077	0.194*	0.250**	0.334	–0.051
	(0.098)	(0.127)	(0.126)	(0.117)	(0.115)	(0.452)	(0.513)
Upstream Import Exposure	0.177**	0.482***	0.370***	0.472***	0.508***	–0.236	0.047
	(0.088)	(0.182)	(0.126)	(0.121)	(0.127)	(0.377)	(0.444)
Upstream Export Exposure	–0.233***	–0.383**	–0.334***	–0.361***	–0.421***	0.158	0.014
	(0.074)	(0.149)	(0.092)	(0.081)	(0.082)	(0.336)	(0.37)
Observations	50,325	50,327	50,327	50,327	50,325	50,325	50,325
R-squared	0.481	0.331	0.349	0.381	0.382	0.075	0.066
Firm Controls	Yes	No	No	Yes	Yes	Yes	Yes
Industry Controls	Yes	No	Yes	Yes	Yes	Yes	Yes
Selection Controls	Yes	No	No	No	Yes	Yes	Yes
F-test	154.8	139.3	89.92	148.6	159.9	35.97	36.29
Clusters	304	304	304	304	304	304	304
Weak instruments (F-stat)		56.48	53.57	53.13	53.35		53.35

In columns 1-5, the dependent variable is the difference in the average firm component estimated in Eq. (2.4) for the average in 1997–2000. In columns 6–7, the dependent variable is the log of the number of employees. The models are estimated from Eq. (3.2). Columns 1 and 6 show OLS specification (endogenous). Columns 2 to 5 and 7 show the Instrumental Variables specifications. All regressions include State-Sector fixed effects and pre-2000 levels of exposure to Chinese imports and exports. Industry controls (baseline, 2000): log of employees, (unconditional) average wages, formality rate, and share of workers whose earnings are smaller than minimum wage plus 10 percent. Firm controls (baseline, 2000): log wages, log-firm size, the share of highly educated workers, and white-collar workers. Selection controls, the third-order polynomial of the Inverse-Mills term for the probability of a firm to operate. Bootstrapped standard errors are clustered at the industry level (4 digits), with 1000 replications. *** p<0.01, ** p<0.05, * p<0.1.

In contrast, downstream import exposure and upstream export exposure industries negatively relate to firm wages and are robust to different specifications. Higher downstream import exposure decreases the demand for a firm's output and thus represents a negative shift in the demand with a decrease in wages. Higher upstream export exposure increases the competition with the external market, which increases input prices, meaning a downward shift in the firm's demand for labor. Again, these estimates align with our hypotheses $\alpha_I < 0$ and $\beta_E < 0$.

Using values in Table 3 column 5, the difference in changes in wages between the 90^{th} and 10^{th} percentiles of downstream import exposure reflects a decrease of 10 percent in the average per hour (-0.280×0.386). Downstream export exposure is related to a 3.5 percent increase in the average wage per hour (0.250×0.140). In contrast, the difference in changes in firm wages between the 90^{th} and 10^{th} percentiles of upstream import exposure is about 16 percent (0.588×0.276). For upstream export exposure, the difference is 5 percent (-0.421×0.115).

In columns 6 and 7, the model in Eq. (3.2) is estimated with the log-employment. The results suggest that trade shocks have a statistically insignificant impact on the number of employees. These results support the earlier estimates in this section when we found sizable effects of the China shock on industry-level employment.

To further assess the channels through which sector-level trade shocks translate into different impacts on firms' outcomes, we estimate Eq. (3.2) with the probability of a firm being an importer or an exporter as the dependent variable in a Probit model.[11] Moreover, we investigate the heterogeneous consequences of trade shocks for importer/non-importer and exporter/non-exporter firms. Note that those groups may overlap.[12] Results are reported on Table 4.

The first two columns report the estimates of Probit models with Import and Export status as dependent variables. The estimates for upstream and downstream shocks affect the probability of firms selecting to be importers or exporters. In column 1, the coefficient for upstream import exposure is positive and significant at a 5 percent level. Thus, when an import shock affects the input market, firms are more likely to become importers to take advantage of lower input prices from the external market. In column 2, the coefficients for downstream export exposure are particularly relevant in that they are positive and statistically significant at a 1 percent level. Thus, firms are more likely to export when facing a positive shift in their output's demand.[13]

[11]Other specifications, such as Logit and Poisson, are presented in the Appendix.

[12]Estimates for other definitions of groups are reported in the Appendix.

[13]Note that the coefficient for upstream import exposure is also significant in column 2. That is because there is a positive relationship between import and export status. The coefficients for upstream export exposure are negative and significant in both specifications, indicating that a negative shift in output's demand decreases firms' probability of engaging in international trade.

Table 4. Probability of Import and Export and Heterogeneous Effects

	(1)	(2)	(3)	(4)	(5)	(6)
	Probability	Probability	Average Firm Wage 2006-2008			
	Importer	Exporter	Non-Importer	Importer	Non-Exporter	Exporter
Downstream Import Exposure	0.594	–1.535	–0.277***	–0.256**	–0.344***	–0.155
	(0.925)	(0.988)	(0.098)	(0.104)	(0.099)	(0.097)
Downstream Export Exposure	0.492	4.357***	0.283**	0.250*	0.319**	0.232
	(1.519)	(1.601)	(0.132)	(0.147)	(0.134)	(0.15)
Upstream Import Exposure	2.900**	3.519**	0.519***	0.407***	0.578***	0.299**
	(1.275)	(1.458)	(0.132)	(0.129)	(0.128)	(0.122)
Upstream Export Exposure	–0.679***	–0.667***	–0.336***	–0.448***	–0.352***	–0.421***
	(0.133)	(0.155)	(0.087)	(0.111)	(0.083)	(0.12)
Observations	50,024	50,090	38,261	12,061	39,573	10,748
(Pseudo) R-squared	0.35	0.301	0.369	0.294	0.368	0.297
Clusters	304	303	300	290	299	287
F-test			122.7	99.44	127.1	102.2
Weak instruments (F-stat)			50.8	44.18	57.22	40.87

The dependent variables are the indicator of importer (column 1), the indicator of exporter (columns 2), and the change in the firm wage component (columns 3-6). The models are analogous to Eq. (3.2), except for the dependent variable in columns 1-2. All regressions include state-sector fixed effects and pre-2000 levels of exposure to Chinese imports and exports, baseline industry, and firm controls. Industry controls (baseline, 2000): log of employees, (unconditional) average wages, formality rate, and share of workers whose earnings are smaller than minimum wage plus 10 percent. Firm controls (baseline, 2000): log wages, log-firm size, the share of highly educated workers, and white-collar workers. Selection controls: third-order polynomial of Inverse-Mills term for the probability of a firm to operate. Bootstrapped standard errors are clustered at the industry level (4 digits), with 1000 replications. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

The models in columns 3 to 6 are estimated separately for each group, importer/non-importer and exporter/non-exporter. Note that the coefficients are similar across groups and also similar to the findings on Table 3. Indeed, the point estimates for those groups suggest that importers and exporters are less sensitive to trade shocks than non-importers and non-exporters. Nonetheless, the estimates' distributions overlap, so we cannot imply a statistical difference.

3.3 Overall Trade Effects by Sector

To illustrate the overall effect of the China shock, we convert the estimates in Table 2, Table 3, and Table 4 to represent their economic magnitude. Firstly, we split the tradable industries into 3 sectors: Agriculture-Mining, Low-Tech Manufacturing, and High-Tech Manufacturing. The first sector produces primary goods, which faced a large increase in exports over the first decade of the 2000s. Manufacturing industries are divided into Low- and High-Tech. The former is composed of industries for which Brazil has a greater comparative advantage, while the latter comprises industries in which the country has comparative disadvantages.[14] Manufacturing industries are also characterized by their input-output linkages: High-tech industries are more linked with other industries upstream and downstream of the production network.

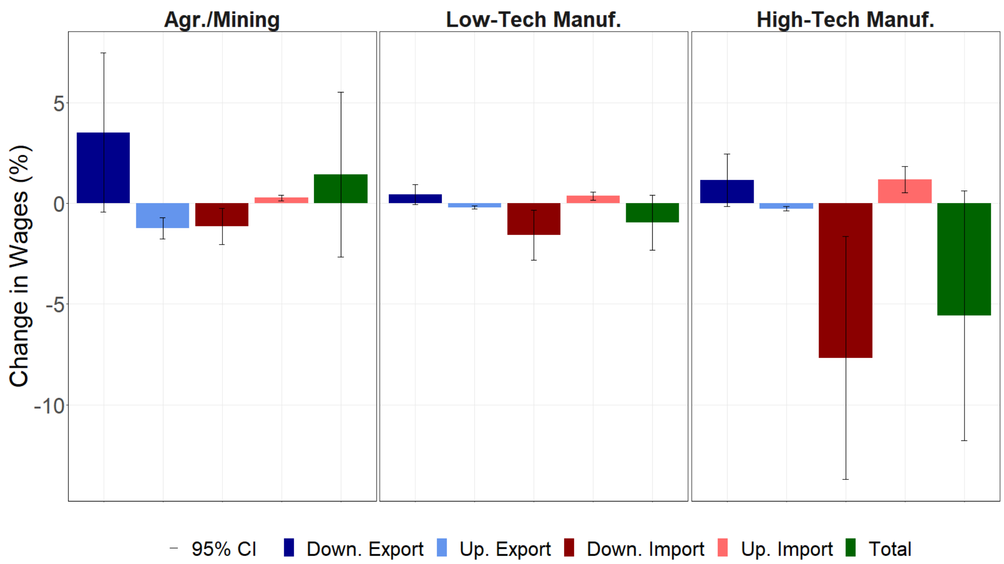
Figure 3 converts the reduced form results into their sector-level impact. In Panel (A) of Figure 3, we present the predicted changes in the average wage per sector. An average firm within the Agriculture/Mining sector experiences an overall increase of 1 percent in their wages: export exposure increases wages by 1.7 percent, whereas import exposure decreases wages by 0.9 percent. Most of their gains come from downstream export exposure (which contributed to about a 3 percent increase). On the other hand, downstream import exposure leads to a decrease of approximately 1.3. Competition with imported inputs (upstream export exposure) leads to a decline of 1.2 percent.

A firm in the Low-tech manufacturing sector faces an average decline in wages by around 1 percent. Most of this decline is driven by the competition with Chinese products in the output market (i.e., downstream import competition), contributing to a decrease of around 1.6 percent in the average wages. Nonetheless, import competition affecting the input markets is highly beneficial to those firms: upstream import exposure is related to an almost 0.5 percent increase in wages.

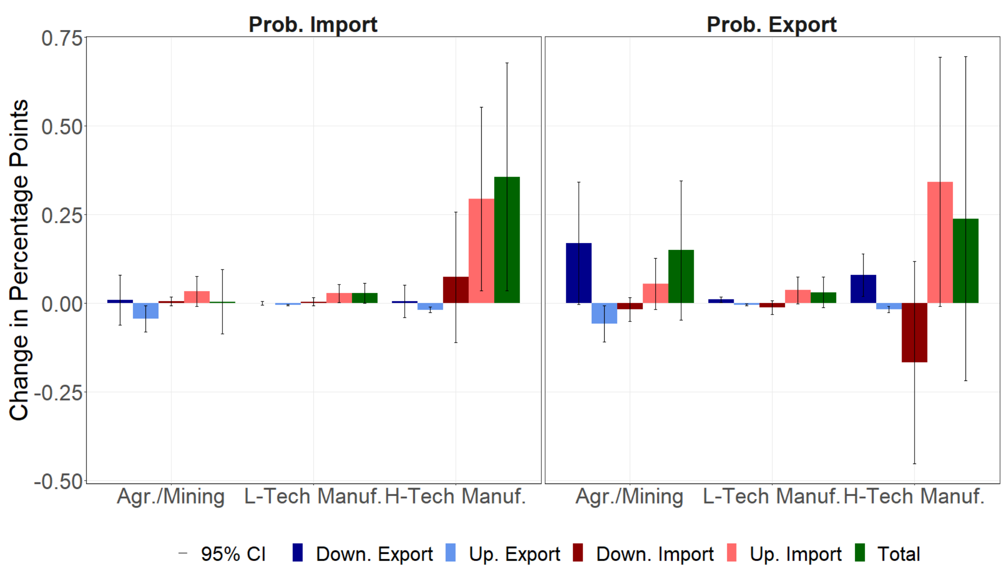
Finally, an average firm in the High-Tech manufacturing sector experiences a negative net effect on wages derived from the bilateral trade integration with China of around 6 percent. Although those firms benefit from cheaper imported goods, they mainly demand inputs from other manufacturing sectors, and upstream import exposure leads to a 1.3 percent increase in wages. Nonetheless, because the main destination of their production is other manufacturing industries, losses due to import competition downstream in production also have a sizable effect on wages (almost 8 percent fall).

Using the estimated coefficients from columns 1 and 2 of Table 4, we also estimate the predicted changes in the probabilities of import and export for each sector. The results are presented in Panel (B) of Figure 3. The overall impact of the China shock increases the firm's probability of importing, mainly for firms in high-tech manufacturing, which are highly exposed to import competition shocks. On the other hand, the firm's probability of exporting increases (statistically insignificant), driven by the export exposure in the Agriculture/Mining and High-Tech manufacturing sectors.

[14] See Dix-Carneiro (2014).



(A) Average Wages



(B) Probability of Import and Export

Figure 3. Predicted Impact of the China Shock on the Changes in Averages Wage and on the Probability of Import or Export. The Figures display the predicted impact of the China Shock on wages (Panel A) and the probability of import or export (Panel B). The values are based on estimates in column 5 of Table 3 and columns 1 and 2 of Table 4. The bars decomposed the partial impact of upstream and downstream import and export exposure per sector and the total for the economy. Vertical, black lines represent the 95% confidence intervals.

In summary, our results show that the China shock significantly impacted labor market outcomes in Brazil and played an important role in the probability of firms participating in international trade as exporters and importers. Nonetheless, the reduced-form analysis is limited in two crucial aspects. Firstly, it does not provide evidence of the mechanisms through which the shock impacts labor markets. Secondly, it does not enable us to perform any credible counterfactual analysis. Based on the empirical evidence we presented in the last two sections, we will introduce and estimate a structural model highlighting the mechanisms through which the China shock may influence Brazilian firms. The model provides the relevant parameters to perform the counterfactual analysis.

4. Structural Model

In this section, we provide a brief overview of the theoretical framework based on the models of Helpman et al. (2017) (henceforward HIMR) and Helpman et al. (2010), which accounts for the reduced-form estimates in Section 3 and other stylized facts presented in the Appendix. More details on the model are provided in the Appendix and Helpman et al. (2017) and Helpman et al. (2010). Similar to HIMR, we develop a static model to explain steady-state patterns. In addition, we extend the model to incorporate firm selection into import markets and heterogeneous sectors as alternative mechanisms through which trade shocks may affect the earnings distribution.[15]

4.1 Theoretical Framework

The world consists of two countries (Home and Foreign) and S sectors. Home is a small economy with no influence on external prices. Each sector is indexed as s. Each country has a *continuum* of workers who are ex-ante identical. The goods in each sector are differentiated and produced by a primary factor, labor. Workers are endowed with one unit of labor supplied inelastically with zero disutility.

Moreover, nested within domestic and imported goods, consumers choose between varieties. There is a *continuum* of monopolistically competitive firms in each sector, each supplying a distinct, horizontally differentiated variety, represented by q_j, for $j \in J_s$. To import goods, consumers face an iceberg cost $\tau_m > 1$, which gives the relative cost between imported

[15] We choose this model because it provides a clear, straightforward interpretation of the mechanisms through which trade affects earnings inequality. Moreover, the model delivers intuitive structural equations that are simple to estimate compared to more sophisticated general equilibrium models in the literature.

and exported varieties. For every imported unit, consumers must pay τ_m to acquire the same quantity. Additionally, we assume there are further barrier terms that determine the relationship between countries so that prices of foreign goods are given by $P^* = {}^1/_{A_d}\tau_m P$, where P^* and P are the price indexes for foreign and domestic goods, respectively, ${}^1/_{A_d}$ is the non-tariff shifter in the barriers between the two countries.

By solving the domestic consumer's problem, we get the following relationship for the revenues of firms operating in the domestic market

$$R_j = Aq_j^{\beta}, \tag{4.1}$$

where

$$q_j = I_j \, Y_j, \tag{4.2}$$

and

$$A = \bar{A}_s \left(1 + A_d \tau_m^{-\epsilon/(1-\epsilon)}\right)^{-(1-\beta)}, \tag{4.3}$$

I_j is the quantity of intermediate inputs, Y_j is firm j's production, and $\bar{A}_s$ is a sector-specific constant. $\beta \in (0,1)$ determines the elasticity of substitution between varieties equal to ${}^1/_{(1-\beta)} > 1$. $\epsilon \in (0,1)$ determines the elasticity between domestic and imported goods ${}^1/_{(1-\epsilon)} > 1$.

Note that domestic revenues are negatively related to domestic consumption relative to the price shifter for imported goods A_d. Moreover, domestic revenues are positively related to import tariffs τ_m. Hence, an increase in import tariffs makes imported varieties more expensive, which increases the relative demand for domestic goods and revenues.

Firms decide the amount of intermediate inputs between domestic and imported varieties. Intermediate inputs shift the firm's production up. By being able to import intermediate inputs, the shift is able to enhance production further. Moreover, firms may also decide to sell part of their production in the external market. Thus, by engaging in imports or exports, firms are able to increment their revenue. The detailed derivation of the firm's revenue is presented in the Appendix.

To export, a firm has to incur a fixed cost $e^{\varepsilon_x} C_{x,s}$ where ε_x is a firm-specific random draw and $C_{x,s}$ is common to all firms in the sector s. In addition, there is an iceberg transportation cost $\tau_x > 1$ for shipping products across the two countries. This iceberg cost means that for every unit of output the firm sells abroad, it must produce an amount τ_x. The exporting firm's problem is to maximize its revenue by allocating its production between the domestic and export markets.

Analogously, to import, a firm incurs a cost $e^{\varepsilon_m} C_{m,s}$, a firm-specific random draw ε_m and common sector-wide import cost $C_{m,s}$. By having access to a wider variety of inputs at potentially lower prices, importing firms can improve their production quality, which increases their productivity from A_d to A_m. In other words, those firms that can afford higher quality/quantity inputs will get higher revenues for their output. However, input imports are also subject to the iceberg cost $\tau_m > 1$, which gives the relative cost between imported and exported inputs. So, for every unit of imported input, an importer firm must pay τ_m. We can write a firm's total revenue as:[16]

$$R = \left[1 + \iota_x \left(\Upsilon_x - 1\right)\right]^{1-\beta} \left[1 + \iota_m \left(\Upsilon_m - 1\right)\right]^{\beta/\epsilon} \left[\Upsilon_d\right]^{-(1-\beta)} \bar{A}_s \bar{B}_s Y^{\beta}, \tag{4.4}$$

with

$$\Upsilon_x = 1 + A_x \tau_x^{\frac{-\beta}{1-\beta}} > 1 \quad \text{and} \quad \Upsilon_m = 1 + A_m \tau_m^{\frac{-\epsilon}{1-\epsilon}} > 1 \quad \text{and} \quad \Upsilon_d = 1 + A_d \tau_m^{-\epsilon/(1-\epsilon)}$$

In these equations, (ι_x, ι_m) are the indicators of whether firms export or import, respectively. $\Upsilon_x^{1-\beta}$ and $\Upsilon_m^{\beta/\epsilon}$ are the firm revenue premium from exporting and importing, respectively. They are decreasing in the bilateral trade cost parameter (τ_x, τ_m) and increasing in the demand shifters (A_x, A_m). The firm's revenue is decreasing on shifters of demand for external goods (A_d), reflecting the effect of importing competition. $\bar{A}_s$ is a final good demand shifter $\bar{B}_s$ is an intermediate input demand shifter.

The labor market structure follows straight from Helpman et al. (2010), so we briefly describe it here. The production technology is:

$$Y = e^{\theta} H^{\gamma} \bar{a}, \quad 0 < \gamma < 1, \tag{4.5}$$

where $\bar{a}$ represents the average ability of the hired workers, γ is the elasticity of employed workers. Following Helpman et al. (2017), workers choose a sector in which to search for employment, where each firm bears the search cost bN to match with N workers randomly. The hiring cost b is exogenously determined by the labor market tightness and taken as given by each firm. In the econometric model, labor market tightness and the product market demand

[16] Refer to the Appendix for the derivation

shifters are absorbed in the sector fixed effects. Each firm that searched for N workers and chose the ability cutoff a_c hires $H = N[1 - G(a_c)] = N a_c^{-k}$ workers whose expected ability is $\bar{a} = \mathbb{E}\{a \mid a \geq a_c\} = \frac{k}{k-1} a_c$. After hiring, firms collectively bargain with workers, resulting in a common wage given by a fixed share of the firm's revenue.[17]

Timing i) firms independently draw a cost of operating in each sector of the economy $C_{\pi,s}$, and choose the sector to operate based on the expected profit; ii) Once in a sector, firms draw their idiosyncratic components $(\theta, \eta, \varepsilon_x, \varepsilon_m)$; iii) pay for fixed costs of searching, screening, exporting, and importing; iv) choose the intermediate inputs quantity, workers, production; and v) finally engages in multilateral bargaining with its H workers over wages. Firms solve the following problem (we omit firm and sector subscripts for simplification):

$$\Pi(\theta, \eta, \varepsilon) = \max_{N, a_c, \iota_x, \iota_m \in \{0,1\}} \left\{ \frac{1}{1+\beta\gamma} R(N, a_c, \iota; \theta) - bN - e^{-\eta} \frac{C}{\delta} (a_c)^{\delta} - \iota_x e^{\varepsilon_x} C_x - \iota_m e^{\varepsilon_m} C_m \right\}, \quad (4.6)$$

where the revenue $R(N, a_c, \iota; \theta)$ is defined by eq. (4.4), eq. (4.5), and the functions that determine the workers hired and their expected ability. The solution to the firm's profit maximization problem yields the following equations:

$$R = \kappa_r [1 + \iota_x (\Upsilon_x - 1)]^{\frac{1-\beta}{\Gamma}} [1 + \iota_m (\Upsilon_m - 1)]^{\frac{\beta}{\epsilon\Gamma}} (\Upsilon_d)^{\frac{1}{\Gamma}} \left(e^{\theta}\right)^{\frac{\beta}{\Gamma}} (e^{\eta})^{\frac{\beta(1-\gamma k)}{\delta\Gamma}}, \quad (4.7)$$

$$H = \kappa_h [1 + \iota_x (\Upsilon_x - 1)]^{\frac{(1-\beta)(1-k/\delta)}{\Gamma}} [1 + \iota_m (\Upsilon_m - 1)]^{\frac{\beta(1-k/\delta)}{\epsilon\Gamma}} (\Upsilon_d)^{\frac{(1-k/\delta)}{\Gamma}} \left(e^{\theta}\right)^{\frac{\beta(1-k/\delta)}{\Gamma}} (e^{\eta})^{-\frac{k-\beta}{\delta\Gamma}} \quad (4.8)$$

$$W = \kappa_w [1 + \iota_x (\Upsilon_x - 1)]^{\frac{k(1-\beta)}{\delta\Gamma}} [1 + \iota_m (\Upsilon_m - 1)]^{\frac{k\beta}{\epsilon\delta\Gamma}} (\Upsilon_d)^{\frac{k}{\delta\Gamma}} \left(e^{\theta}\right)^{\frac{\beta k}{\delta\Gamma}} (e^{\eta})^{\frac{k(1-\beta\gamma)}{\delta\Gamma}}, \quad (4.9)$$

Eq. (4.7) to eq. (4.9) are sufficient to determine a firm's profits. Thus, we also find sufficient conditions for firms to export or import as follows:

$$\kappa_\pi \left(\Upsilon_x^{\frac{1-\beta}{\Gamma}} - 1 \right) \left(e^{\theta}\right)^{\frac{\beta}{\Gamma}} (e^{\eta})^{\frac{\beta(1-\gamma k)}{\delta\Gamma}} \geq C_x e^{\varepsilon_x} \quad (4.10)$$

$$\kappa_\pi \left(\Upsilon_m^{\frac{\beta}{\epsilon\Gamma}} - 1 \right) \left(e^{\theta}\right)^{\frac{\beta}{\Gamma}} (e^{\eta})^{\frac{\beta(1-\gamma k)}{\delta\Gamma}} \geq C_m e^{\varepsilon_m}. \quad (4.11)$$

Eq. (4.7) to eq. (4.11) are the equilibrium firm-level variables within each sector. κ_r, κ_h, κ_w, and Γ are constants that depend only the model's parameters. Eq. (4.7), eq. (4.8) and eq. (4.9)

[17] See the Appendix for details.

show that exporting firms increase revenues, employment, and wages by a shift of size Υ_x. Analogously, importing firms increase revenues, employment, and wages by Υ_m. Eq. (4.10) and Eq. (4.11) establishes a sufficient condition for the firm to become an exporter or an importer.

Eq. (4.8) and eq. (4.9) establish the relationship between productivity and firm size and wages, respectively. More productive firms, those with higher draws of θ and η, are larger and pay higher wages. The first term, θ, is the production productivity, whereas the second term, η, is the human resources management productivity, which gives higher screening efficiency to firms. As a consequence, it also characterizes the positive correlation between firm size and wage.[18] As suggested in HIMR and other models that followed Melitz (2003), this is the first source of firm heterogeneity.

The second source of heterogeneity is related to the selection of firms into exporting and importing. Eq. (4.10) and Eq. (4.11) implies that only high-productivity firms can afford the trading costs c_x and c_m to engage in the international market. By exporting their output to foreign markets or importing higher quality/lower price inputs from abroad, firms are enabled to pay higher wages and employ more workers, as determined in eq. (4.8) and eq. (4.9). This is consistent with our findings in Section 3 and other papers in the literature. HIMR calls the mechanism derived from Eq. (4.10) and Eq. (4.11) as *selection effect* and the premia implied in eq. (4.8) and eq. (4.9) as *market access*. Amiti and Davis (2012) calls the combination of such effects as *import globalization* and *export globalization*.

4.2 Econometric Model and Estimation

By taking logs and rearranging the terms of eq. (4.8)–(4.11), we obtain the following reduced-form equations from the structural model:

$$\begin{aligned} h_s &= \alpha_{hs} + \mu_{h,xs}\iota_{xs} + \mu_{h,ms}\iota_{ms} + u \\ w_s &= \alpha_{ws} + \mu_{w,xs}\iota_{xs} + \mu_{w,ms}\iota_{ms} + \zeta u + v \\ \iota_{xs} &= \mathbb{1}\{z_x > c_{x,s}\} \\ \iota_{ms} &= \mathbb{1}\{z_m > c_{m,s}\} \end{aligned} \tag{4.12}$$

[18] We assess this correlation using other measures for size and productivity, such as profits, revenues, and value-added. In general, controlling for industry characteristics, those variables are related to a higher number of employees.

where $\mathbb{1}[\cdot]$ denotes an indicator function. $x = (h, w, \iota_x, \iota_m, s)$ is the vector of observable variables: log of employees, firm wages (we use the firm's wage component Ψ estimated in eq. (2.4)), ι_x is an indicator of exporter status, ι_m is an indicator of exporter status, and s is the firm's sector choice. (u,v,z_x,z_m) are the reduced-form shocks, which are linear transformations of the structural shocks $(\theta, \eta, \varepsilon_x, \varepsilon_m)$ defined from the structural eq. (4.8)–(4.11).

$\mu_{h,xs}$ and $\mu_{w,xs}$ are the market access parameters to supplying in the external markets for sector s, and $\mu_{h,ms}$ and $\mu_{w,ms}$ are the market access parameters to external inputs utilization. Those terms capture important characteristics observed in the data: exporter and importer firms are larger and pay higher wages. $c_{x,s}$ and $c_{m,s}$ are the selection effects, which capture the fact that exporting and importing firms are more productive than non-exporters/non-importers. Based on our findings in Section 3, we argue that these terms vary across sectors and are potentially affected by bilateral trade shocks.

We assume that the joint distribution of shocks u, v, z_x, and z_m is common across firms, regardless of their sector. Therefore, their joint distribution drives the overall trends in inequality. In addition, firms' selection into exporting and importing markets drive within-sector inequality, generating employment and wage premia (μ_h and μ_w).[19] Because we include sector heterogeneity, cross-sector wage inequality is determined by the intercept levels of employment and wage levels, α_h and α_w, which capture labor market tightness and competition that affects all firms within a sector.

We impose that the reduced form of the structural shocks is jointly normally distributed:

$$(u, v, z_x, z_m) \sim N(0, \Sigma) \qquad with \qquad \Sigma = \begin{pmatrix} \sigma_u^2 & 0 & \rho_{ux}\sigma_u & \rho_{um}\sigma_u \\ 0 & \sigma_v^2 & \rho_{vx}\sigma_v & \rho_{vm}\sigma_v \\ \rho_{ux}\sigma_u & \rho_{vx}\sigma_v & 1 & \rho_{xm} \\ \rho_{um}\sigma_u & \rho_{vm}\sigma_v & \rho_{xm} & 1 \end{pmatrix}. \tag{4.13}$$

Note that we construct the variance-covariance matrix so that u and v are independent. The variances of z_x and z_m are equal to 1.[20] The error structure in eq. (4.13) implies that the probability

[19] Another possible source of heterogeneity to incorporate is regional differences, which we can derive from the quality of the local labor market where the firm operates.

[20] In HIMR as well as in the Appendix, we show the proofs that imply the structure of the variance-covariance matrix, which makes it more tractable and reduce the number of parameters we estimate.

distribution of x_f given the set of parameters Θ is given by

$$P(x_f|\Theta) = \frac{1}{\sigma_u}\phi(\bar{u}_f)\frac{1}{\sigma_v}\phi(\bar{v}_f)\left[\Phi(\bar{z}_x,\bar{z}_m)\right]^{(1-\iota_{x,f})(1-\iota_{m,f})}\left[\Phi(-\bar{z}_x,\bar{z}_m)\right]^{\iota_{x,f}(1-\iota_{m,f})}$$
$$\left[\Phi(\bar{z}_x,-\bar{z}_m)\right]^{(1-\iota_{x,f})\iota_{m,f}}\left[\Phi(-\bar{z}_x,-\bar{z}_m)\right]^{\iota_{x,f}\iota_{m,f}}, \quad (4.14)$$

where ϕ is the density from a standard normal distribution and Φ is the cumulative distribution of a bivariate standard normal. $(\bar{z}_x, \bar{z}_m)' = \bar{\Sigma}_{xm}^{-1}(c_x - \bar{m}_x, c_m - \bar{m}_m)'$ is the transformed vector of shocks that determine the exporting/importing decisions. $(\bar{m}_x, \bar{m}_m)$ is the vector of means and $\bar{\Sigma}_{xm}$ is the joint variance-covariance matrix of the conditional distribution $\{z_x, z_m|u, v\}$.

Identification of the parameters in Θ relies on some assumptions. As discussed in HIMR, to construct the structural restriction, we reconcile the theoretical and the econometric models given by eq. (4.12) and eq. (4.13). Firstly, the assumptions that unconditional variance of z_x and z_m equal one, which are derived from Eq. (4.10) and Eq. (4.11). Moreover, the assumption that the structural error terms θ and η are unrelated, which implies that u and v are also unrelated, and hence the bounds for the exporting and importing market access $\mu_{w,xs}/\mu_{h,xs}$ and $\mu_{w,ms}/\mu_{h,ms}$ leads to[21]

$$\zeta \;\leq\; \frac{\mu_{w,xs}}{\mu_{h,xs}}, \frac{\mu_{w,ms}}{\mu_{h,ms}} \;\leq\; \frac{\sigma_v^2}{(1+\zeta)\sigma_u^2}, \quad (4.15)$$

$$\mu_{w,xs}, \mu_{h,xs}, \mu_{w,ms}, \mu_{h,ms} \;>\; 0. \quad (4.16)$$

Additionally, we also need a positive definite conditional variance-covariance matrix $\bar{\Sigma}$, and thus invertible. For that, the sufficient condition is that the determinant of $\bar{\Sigma}$ be positive, so

$$(1-\rho_{ux}^2-\rho_{vx}^2)(1-\rho_{um}^2-\rho_{vm}^2)-(\rho_{xm}-\rho_{ux}\rho_{um}-\rho_{um}\rho_{vm})^2 \;>\; 0. \quad (4.17)$$

Given this structure for the probability of the data conditional on parameters, $P(x_f|\Theta)$, we obtain estimates for Θ by solving the constrained maximum likelihood problem:

$$\hat{\Theta} \;=\; argmax_{\Theta} \quad \prod_f P(x_f|\Theta). \quad (4.18)$$

subject to eq. (4.14) and constraints eq. (4.15), eq. (4.16), and eq. (4.17).[22]

[21] We omit the formal derivation of those terms but can provide them upon request. Nonetheless, they do not fundamentally differ from Helpman et al. (2010), Helpman et al. (2017) and their respective online appendices.

[22] An additional constraint is $\rho_{xm} > 0$, which accounts for the abstraction in the implied by the sufficient conditions imposed in Eq. (4.10) and Eq. (4.11), as well as the empirical fact that there is a positive relationship between exporter

5. Results and Counterfactual

5.1 Results and Model Fit

We estimate the Maximum Likelihood model separately for each year between 1997-2012. The observation unit is a firm f in each period t. We expect that the parameters may change over time to reflect the changes in the Brazilian economy in that period. We present more details about the estimated coefficients along with their 95% confidence intervals in the Online Appendix.[23]

We begin by assessing the model's goodness of fit by comparing some statistics derived from the model estimates with the ones derived from the data. We are particularly interested in matching the first and second moments of the distribution of wages and employment, conditional moments on sector choice, and exporter/importer status. It is desirable that the model also approximate trends observed in the data. For simplicity, Table 5 compare the model and data (we use the year 2000 as our benchmark).[24]

Table 5. Model vs. Data: Firm Moments (2000)

	All Firms		Agr./Min.		Low-Tech Manuf.		High-Tech Manuf.	
	Data	Model	Data	Model	Data	Model	Data	Model
Average h	2.75	2.72	2.80	2.80	2.70	2.67	2.98	2.95
Average w	−0.32	−0.33	−0.45	−0.44	−0.39	−0.39	0.11	0.09
SD h	0.99	0.96	1.02	0.93	0.96	0.95	1.11	1.00
SD w	0.48	0.46	0.48	0.43	0.43	0.43	0.49	0.41
Corr(h,w)	0.26	0.23	0.14	0.19	0.24	0.21	0.32	0.25
Corr(x,m)	0.51	0.43	0.42	0.34	0.47	0.38	0.55	0.48
Share of Workers	1.00	1.00	0.09	0.08	0.71	0.76	0.20	0.16
Share of Workers in Exporters	0.30	0.14	0.05	0.03	0.58	0.54	0.41	0.62
Share of Workers in Importers	0.32	0.15	0.04	0.03	0.63	0.59	0.47	0.68

Note: This table compares baseline statistics between the model estimates and the data for 2000.

Overall, the model approximates well most of the observed statistics from the data. For the average log-employment per firm (a) and the average wage per firm (b), our

and importer status. Another way to put it is through the positive relationship between export and import costs drawn from ε_x and ε_m. We do not impose this restriction during estimation but observe their validity after the estimation.

[23] We use robust standard errors (sandwich-form) to construct the confidence intervals. We apply the delta method to obtain the standard errors for the aggregated coefficients.

[24] We present detailed results for the first moments in the Appendix.

model underestimates the statistics from the data by a narrow margin. In contrast, the dispersion of employment and wages (measured by the standard deviation) is slightly overestimated. The upward shift in employment and wages also increases the correlation between them. Nonetheless, although the model does not predict the data with perfection, it accurately represents the trends for the relevant measures.

The difficulty separating market access and selection effects is the main challenge in identifying this type of model. In Table 5, we display the statistics for the share of firms and workers across sectors. Although we can approximate the total share of firms and workers well, the same shares for exporters, importers, and exporter-importer firms underestimate the observed shares in the data by a significant margin. Nonetheless, the observed and simulated size premium and import and export premia are remarkably closer.

Table 6 displays wage statistics for the year 2000 using firm size as weight.[25] Our model also performs well in replicating the observed aggregated measures of dispersion. The model predictions for the overall and within-sector variance are slightly underestimated. Looking at the percentiles, the model does not seem to match precisely the top of the distribution, whereas the predictions for the bottom are closer to the data. These patterns suggest that the generated data tend to be more concentrated around the median wage than the observed data. Nonetheless, as for the other measures of centrality and dispersion, the trends over time are well represented.[26]

Table 6. Model vs. Data: Worker Moments (2000)

	All Firms		Agr./Min.		Low-Tech Manuf.		High-Tech Manuf.	
	Data	Model	Data	Model	Data	Model	Data	Model
Mean w	–0.12	–0.18	–0.33	–0.35	–0.21	–0.26	0.34	0.27
Var w	0.28	0.25	0.28	0.20	0.23	0.21	0.22	0.21
Perc. 90	0.66	0.48	0.44	0.22	0.44	0.33	0.94	0.86
Perc. 50	–0.15	–0.19	–0.39	–0.35	–0.24	–0.27	0.37	0.27
Perc. 10	–0.81	–0.82	–0.97	–0.92	–0.83	–0.85	–0.30	–0.32

Note: This table compares baseline statistics between the model estimates and the data for 2000.

[25] We assume that firms pay the same wage for each worker. In other words, we calculate the aggregated statistics by weighting observations with the number of employees in the firm. In the Appendix, we derive and estimate a simple model where workers may have different wages within a firm. The overall conclusions are unchanged.

[26] More details in the Appendix.

5.2 Counterfactual Analysis

In this section, we use the estimated model to perform counterfactual analyses. This paper is interested in assessing the impact of the China shock, both import and export exposure, on the between-firm wage dispersion. Thus, we propose two scenarios to separate the effects of each side of the trade integration with China.

1. *Import Shock Only:* the partial effect of import exposure. Imports change between 2000 and 2008, whereas exports remain at the levels of 2000.

2. *Export Shock Only:* the partial effect of export exposure. Exports change between 2000 and 2008, whereas imports remain at the levels of 2000.

Our benchmark economy is based on the estimated parameters using data for 2000, right before China joined as a member of the WTO. Thus, changes in the economic environment driven by China will be measured relative to the simulated economy in 2000.

The changes from import and export exposure affect the demand/supply shifters presented in Section 4: $A_{d,s}$, $A_{x,s}$, and $A_{m,s}$, where s indexes sector. The first term, $A_{d,s}$, incorporates the competition relationship between domestic and external markets for the firm's output. The export and import shocks impact $A_{d,s}$ through downstream and direct exposure. On the one hand, import competition increases $A_{d,s}$ because of the rise in competition with Chinese products, which leads to a decrease in wages and employment. These assumptions are supported by our reduced form results and several papers in the literature investigating import competition shocks (Autor et al., 2013, 2014; Bloom et al., 2016, 2019; Costa et al., 2016). On the other hand, the $A_{d,s}$ decreases due to direct and downstream export exposure, which induces higher demand for firms' output, leading to an increase in wages and employment.[27]

The term $A_{x,s}$ affects the export shifter $Y_{x,s}$, which increases the firm's wage and size through $\mu_{wx,s}$ and $\mu_{hx,s}$ (market access) and decreases the fixed export cost $c_{x,s}$, implying a higher probability of a firm to become an exporter (selection) given its productivity draws. The term A_m affects the import shifter $Y_{,s}$, impacting firms through two channels. First, through an increase in the import premium $\mu_{hm,s}$ and $\mu_{wm,s}$ (market access). Second, a fall in the fixed importing cost

[27] Costa et al. (2016) and Feenstra et al. (2019) are examples of studies that show this relationship. In the discussion on the impact of trade opening on models derived from Melitz (2003), it is common for authors to consider potential impacts on fixed costs for firms to enter into the domestic market (or the productivity cutoff for firms to produce), even though it is not necessarily related to trade. In those models, trade opening increases the production cutoff, displacing unproductive firms out of the market.

c_m reduces the productivity threshold for firms to import and raises the probability of importing, given its productivity draws. For simulations, we draw 10 million observations, each representing a firm, selected with a random shock from the distribution of (u, v, z_x, z_m) in eq. (4.13).

The first step of our counterfactual strategy is similar to Caliendo et al. (2019):[28] we calibrate the changes in parameters $A_{d,s}$, $A_{x,s}$, and $A_{m,s}$ that replicate our reduced-form findings. For each sector, we set a range from 0 to 100 for percentage changes in $\alpha_{h,s}$, $\alpha_{w,s}$, $\mu_{x,s}$ and $\mu_{m,s}$, from which we can obtain changes in $c_{x,s}$ and $c_{m,s}$. Because we only match the changes in the average wages, we restrict the relative variation on α and μ proportionally to the relative downstream and upstream exposure.

Downstream import exposure decreases α_h and α_w. Upstream import exposure increases μ_m and decreases c_m. Downstream export exposure increases α_h, α_w, and μ_x, and decreases c_x. Across sectors, those changes in the parameters are proportional to their level of import or export exposure relative to the Agriculture/Mining sector, which we consider as benchmark.[29] In each interaction over percentage changes in the range 0-100, we recover the change in the model's predictions for average wages for each sector relative to their benchmark value. We compare these values with the point estimates of average wages predicted by the reduced form on Figure 3. We select the percentage variation in the parameters that minimize the average squared difference between these statistics, weighted by the number of employees in each sector in 2000.

To obtain the updated values for c_x and c_m, we use the structural equations in the model, as proposed in HIMR. Based on the values for μ_x and μ_m, we can obtain A_x and A_m as

$$A_x = \left[\exp(\mu_{hx} + \mu_{wx})^{-\frac{\Gamma}{1-\beta}} - 1\right] \tau_x^{\frac{\beta}{1-\beta}} \tag{5.1}$$

and

$$A_m = \left[\exp(\mu_{hm} + \mu_{wm})^{-\frac{\epsilon\Gamma}{\beta}} - 1\right] \tau_m^{\frac{\epsilon}{1-\epsilon}}. \tag{5.2}$$

[28]Caliendo et al. (2019) using the average changes in manufacturing wages found in Autor et al. (2013) to obtain the respective changes in the productivity parameters that imply the same change in the average wage predicted in their model. Then, they use that variation in productivity to conduct their counterfactual analysis.

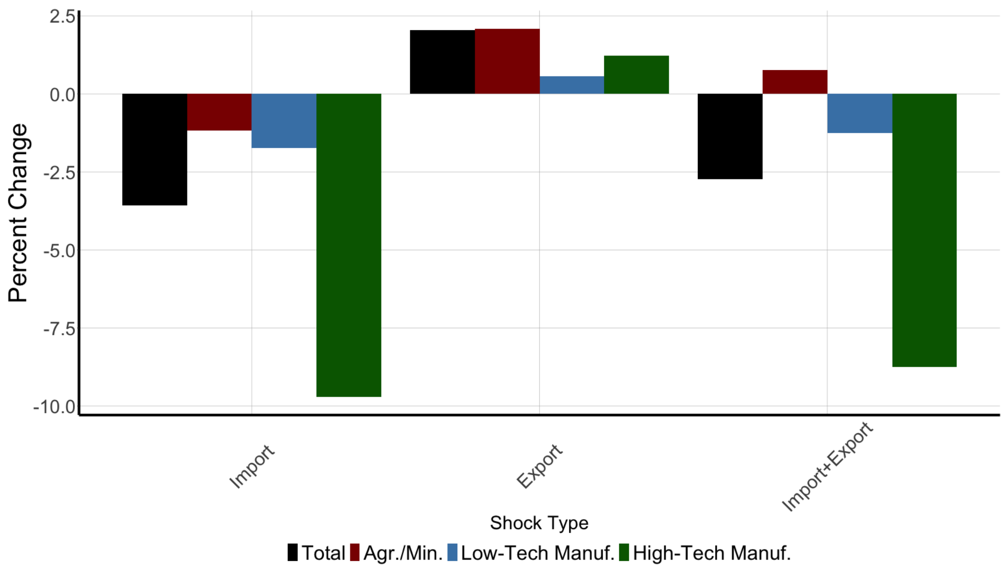
[29]For example, a one percent decrease in α_w for the Agriculture/Mining sector due to import exposure represents a $I\bar{P}W_{High-Tech}/I\bar{P}W_{Agr./Min.}$ percent decrease in α_w for the High-Tech Manufacturing sector, where $I\bar{P}W_s$ is the average import exposure for sector s. Because we showed that $I\bar{P}W_{High-Tech} > I\bar{P}W_{Agr./Min.}$, since the High-Tech manufacturing sector has higher import exposure, that decrease in $\alpha_w^{High-Tech}$ is greater than the decrease in $\alpha_w^{Agr./Min.}$. We proceed similarly with all parameters.

Next, we pin down the values for becoming an exporter and importer, c_{xs} an c_{ms}. The Online Appendix presents more details and shows that changes in c_{js} due to the China shock impact not only via Y_j as in HIMR, but also via α_π and $\log(C_{js})$. We assume that changes in the latter terms are proportional, so we can calibrate the parameters to approximate the results found in the reduced-form analysis in Section 3. In the Appendix, we summarize the changes in the parameters for each sector and type of shock. For the remaining parameters in the model, we use the values from HIMR.

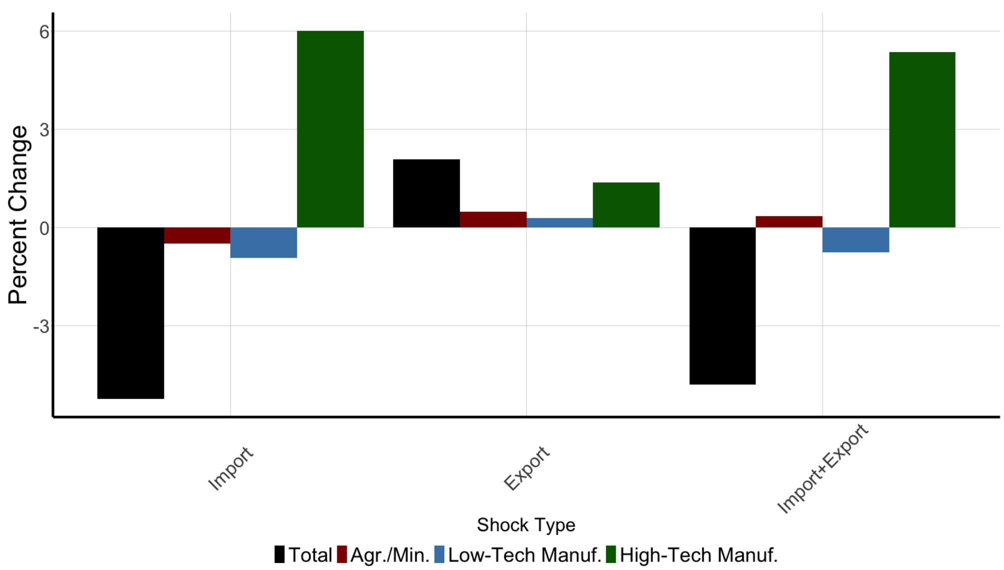
Figure 4 presents the main results on the impact of the China shock. Figure 4.A shows that import exposure reduces the average wages substantially, especially for the High-Tech manufacturing industries. In contrast, export exposure has a positive effect on the average wages. For Agriculture and Mining industries, the effect of export exposure is higher, leading to an overall net increase in wages. For manufacturing sectors, the positive impact of export exposure does not compensate for the negative import exposure, leading to a net negative impact. Overall, the China shock decreases the average (nominal) wages for the whole economy by around 3 percent.

Nonetheless, as Figure 4.B presents, the higher import exposure is associated with lower wage variance for all sectors, except high-tech manufacturing. For the High-Tech Manufacturing sector, wage variances increase by about 6 percent due to the import exposure. In contrast, export exposure is associated with higher wage inequality across all sectors. For the Agriculture and Mining sector, the effect of export exposure is higher, leading to an overall net increase in wage variance. For low-tech manufacturing, the import shock is higher, causing a net decrease in wage inequality in the sector. For the high-tech manufacturing sector, both shocks contribute to an increase in wage inequality. Overall, the China shock decreased the wage variance for the whole economy by around 5 percent.

Previous studies focusing on the impact of trade liberalization on between-firm wage inequality have found that different episodes of trade liberalization increased wage inequality within the manufacturing sector (Coşar et al., 2016; Helpman et al., 2017). Our results in Figure 4.B indicate a similar pattern for the high-tech manufacturing sector, showing an increase in wage variance within the sector in response to higher trade exposure. However, we show that by expanding the analysis to account for multi-sector heterogeneity in trade exposure and firm selection into international markets, trade integration can generate a net decrease in overall wage inequality. This finding underscores the importance of incorporating these features in studies examining the impacts of globalization on inequality.



(A) Average Wages



(B) Wage Variance

Figure 4. Impact of the China Shock on Average Wages and Wage Variance Panel (A) displays the changes in average wage and Panel (B) the wage variance across sectors and for the whole economy relative to the model's predictions in 2000. The horizontal axis displays the shock type: "Import" refers to import exposure only. "Export" refers to export exposure only. "Import+Export" refers to both import and export exposure.

Our study builds on previous research examining the impact of trade shocks on labor markets, mainly focusing on the China shock. While existing studies have primarily focused on the one-sided import penetration effects on labor market outcomes (Autor et al., 2013, 2014, 2016), Figure 4 shows that extending the analysis to include both import and export exposures allows for a more balanced approach in assessing the overall net effect of the China shock on its trade partners.

5.3 China Shock and Trade Opening

Inspired by Dix-Carneiro et al. (2021), we conduct another counterfactual analysis by examining the impact of the China shock in the event of tariff reductions on labor market outcomes. The Brazilian economy went through a rapid trade opening between 1990 and 1994. During that period, industries faced a unilateral fall in importing tariffs. The average tariff fell from 30.5% to 12.8% (Dix-Carneiro and Kovak, 2017, 2019). This generates an interesting natural experiment that the international trade literature has extensively exploited.[30]

The impact of the China shock on the Brazilian labor market could be amplified by another change in importing tariffs. So a question we pose here is: if Brazil implemented an additional round of tariff reduction, what would be the impact of the China shock on the Brazilian economy? On the one hand, a decrease in importing tariffs increases the competition with imported products, leading to a fall in wages and employment in higher exposed sectors. This happens through a decrease in A_{ds}, and then α_{ws} and α_{hw}, which affects all firms. On the other hand, a decrease in importing tariffs increases market access ($\mu_{wm,s}$ and $\mu_{hm,s}$) and selection into import (c_{sm}) and export (c_{sx}) implying an increase in the share of workers in importing and exporter firms. The overall impact on average wages is ambiguous, depending on which effect is stronger. However, we can expect that: i) sectors facing higher competition may decrease in size (measured by the number of employees); and that ii) within sectors, larger differences between importers and non-importers (or exporter and non-exporters), which will increase within-sector wage dispersion.[31]

[30]Despite the substantial decrease in tariffs, it is arguable that the Brazilian economy is still considerably closed. According to the World Bank, the total volume of trade in Brazil as a share of GDP during the 1980s and 1990s ranged between 14.9% and 21.5%. By 2012, the share was 25.11%. These numbers illustrate that the share of trade in the Brazilian GDP is relatively modest compared to other similar countries. For instance, the total trade over GDP for middle-income countries grew from 27.5% in 1980 to 50% in 2000. In contrast, high-income countries experienced a growth in trade over GDP between 38.5% and 46.9% during the same period. Furthermore, in 2000, the average tariffs in the bilateral trade Brazil-China were around 15% and remained between 10% and 15% until 2012.

[31]That may happen for a low reduction in tariffs, which pushes firms into the exporting markets. For higher reductions, which implies low tariffs, most firms will select into imports, which drives wage dispersion down.

Under our theoretical framework, the predominant effect depends on the relative elasticities of substitution between domestic and imported goods, also commonly referred to as Armington's elasticity or National Product Differentiation (Das and Sant'Anna, 2023), determined by ϵ (see Section 4), and between domestic varieties within the composite domestic good, which is determined by β (see Section 4). HIMR does not include the former and assumes a value for $\beta = 3/4$, which gives an elasticity of substitution among domestic varieties of 4. Feenstra et al. (2018) estimates both the Armington's elasticity substitution (which they name macro elasticity) and the elasticity of substitution between domestic varieties (which they call micro elasticity). The estimates suggest a significant heterogeneity across products, with many showing no statistical difference. However, the findings support the claim that the macro elasticity is smaller than (or at the most equal to) the micro elasticity. On average, the macro elasticity is about half the size of the micro elasticity. Hence, we use $\epsilon = 1/2$, which implies an elasticity of substitution between domestic and imported varieties of 2.[32]

To study the effect of the China shock under different tariff regimes, we simulate the model separately for each reduction level. Based on Dix-Carneiro et al. (2021), we consider import tariff reductions of 5%, 10%, 20%, and 40% relative to our benchmark level in 2000. We then simulate the model using the same changes on $A_{d,s}$, $A_{x,s}$, and $A_{m,s}$ calibrated for the China shocks as well as the implied changes on $Y_{x,s}$, $Y_{m,s}$, $c_{x,s}$, and $c_{m,s}$ from the combination between the China shock and the reduction on import tariffs (τ_m). The main results are presented on Figure 5 (average and variance of wages) and Figure 6 (share of workers in exporter and importer firms).

In the figures, "Benchmark" (normalized to 0) are the model predictions for the year 2000. The Figures consider both import and export shocks from Brazil-China trade. The remaining terms refer to the China Shock associated with changes in tariffs by 0% (i.e., the China shock as we showed in the previous section) 5%, 10%, 20%, and 40%. Average wages and variance are weighted by the firm's number of employees. As argued in HIMR and the theoretical model presented in Section 4, it is implicitly assumed that each worker within a firm receives the same wage.

Panel (A) of Figure 5 displays the changes in average wages, both total (solid line) and for each sector (dashed lines). As expected, changes in trade exposure are followed by a fall in the overall average wages, especially for the high-exposed High-Tech Manufacturing sector and to a less intensity the Low-Tech Manufacturing sector. The Agriculture and Mining sector, on

[32] We also test scenarios where $\epsilon = 1/4$ and $\epsilon = 3/4$, which leads to elasticities of substitution equal to 1.33 and 4, respectively. Finally, we summarize the comparison between elasticities in the Appendix. The results remain qualitatively the same across different choices for the elasticity.

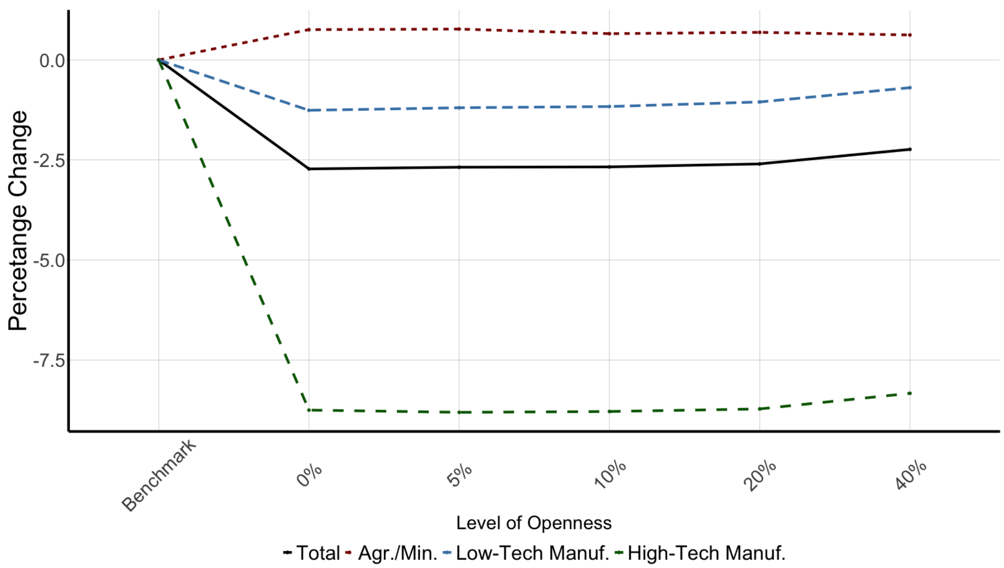
the other hand, disproportionately exposed to the export shock, faced a slightly increase in the average wages. With higher levels of openness, the effects on the average wage by sector remain unchanged. Figure 5 Panel (B) depicts the total changes in the overall wage variance (solid line) and the wage variance within-sectors (dashed lines). Note that the China shock alone leads to a decrease of almost 5 percent in the overall wage variance. However, our results suggest that trade openness reduces the magnitude (in absolute terms) of the decline in wage variance. For instance, in the scenario of a 40% tariff reduction, the wage variance would have decreased by a little over 2.5%. This happens because of the within-sector effect of wage trade openness plus the China shock on wage variance.

Figure 6 and Figure 7 illustrate the mechanisms explaining these results. Figure 6.A shows that the share of workers in High-Tech Manufacturing decreases by about 0.7 percentage points following the effects of the China shock and the Agriculture/Mining sector absorbs most of those workers. The openness level has no additional impact on cross-sector employment level, in line with Figure 5.A.

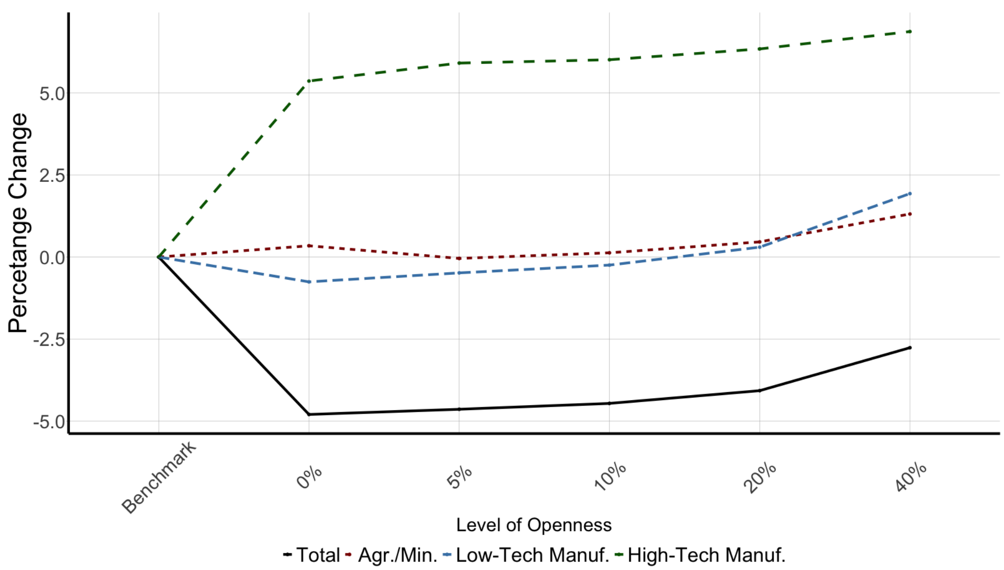
When we focus on the participation of the exporting and importing firms, Figure 6.B and Figure 6.C show that the reduction in import tariffs has a stronger effect in inducing firms into importing and exporting, leading to an increase in the share of workers in importer and exporter firms for all sectors, but especially for High-Tech Manufacturing.[33] Also, the combination of the China shock and import tariff reduction largely increased the import premium, as shown in Figure 7. These effects lead to the positive association between trade openness and the increase in wage inequality observed in Figure 5 Panel (B).

As we have shown previously, the High-Tech manufacturing sector is the main loser from import exposure to China, but tariff reductions favor the most productive firms in that sector, allowing them to enter the export and import markets and increase their market share (as measured by the share of workers). Similar to the results in Dix-Carneiro et al. (2021), we find that under a high openness level (about 40% reduction in tariffs), the share of workers in High-Tech manufacturing exporter firms increases by 5 percentage points, and importer firms increase by 8 percent.

[33]Note that despite we only simulate a reduction in importing tariffs, firms also become exporters due to an implicit correlation between importer and exporter selection costs. In the Appendix, we also explore the inclusion of an even more explicit correlation between the selection effects. Particularly, that will make the effects slightly stronger by making more firms select to become exporters following the trade opening.

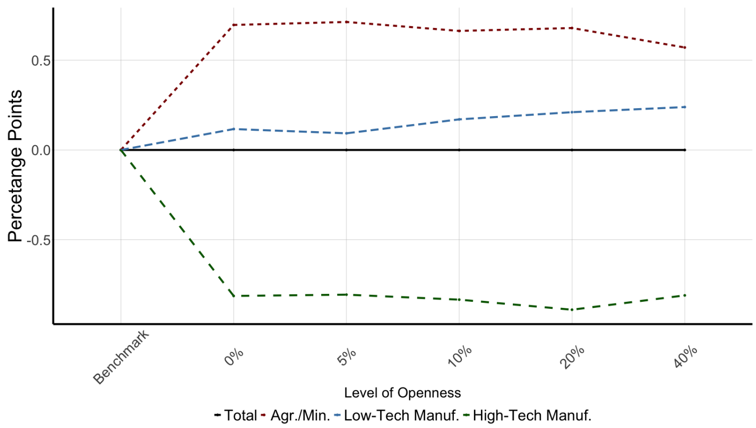


(A) Average Wage

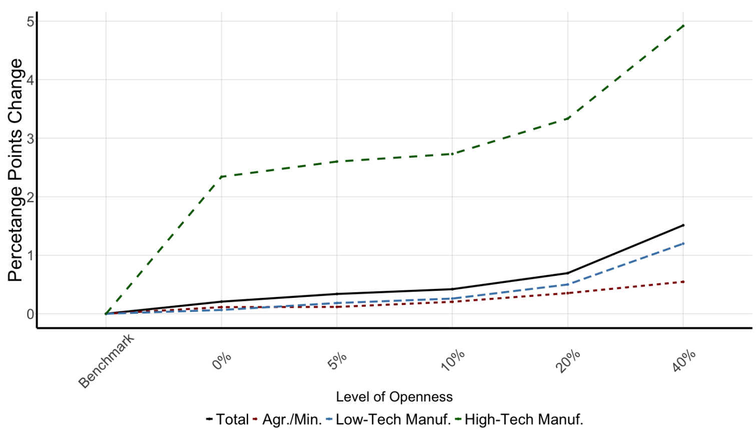


(B) Wage Variance

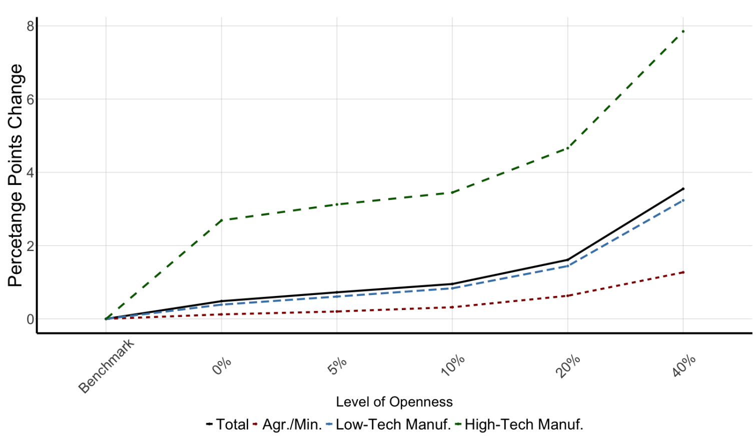
Figure 5. Impact of Trade Exposure and Openness on Wages. The figures compare the average wages (Panel A) and wage variance (Panel B) for different exposures to trade shocks and levels of openness. The horizontal axis displays levels of openness: "Benchmark" are the model predictions in 2000 (normalized to 1); "0%" are the model predictions under Import+Export exposure and no change in tariffs; the remaining terms refer to predictions that combine both Import+Export exposure and assumptions on tariff reduction: 5%, 10%, 20%, and 40%.



(A) Share of Workers per Sector



(B) Share of Workers in Exporter Firms



(C) Share of Workers in Importer Firms

Figure 6. Impact of Trade Exposure and Openness on the Share of Workers in Exporter and Importer Firms. The figures compare the changes in the share of workers in exporter firms (Panel A) and importer firms (Panel B) firms for different exposure to trade shocks and levels of openness. The horizontal axis displays levels of openness: "Benchmark" are the model predictions in 2000 (normalized to 1); "0%" are the model predictions under Import+Export exposure and no change in tariffs; the remaining terms refer to predictions that combine both Import+Export exposure and assumptions on tariff reduction: 5%, 10%, 20%, and 40%.

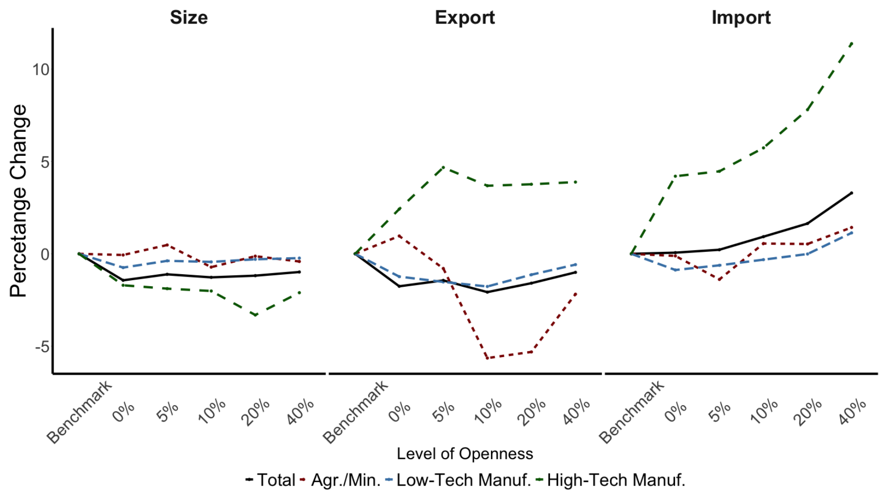


Figure 7. Impact of Trade Exposure and Openness on Size, Export and Import Premia. The figures compare the change on size, export, and import premia. The horizontal axis displays levels of openness: "Benchmark" are the model predictions in 2000 (normalized to 1); "0%" are the model predictions under Import+Export exposure and no change in tariffs; the remaining terms refer to predictions that combine both Import+Export exposure and assumptions on tariff reduction: 5%, 10%, 20%, and 40%.

6. Conclusion

This paper provides empirical evidence of the China shock's role in the observed fall of wage inequality in Brazil in the 2000s. Unlike the literature in this field, which focuses on the impact of import competition on manufacturing industries, we focus on the two-sided effect of China on the Brazilian economy by adding export exposure and the indirect effects due to input-output linkages.

We gather facts to understand how bilateral trade integration, such as the China shock, may affect wage dispersion. First, we decompose the log hourly wage into a firm wage component, labor force composition, and the residual wage. The decomposition results show that the between-firm term accounts for two-thirds of the wage variance.

Additionally, we use an instrumental variable approach to estimate the effect of the China shock on employment and wages. Our findings suggest that downstream import exposure decreases employment and wages, whereas downstream export exposure increases wages. Nonetheless, upstream import exposure is related to higher wages and higher probabilities of importing. Firms also respond positively to downstream export shocks by entering the export markets. Hence, firms may also benefit from a rise in trade integration through better importing and exporting conditions.

To address these facts, we adapted the model proposed by Helpman et al. (2010) and Helpman et al. (2017) to a multi-sector setting with selection into exporting and importing markets through two terms. First, sector heterogeneity means that firms in distinct sectors will have different responses to trade shocks in terms of wages and employment. Second, selection into importing and exporting enables firms to increase revenues (and thus employment and wages) by entering the import and export markets to respond to trade shocks.

We use the model to study the effects of two counterfactual scenarios when shocks occur only in imports or only in exports. We also experiment with these scenarios under different importing tariff regimes. In the model, we have an ambiguous effect of import exposure and import tariffs. While import exposure has adverse labor market effects of increasing competition, it also has the positive effect of enabling firms to access imported inputs. Our results suggest that the China shock had an overall negative impact on average wages and is associated with a 5 percent decrease in wage inequality between 2000 and 2008. Moreover, under some conditions in the model's elasticities, tariff reduction may attenuate the harmful effects of import exposure on average wages.

This work contributes to the literature by measuring the impact of the China shock in Brazil, a developing country. We highlight the potential gains from trade, even under negative demand shocks, with significant policy implications for removing trade barriers. Despite our contributions to bilateral trade integration and trade liberalization in developing countries, this paper abstracts away from many important questions and labor market mechanisms. For instance, our model does not address: i) welfare gains from trade due to higher trade and lower relative prices; ii) changes in the sectoral (and aggregated) productivity; iii) the relationship between formal and informal labor markets.

Nonetheless, we acknowledge several possible extensions to our analysis. A straightforward possibility is to add regional heterogeneity. In this sense, our work could be compared to Autor et al. (2013) and Dix-Carneiro and Kovak (2017), who study the trade shock consequences on local labor markets. This extension would not require significant modifications to the model. However, the biggest challenge is the increased number of estimated parameters, which could impair their identification.

We also point to several potential extensions for the model to encompass the recent concerns in the literature about the impact of international trade. First, one could extend the model to include the welfare impacts of trade shocks and tariff reduction. One possibility is to use a general equilibrium model. One may also add within-firm heterogeneity. A straightforward, exogenous way would be to assume different bargaining power for high- and low-skilled workers. In this sense, trade shocks could disproportionately affect different types of workers, which could address the changes in the skilled/unskilled composition of the labor force.

Following Coşar et al. (2016), one could include firm dynamics and the firm's entry or exit decision. Helpman et al. (2017) partially addresses the first, showing that their results would be similar. However, Helpman et al. (2017) is based on Melitz (2003) and requires additional assumptions over the error structure in our econometric estimation.

Finally, Dix-Carneiro and Kovak (2019) documents a significant displacement of workers to the informal sector after the Brazilian trade opening in 1990-1994. Dix-Carneiro et al. (2021) calibrate a model similar to Coşar et al. (2016) that that includes the informal sector. They find that the informal sector acts as a buffer for welfare losses from trade. Furthermore, they argue that stricter enforcement of regulations against informality decreases welfare loss.

References

Abowd, J. M., F. Kramarz, and D. N. Margolis (1999): "High Wage Workers and High Wage Firms," *Econometrica*, 67, 251–333.

Acemoglu, D., D. Autor, D. Dorn, G. H. Hanson, and B. Price (2016): "Import competition and the great US employment sag of the 2000s," *Journal of Labor Economics*, 34, S141–S198.

Adão, R. (2016): "Worker Heterogeneity, Wage Inequality, and International Trade: Theory and Evidence from Brazil," *Working Paper*.

Adao, R., P. Carrillo, A. Costinot, D. Donaldson, and D. Pomeranz (2022): "Imports, exports, and earnings inequality: Measures of exposure and estimates of incidence," *The Quarterly Journal of Economics*, 137, 1553–1614.

Alvarez, J., F. Benguria, N. Engbom, and C. Moser (2018): "Firms and the decline in earnings inequality in Brazil," *American Economic Journal: Macroeconomics*, 10, 149–89.

Amiti, M. and D. R. Davis (2012): "Trade, Firms, and Wages: Theory and Evidence," *Review of Economic Studies*, 79, 1–36.

Autor, D., D. Dorn, and G. Hanson (2016): "The China Shock: Learning from Labor-Market Adjustment to Large Changes in Trade," *Annual Review of Economics*, 8, 205–240.

Autor, D. H., D. Dorn, and G. H. Hanson (2013): "The China syndrome: Local labor market effects of import competition in the United States," *American Economic Review*, 103, 2121–68.

Autor, D. H., D. Dorn, G. H. Hanson, and J. Song (2014): "Trade adjustment: Worker-level evidence," *The Quarterly Journal of Economics*, 129, 1799–1860.

Bloom, N., M. Draca, and J. Van Reene (2016): "Trade Induced Technical Change? The Impact of Chinese Imports on Innovation, IT and Productivity," *The Review of Economic Studies*, 83, 87–117.

Bloom, N., A. Kurmann, K. Handley, and P. Luck (2019): "The Impact of Chinese Trade on U.S. Employment: The Good, The Bad, and The Apocryphal," 2019 Meeting Papers 1433, Society for Economic Dynamics.

Burdett, K. and D. T. Mortensen (1998): "Wage Differentials, Employer Size, and Unemployment," *International Economic Review*, 39, 257–273.

Bustos, P., B. Caprettini, and J. Ponticelli (2016): "Agricultural Productivity and Structural Transformation: Evidence from Brazil," *American Economic Review*, 106, 1320–65.

Caliendo, L., M. Dvorkin, and F. Parro (2019): "Trade and Labor Market Dynamics: General Equilibrium Analysis of the China Trade Shock," *Econometrica*, 87, 741–835.

Card, D., A. R. Cardoso, J. Heining, and P. Kline (2018): "Firms and labor market inequality: Evidence and some theory," *Journal of Labor Economics*, 36, S13–S70.

Costa, F., J. Garred, and J. P. Pessoa (2016): "Winners and losers from a commodities-for-manufactures trade boom," *Journal of International Economics*, 102, 50–69.

Coşar, A. K., N. Guner, and J. Tybout (2016): "Firm Dynamics, Job Turnover, and Wage Distributions in an Open Economy," *American Economic Review*, 106, 625–63.

Cravino, J. and S. Sotelo (2019): "Trade-Induced Structural Change and the Skill Premium," *American Economic Journal: Macroeconomics*, 11, 289–326.

Das, S. P. and V. P. Sant'Anna (2023): "Determinants of bilateral trade in manufacturing and services: A unified approach," *Economic Modelling*, 123, 106246.

Dhyne, E., A. K. Kikkawa, M. Mogstad, and F. Tintelnot (2021): "Trade and domestic production networks," *The Review of Economic Studies*, 88, 643–668.

Dix-Carneiro, R. (2014): "Trade Liberalization and Labor Market Dynamics," *Econometrica*, 82, 825–885.

Dix-Carneiro, R., P. Goldberg, C. Meghir, and G. Ulyssea (2021): "Trade and Informality in the Presence of Labor Market Frictions and Regulations," *NBER Working Paper n.28391*.

Dix-Carneiro, R. and B. K. Kovak (2017): "Trade liberalization and regional dynamics," *American Economic Review*, 107, 2908–46.

——— (2019): "Margins of labor market adjustment to trade," *Journal of International Economics*, 117, 125–142.

Engbom, N. and C. Moser (2022): "Earnings inequality and the minimum wage: Evidence from Brazil," *American Economic Review*, 112, 3803–47.

Feenstra, R. C., P. Luck, M. Obstfeld, and K. N. Russ (2018): "In Search of the Armington Elasticity," *The Review of Economics and Statistics*, 100, 135–150.

Feenstra, R. C., H. Ma, and Y. Xu (2019): "US exports and employment," *Journal of International Economics*, 120, 46–58.

Felix, M. (2021): "Trade, labor market concentration, and wages," *Working Paper, MIT*.

Ferreira, F. H., S. P. Firpo, and J. Messina (2021): "Labor Market Experience and Falling Earnings Inequality in Brazil: 1995–2012," *World Bank Economic Review*.

Ferreira, F. H. G., S. Firpo, and J. Messina (2017): "Ageing Poorly? Accounting for the Decline in Earnings Inequality in Brazil, 1995-2012," IZA Discussion Papers 10656, Institute of Labor Economics (IZA).

Galle, S., A. Rodríguez-Clare, and M. Yi (2023): "Slicing the pie: Quantifying the aggregate and distributional effects of trade," *The Review of Economic Studies*, 90, 331–375.

Guilhoto, J. and U. Sesso-Filho (2005): "Estimação da Matriz Insumo-Produto a Partir de Dados Preliminares das Contas Nacionais," *Economia & Tecnologia*, 9, 277–299.

——— (2010): "Estimação da Matriz Insumo-Produto Utilizando Dados Preliminares das Contas Nacionais: Aplicação e Análise de Indicadores Econômicos para o Brasil em 2005," *Economia & Tecnologia*, 23.

Heckman, J. J. (1979): "Sample Selection Bias as a Specification Error," *Econometrica*, 47, 153–161.

Helpman, E., O. Itskhoki, M.-A. Muendler, and S. J. Redding (2017): "Trade and inequality: From theory to estimation," *The Review of Economic Studies*, 84, 357–405.

Helpman, E., O. Itskhoki, and S. Redding (2010): "Inequality and unemployment in a global economy," *Econometrica*, 78, 1239–1283.

Huneeus, F. (2018): "Production Network Dynamics and the Propagation of Shocks," *Working Paper*.

Melitz, M. J. (2003): "The impact of trade on intra-industry reallocations and aggregate industry productivity," *Econometrica*, 71, 1695–1725.

Messina, J. and J. Silva (2017): *Wage Inequality in Latin America: Understanding the Past to Prepare for the Future*, The World Bank.

Muendler, M.-A. (2017): "Trade, technology, and prosperity: An account of evidence from a labor-market perspective," Tech. rep., WTO Staff Working Paper.

Nopo, H. (2012): *New Century, Old Disparities: Gender and Ethnic Earnings Gaps in Latin America and the Caribbean*, The World Bank.

Olley, G. S. and A. Pakes (1996): "The Dynamics of Productivity in the Telecommunications Equipment Industry," *Econometrica*, 64, 1263–1297.

Pessoa, J. P. and F. Costa (2019): "Winners and Losers from China's Ascension in International Trade: a Structural Approach," *Brazilian Review of Econometrics*, 39, 185–216.

Pierce, J. R. and P. K. Schott (2016): "The surprisingly swift decline of US manufacturing employment," *American Economic Review*, 106, 1632–62.

Rodrik, D. (2013): "Unconditional Convergence in Manufacturing," *The Quarterly Journal of Economics*, 128, 165–204.

Stolper, W. F. and P. A. Samuelson (1941): "Protection and real wages," *The Review of Economic Studies*, 9, 58–73.

United Nations (2018): "UN Commodity Trade Statistics Database, Statistics Division, United Nations," *http://comtrade.un.org/*.