Globalization and Top Income Shares*

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Abstract

This paper documents empirically that access to global markets is associated with a higher executive-to-worker pay ratio within the firm. It then uses China's 2001 accession to the World Trade Organization as a trade shock to show that firms that exported to China prior to 2001 subsequently exported more, grew larger, and grew more unequal in terms of executive-to-worker pay. To analytically and quantitatively evaluate the impacts of globalization on top income inequality, this paper builds a model with heterogeneous firms, occupational choice, and executive compensation. In the model, executive compensation grows with the size of the firm, while the wage paid to ordinary workers is determined in a country-wide labor market. As a result, the extra profits earned in the foreign markets benefit the executives more than the average workers. We calibrate the model to the U.S. economy and match the income distribution closely in the data. Counterfactual exercises suggest that trade and FDI liberalizations can explain around 52 percent of the surge in top 0.1 percent income shares in the data between 1988 and 2008.

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1 Introduction

The real income of the top 0.1 percent of the population increased by 85.8 percent between 1993 and 2011 in the United States; the real income of the bottom 99 percent increased by only 5.8 percent over the same period.[1] At the same time, the past several decades witnessed the fastest pace of globalization since the start of the First World War. The existing literature does not provide a clear link between globalization and the runaway top income shares. Researchers working on the distributional effects of trade usually focus on wage inequality and especially on the "skill premium," the wage difference between skilled and unskilled workers.[2] However, the income of the top 0.1 percent—which usually consists of executive compensation, business profits, and capital gains—cannot be easily explained using the "skill premium."[3]

Complementing the literature on the skill premium, this paper examines how globalization shapes the income gap between the very rich and the rest of the population. We first document a novel empirical pattern: income gaps between the top executives and the average workers are higher among exporting firms than among non-exporting firms in the United States. We then provide causal evidence on this relationship using China's accession to the World Trade Organization (WTO) as a trade shock: firms that benefit from lower trade barriers export more, grow larger, and grow more unequal. Motivated by the empirical findings, we develop a new model that incorporates occupational choice and executive compensation into a heterogeneous firms model of trade. The model reproduces the empirical patterns we documented at the firm level and generates income and firm size distributions that closely resemble the aggregate U.S. data. We then perform a quantitative assessment of the impacts of globalization on the CEO-to-worker pay ratio within a firm and on the top income shares within the country as a whole. The counterfactual simulation suggests that globalization can explain up to 52 percent of the surge in top 0.1 percent income shares in the U.S. between 1988 and 2008.

To establish a link between globalization and the income gap between the very rich and the rest, we create a new dataset that matches executive compensation to confidential U.S. Census micro data on payroll and international transactions. The resulting dataset focuses on publicly-listed firms and provides detailed information on executive compensation, employment, payroll, and export sales.[4] We focus on the top executives because they

[1] Piketty and Saez (2003), with data updated to 2011.

[2] Among many others, see Goldberg and Pavcnik (2007), Helpman et al. (2010), and Burstein and Vogel (2012).

[3] For example, numerous studies have shown that education level, a widely used measure of skill, has no clear correlation with CEO compensation (Belliveau et al., 1996; Geletkanycz et al., 2001) .

[4] Appendixes A and B.1 construct the data and repeat the analysis for a limited set of privately-held firms.

constitute a large fraction of the top earners. Around 40 percent of the top 0.1 percent income earners in the U.S. are professional executives, and these 0.04 percent earners are responsible for about 4 percent of the national income (Bakija et al., 2012). To our knowledge, this is the first dataset assembled that can be used to study the relationship between international trade and the CEO-to-worker pay ratio.

With this new dataset, we document that globalization disproportionately benefits the top executives relative to the workers within the same firm. Specifically, the gap in compensation between the CEO and the average worker in the firm—the CEO-to-worker pay ratio—is 50 percent larger for exporting firms compared to domestic firms. This globalization premium for the CEO-to-worker pay ratio holds for manufacturing and non-manufacturing firms, for multinationals as well as exporters, for private as well as public firms, for comparisons across firms, and for comparisons within firms as they transition to exporting. As in the simplest Melitz (2003) model of trade, the impact of globalization is intermediated through firm size. We show that accounting for the firm-size channel is sufficient to explain the differential in CEO-to-worker pay ratios between exporters and non-exporters. One can imagine other channels — CEO skill premium for exporting or compensation for higher risk — that would increase the exporting CEO premium over and above what is implied by size. We do not find evidence of a meaningful premium in excess of that explained by size. Hence, our quantitative assessment focuses on the size channel.

We use China's 2001 accession to the WTO to provide direct evidence from a trade shock to firm exports, firm size, and CEO-to-worker pay ratios. Following its accession to the WTO, China gradually lowered import tariffs from an average of 15 percent in 2000 to 10 percent by 2007 (Lu and Yu, 2015). The tariff reductions potentially benefit firms with existing export links to China more than those without such existing relationships. Using a difference-in-differences methodology, we compare a treatment group of firms with China-specific trading relationships prior to 2001 to control groups drawn from the remaining firms. We find that, in the aftermath of China's WTO accession, the firms in the treatment group exported 57 percent more, grew 40 percent larger in terms of employment and payroll, and grew 13 percent more unequal as measured by the CEO-to-worker pay ratio. These results suggest that globalization might be responsible for the widening income gaps between the rich and the poor through within-firm inequality.

To evaluate the aggregate implications of the firm-level findings, we develop a framework that bridges the heterogeneous firm trade model based on Melitz (2003) with the literature on occupational choice and executive compensation. The model world consists of two countries. Each country is populated by a fixed measure of individuals who are endowed with different levels of human capital. An individual chooses between different occupations, as in Lucas (1978). She can either (1) create a new firm and become the founder and CEO of the firm or (2) work for an existing firm. If she chooses to create a new firm, her human capital determines the productivity of the firm, and her income depends positively on the size of the firm.[5] If she chooses to be a worker, her human capital determines the amount of efficiency labor she supplies to the market. The wage rate of efficiency labor is determined in a competitive countrywide labor market and equalized across firms within the same country. In equilibrium, only the individuals with human capital above a certain threshold choose to create firms, while the majority of the population chooses to work for an existing firm. Each firm produces a distinct variety and sells it in a monopolistic competitive market. Firms can choose to export to the foreign market after incurring fixed costs.

The model replicates the new empirical pattern documented in this paper; in equilibrium, within-firm inequality is higher among the firms that sell to the foreign market. The key mechanism is that the extra profits earned in the foreign market are not distributed evenly within the same firm. The compensation paid to the CEO of a firm is linked to the sales of the firm, while the wage rate of a typical worker is determined in a countrywide labor market. Any extra profits earned in the foreign market benefit the CEO directly, but benefit the workers only through general equilibrium effects. In the end, as the firm sells to the foreign market, its within-firm inequality will be higher. At the aggregate level, trade creates a gap in within-firm inequality between the exporting and domestic firms. Consistent with the empirical patterns described above, in the model, the size of the firm solely determines the level of within-firm inequality; once the size is controlled for, the exporting status of a firm has no impact on its CEO-to-worker pay ratio.

Before using the model to quantify the impact of globalization on top income shares, we show that the model can parsimoniously and precisely characterize the U.S. income and firm distributions at the same time. Empirically, the U.S. income distribution is well approximated by an exponential distribution for the majority at the left end and a Pareto distribution for the right tail.[6] At the same time, the U.S. firm size distribution can also be well described by a fat-tailed Pareto distribution (Axtell (2001)). These two distributions are captured simultaneously within the model by two assumptions: (1) human capital is distributed exponentially, and (2) firm productivity is an exponential function of the

[5] In the appendix, we provide an extension of the model to micro-found a market in which existing heterogeneous firms match with potential entrepreneurs. The micro-foundation delivers assortative matching between the CEOs and the firms, which in turn leads to the same compensation function that is exogenously assumed in the benchmark model.

[6] See Drăgulescu and Yakovenko (2001a), Drăgulescu and Yakovenko (2001b), Clementi and Gallegati (2005), and Yakovenko and Silva (2005) for details.

founder's human capital. The model then features a Pareto firm size distribution and a two-class-structured income distribution. The workers' wage depends on their human capital, which implies an exponentially distributed income outside of the very rich. The individuals at the right tail of the income distribution are the CEOs, whose income is linked to the size of the firm they manage. This implies that the right tail of the income distribution will follow the firm size distribution and thus be Pareto. Once the model is calibrated, it reproduces both the firm size and the income distribution observed in the data with reasonable precision.

Model counterfactuals suggest that trade liberalizations can explain 52 percent of the surge in the top 0.1 percent income shares in the United States between 1988 and 2008. To arrive at these values, we match one country in the model to the U.S. economy and the other to the rest of the world; we then calibrate their trade barriers and their relative TFP to match the data for each year. Targeting these moments alone, we compare the income distribution in the model to the income distribution in the data to quantify the potential explanatory power of our channel, linking globalization, firm size, and inequality. In other counterfactual exercises, we also study how income inequality responds to changes in trade barriers as we move from autarky to the observed level of trade openness. For 2008, this latter exercise more than triples the CEO-to-worker pay ratio at the largest firms in the United States. At the aggregate level, this opening to trade skews the income distribution rightward: the top 0.1 percent income share increases from 9.1 percent to 10.2 percent between autarky and trade.

By linking globalization and top income shares, this paper contributes to the literature on the distributional effects of globalization and the discussion on rising income inequality in the United States. The majority of the existing research in the international trade literature focuses on how globalization affects wage inequality, and particularly the wage and income gap between skilled and unskilled workers.[7] Top income inequality, such as the income gap between top managers and workers or the overall top income shares, is often overlooked in the trade literature. At the same time, researchers working on income inequality documented that the rising income inequality in the U.S. is mainly driven by the widening gaps between the top 1 percent and the bottom 99 percent, not by the income inequality within the bottom 99 percent themselves. Moreover, papers in this literature showed that a substantial part of the rise in U.S. top income inequality is due to the rise

[7] For example, see Feenstra and Hanson (1996), Manasse and Turrini (2001),Yeaple (2005), Helpman et al. (2010), and Egger and Kreickemeier (2012). Bernard and Jensen (1997) documented that exporting is associated with higher within-firm inequality in terms of the wage gap between skilled and unskilled workers. This paper focuses on another dimension of within-firm inequality: the wage gap between top managers and workers.

in labor income inequality, especially when business income is included in the category of labor income.[8] This current paper bridges the gap between the two literature by focusing on the impact of globalization on top income inequality. It is the first paper to show empirically that the access to the world markets increases CEO-to-worker pay ratio within the same firm, and thus trade can potentially affect top income shares. This paper also quantitatively shows that a large part of the surge in top income shares in the United States can potentially be attributed to globalization.

In broadening the focus to inequality between the very rich and the rest of the population, this paper complements an existing literature on inequality across executives. Monte (2011) and Meckl and Weigert (2011) developed models exploring the effects of trade on income inequality among the managers. By contrast, the model here is designed to generate a realistic income distribution that spans the entire population in general equilibrium, which has not been done before in the trade literature. This broader scope enables quantitative analysis of the aggregate impacts of globalization on income inequality, both within the right tail, and over the entire population.

By introducing Census data to the study of executive compensation, this paper also interfaces with the large literature on corporate governance and executive compensation (Roberts, 1956; Baker and Hall, 2004; Gabaix and Landier, 2008; Frydman and Saks, 2010). Compared to the existing literature, which mostly focuses on the level of executive compensation, the census data allow us both to measure the magnitude of executive compensation relative to the wages of ordinary workers within the same firm, and to do so on a large and comprehensive sample. In the process, we provide a new perspective to understand the implications of surging executive pay on inequality.[9] This paper is also the first to study executive-to-worker pay ratio among privately-held firms. A small strand of this literature, such as Sanders and Carpenter (1998), Oxelheim and Randøy (2005), Cuat and Guadalupe (2009), and Gerakos et al. (2009) documented that executive compensation in public firms increases as the firms start to participate in the global markets. This paper further documents that the positive link between executive compensation and globalization can also be observed at privately-held firms, though the magnitude is smaller.

The rest of this paper is organized as follows. Section 2 presents the empirical results. Section 3 presents the model and Section 4 focuses on the analytical results. Section 5 provides details of the calibration and quantitative results. Section 6 concludes.

[8]Among many others, see Piketty and Saez (2003) and Atkinson et al. (2011).

[9]It is possible to measure CEO-to-worker pay ratio without using the Census data as well. However, this usually leads to a biased and small sample of firms. This is discussed in detail in Section 2.

2 Empirical Evidence: Trade and Within-Firm Inequality

In this section, we first describe a new data set linking executive compensation to administrative firm-level data; we then document the robust relationships among within-firm inequality, export status, and size; finally, we provide direct evidence that trade shocks drive within-firm inequality using China's access to the WTO. These new empirical patterns motivate our modeling choices in section 3.

2.1 Data

Our empirical evidence focuses on public firms and is based on a linked data set that has three components: ExecuCompustat from Standard & Poor, the Longitudinal Business Database (LBD) from the Census Bureau, and the Longitudinal Firm Trade Transactions Database (LFTTD) from the U.S. Customs and the Census Bureau. Appendix A details the construction of the data set used in the body of the paper and introduces the data on privately held firms to which we return later.

This novel linked data set provides more comprehensive coverage of both payroll and export statistics relative to the data used in the existing literature. First, U.S. public firms are not required to disclose non-executive compensations. As a result, the majority of firms do not report total payroll expenditure in SEC filings, making it almost impossible to compute wages at the firm level and within-firm inequality. For example, as reported by Faleye et al. (2013), around 87 percent of firms have to be dropped from ExecuCompustat due to this missing value problem in their study of the CEO-to-worker pay ratio. The under-reporting also leads to distortions of sectoral representation in the sample. For example, around 43 percent of the sample in ExecuCompustat are manufacturing firms, but they only constitute 16 percent of the sample in Faleye et al. (2013). By contrast, the LBD provides universal coverage of employment and payroll and thus minimizes the loss of observations. Overall, around 50 percent of the ExecuCompustat observations can be matched with the linked LBD-LFTTD, which is on par with most studies that use the Compustat-SSEL bridge provided by the census. The sectoral representation in ExecuCompustat is also preserved in the data set used in this paper (See Table A.1 for details). For example, in the linked data set, manufacturing firms constitute 47 percent of the sample, a significant improvement over the sample used in the existing literature. Second, as firms are not required to report export sales separately, the missing value problem is prevalent in non-administrative data sets, forcing researchers to discard a large proportion of the data in studies that involve exporting behavior. By using the LFTTD, which provides universal coverage of U.S. international transactions, we minimize this reduction in sample size.

The final linked data set contains a sample of 17,233 firm-year observations between 1992 and 2007 with 2,561 unique firms. A total of 13,169 firm-year observations are classified as exporters and the remaining 4,054 as non-exporters. Overall the combined dataset contains around half of the US public firms over the period. Due to the nature of publicly-traded firms, large firms are over-represented in the dataset, as compared to the universe of U.S. firms. As a result of this, this dataset is also heavily skewed toward exporting firms: around 76 percent of the observations are exporting firms, and this is higher than the overall percentage of firms that export in the U.S.[10] Over-representation of large firms naturally leads to problems if one wish to make inferences for the overall economy. This problem is mitigated here, since it is reasonable to believe that the CEO-to-worker pay ratios are much smaller and less variable in small firms, and thus the results for the overall economy will be mainly driven by large firms.

The key variable of interest is the CEO-to-worker pay ratio. We construct this ratio as the total realized compensation (TDC2) divided by the average non-executive wage. To construct the average non-executive wage we subtract the salary and bonus of the CEO from the firm's total payroll for the year and then divide this difference by the total employment less the CEO. We rationalize this construction of the non-executive wage as follows: "Total payroll" as reported in the LBD comes from the Business Register, which is in turn based on IRS tax records. The salary and bonus of the CEO are reported as part of the total payroll for tax purposes, while the income earned from stock options is not.[11] Therefore, we need subtract only the salary and bonus of the CEO when computing the non-executive wage. The denominator is one less the total employment to account for the fact that the CEO is also counted as an employee in tax filings.

2.2 Export Status and Within-Firm Inequality

Over the course of our sample, an average CEO earns 89 times more than an average worker in the same firm; this CEO-to-worker pay ratio varies by exporting status: it is on average 92 for exporting firms and 81 for non-exporting firms. Appendix table A.2 reports these and other summary statistics.

We test these differences in within-firm inequality across exporters and non-exporters by estimating the following equation on the pooled panel data:

$$\log\left(\mathrm{CEO_{it}}/\mathrm{WAGE_{it}}\right) = \beta_0 + \beta_1 \mathrm{EXP}_{it} + \mathbf{b'}_2 \cdot \mathbf{g} + \mathbf{b'}_3 \cdot \mathbf{y} + \epsilon_{it}. \tag{1}$$

[10]For example, Bernard et al. (2009) reports that 18 percent of U.S. manufacturing firms exported in 2002.
[11]The "total payroll" and "employment" items in LBD are compiled from filings of IRS Form-941/943. See IRS Publications 15, 15-A, and 15-B for the details of tax deductions and exemptions.

We define $\mathrm{CEO_{it}/WAGE_{it}}$ as the CEO-to-worker pay ratio, EXP_{it} as the exporter status indicator for firm i at year t, $\mathbf{g}$ as a vector of group fixed effects (e.g., four-digit Standard Industrial Classification (SIC) codes, or firm identifiers), and $\mathbf{y}$ as a vector of year fixed effects. The standard errors are clustered at the year-sector level in the baseline specification. The coefficient of interest is β_1: if the CEO-to-worker pay ratio is significantly higher for exporters, we expect this parameter to be positive.

Table 1 shows that the CEO-to-worker pay ratio is higher among exporters than among non-exporters across a variety of specifications. Column 1 looks at manufacturing firms, includes sector fixed effects and finds that this measure of within-firm inequality is 73.3% higher for exporters than for non-exporters. Column 2 repeats the comparison across all firms and finds an exporter premium of 50.7% for within-firm inequality. We look at the intensive margin of exporting in column 3 by replacing the indicator EXP_{it} with the log of firm exports. In that setting we find that a 1-percent increase in firm exports is associated with an 0.12-percent increase in within-firm inequality. Lastly, column 4 replaces sector-level fixed effects with firm-level fixed effects to identify the key correlation from the time-series variation in export status within a firm; we find the exporter premium on within-firm inequality drops drastically to 9.3% in that case, suggesting firm characteristics can

Table 1: Within-Firm Inequality and Export Status

Dependent Variable	Log CEO-to-Worker Pay Ratio			
	(1)	(2)	(3)	(4)
Exporter	0.733***	0.507***		0.093***
	0.108	(0.030)		(0.028)
Log Exports			0.119***	
			(0.005)	
Sample	Manufacturing	All	All	All
Year Fixed Effects	Yes	Yes	Yes	Yes
Group Fixed Effects	Sector	Sector	Sector	Firm
Observations	8,000	17,000	13,000	17,000
R-squared	0.219	0.270	0.323	0.628

Note: The left-hand side variable for each of the regressions is the (log of) CEO-to-worker pay ratio. "Exporter" is the exporter indicator computed from LFTTD. Exports are dollar values of shipments from LFTTD. The unit of observation is firm-year and year varies between 1992 and 2007. See Table A.1 for sector distribution of the sample. Standard errors are clustered at the year-sector level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

explain a large proportion of the CEO-to-worker pay ratio. All the estimates are statistically significant at conventional levels. In appendix table B.1, we show that the strong positive correlation between within-firm inequality and export status holds for changes in data (e.g., private firms, other executives, different components and different measures of CEO compensation) as well as changes in the specification of the estimating equation (e.g., different clustering choices, different fixed effects, inclusion of firm-specific time trends).

Table 2 suggests that differences in firm size drive most of the differences in the CEO-to-worker pay ratio. We proceed in two steps. First, we show in panel A that larger firms have greater within-firm inequality. Specifically, we replace the exporter indicator in equation 1 with measures of firm size: employment and payroll in the United States. Column 1, focusing on the manufacturing sector, suggests that a 1% increase in the firm's employment is associated with a CEO-to-Worker pay ratio that is 0.39% larger. In the sample with all firms, the same 1% increase in employment also coincides with a 0.39% increase in our measure of within-firm inequality, as per column 2. The remaining two columns affirm that this size-inequality relationship is positive and robust when we use the firm's payroll as a measure of size. Second, in panel B we include in equation 1 both the exporter indicator and a measure of firm size. In each specification, the coefficient on the size measure is positive, statistically significant, and dwarfs in magnitude the coefficient on exporter status. Furthermore, the coefficients on exporter status are close to zero and only sometimes significant. For instance, including employment as a measure of size reduces the coefficient on exporter status in column 2 by an order of magnitude: column 2 now suggests that exporters have a 5.0% larger CEO-to-Worker pay ratio than non-exporters, while same coefficient was 50.7% in table 1 when we did not control for firm size. These patterns repeat throughout the table, both when we change the sample of firms, as well as when we replace employment with payroll as the measure of firm size. In appendix table B.2, we show that the results also hold for firm sales and asset holdings, measures of firm size from COMPUSTAT.[12]

These exercises convey a consistent message: the "exporter premium" for within-firm inequality is driven by the size of the exporters. Larger firms have higher within-firm inequality, and the reason we observe higher within-firm inequality among exporters is precisely because those firms are larger – a stylized fact confirmed by the empirical trade literature that motivated the new generation of heterogeneous firms trade models.[13] These

[12]We focus primarily on measures of employment and payroll from the LBD because these measures reflect a firm's size in the United States. For COMPUSTAT, it is not clear whether a given data point reflects a firm's global or U.S.-based sales and assets; consequently, we relegate the analysis of COMPUSTAT size measures to the appendix.

[13]For example, see Bernard and Jensen (1999).

Table 2: Within-Firm Inequality, Export Status, and Firm Size

Panel A: Within-Firm Inequality and Firm Size in the United States

Dependent Variable	Log CEO-to-Worker Pay Ratio			
	(1)	(2)	(3)	(4)
Log Employment	0.388***	0.391***		
	(0.010)	(0.007)		
Log Payroll			0.378***	0.370***
			(0.010)	(0.008)
Sample	Manufacturing	All	Manufacturing	All
Year Fixed Effects	Yes	Yes	Yes	Yes
Group Fixed Effects	Sector	Sector	Sector	Sector
Observations	8,000	17,000	8,000	17,000
R-squared	0.376	0.407	0.362	0.385

Panel B: Within-Firm Inequality and Export Status, Controlling for Firm Size

Dependent Variable	Log CEO-to-Worker Pay Ratio			
	(1)	(2)	(3)	(4)
Exporter	-0.060	0.050*	0.049	0.070***
	(0.095)	(0.026)	(0.101)	(0.027)
Log Employment	0.389***	0.388***		
	(0.010)	(0.007)		
Log Payroll			0.377***	0.364***
			(0.011)	(0.009)
Sample	Manufacturing	All	Manufacturing	All
Year Fixed Effects	Yes	Yes	Yes	Yes
Group Fixed Effects	Sector	Sector	Sector	Sector
Observations	8,000	17000	8,000	17000
R-squared	0.376	0.407	0.362	0.385

Note: The left-hand side variable for each of the regressions is the (log of) CEO-to-worker pay ratio. "Exporter" is the exporter indicator computed from LFTTD. Exports are dollar values of shipments from LFTTD. Employment is the total annual employment reported in LBD. Payroll is the total annual payroll reported in LBD. The unit of observation is firm-year and the time period spans 1992 through 2007. See Table A.1 for sector distribution of the sample. Robust standard errors are clustered at the year-sector level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

results suggest that within-firm inequality can be naturally incorporated into a Melitz trade model, where exporting behavior and size are linked.

The insignificance of exporting status conditional on size does not imply that trade is irrelevant for within-firm inequality. Without trade, many of the large firms in the sample would not have been able to grow to the size that we observe in the data. In a counterfactual world where all the firms can only sell to the domestic market, many of the large firms would be smaller and, thus, their within-firm inequality would be lower. The insignificance of the exporter dummy implies only that whatever effect trade might have on within-firm inequality, the main channel goes through the size of the firm. In some cases, the coefficient on the exporter dummy is significantly positive after controlling for size, indicating that there are other factors that predict higher within-firm inequality among exporters. For example, exporting firms might need different managerial skills than domestic firms and thus are recruiting their CEOs in a different market. However, as the size of the coefficients suggests, no matter what these factors are, their explanatory power is small relative to firm size. Therefore, the model presented in Section 3 focuses solely on the size of the firm and leaves the other factors to future research.

2.3 Within-Firm Inequality: Evidence from a Trade Shock

Having shown that within-firm inequality is higher for exporters than for non-exporters, we now provide causal evidence on this channel using a trade shock: China's 2001 accession to the World Trade Organization (WTO). Around the time of its accession, China agreed to lower its import tariffs. Following a 6-percentage-point tariff reduction to 17% between 1996 and 1997, China's average tariff rate remained stable until the WTO accession, whereupon the average tariff declined to 10% by 2007 (Lu and Yu, 2015). Moreover, when China became a WTO member on December 11, 2001, it received permanent, reciprocal access to the *most favored nation* status, which reduced policy uncertainty and the threat of trade wars (Handley and Limão, 2017). These changes in trade policy made China a more attractive destination for U.S. exporters and contributed to a rise in exports to China. We next show that the reductions in China's import tariffs primarily benefit the U.S. firms that export to the Chinese market, increasing their export sales, firm size, and within-firm inequality.

To estimate the causal effects of this trade shock, we compare the outcomes of firms that had existing trading relationships with China prior to its WTO accession to firms that did not have China-specific trading relationships. Our starting point is a standard difference-in-differences regression specification, e.g., Angrist and Pischke (2008):

$$\begin{aligned}\text{Outcome}_{\text{it}} = \delta_0 + \mathbf{d'}_1 \cdot \mathbf{f} + \mathbf{d'}_2 \cdot \mathbf{y} \\ + \delta_1 \text{Treatment}_i \times \text{Post China WTO Accession}_t + \epsilon_{it},\end{aligned} \tag{2}$$

where Outcome$_{it}$ is firm i's exports, CEO-to-Worker pay ratio, or firm size in year t; $\mathbf{f}$ and $\mathbf{y}$ are respectively the vectors of firm and year fixed effects; Treatment$_i$ is an indicator taking value one for firms that exported to China prior to the WTO accession, and zero otherwise; and, "Post China WTO Accession$_t$" is an indicator taking value one for years 2002 and onward, and zero otherwise. The coefficient of interest, δ_1, captures the differential impact of China's accession to the WTO for firms that had a China-specific trading relationships prior to the event.

We rely on the "parallel trends" assumption to give this comparison a causal interpretation. Specifically, we posit that the observed outcomes of the untreated firms after the shock parallel the counterfactual outcomes of the treated firms had the shock never taken place. The causal effect is then the difference between the change in outcome for the firms with a China-specific trade relationship and the change in outcome for the firms without such a relationship. In appendix B.2, we provide more details on the timing of the shock, the plausibility of the parallel trends assumption, and robustness for the results that follow. Note also that—unlike the cross-sectional comparison in the previous section—the estimating procedure we use here relies on *within-firm* variation in the CEO-to-worker pay ratio. Since the variation within firms is meaningfully smaller than the variation across firms, this procedure is more demanding of the data.[14]

China's accession to the WTO resulted in increased exports and higher within-firm inequality for firms that exported to China prior to 2001, as per panel A of Table 3. We begin by focusing on the manufacturing sector and in columns 1 and 2 we define firms as "treated" if they exported to China in the three years between 1998 and 2000.[15] For firms with this pre-existing China-specific relationship, China's accession to the WTO led to a 56.8% increase in exports and a 12.5% increase in the CEO-to-worker pay ratio. In columns 3 and 4 we expand the sample to cover firms in all sectors, and we estimate a 76.8% increase in exports and a 7.6% increase in within-firm inequality.

[14]The cross-sectional variance of $\ln$(CEO-to-Worker pay ratio) is 1.205; the within-firm variance is roughly half the size at 0.659.

[15]We choose a three-year window based on the work of Monarch and Schmidt-Eisenlohr (2016), who document that import-export relationships in the United States that last at least three years account for 47% of the value of trade. We show in appendix B.2 that shifting the treatment window to include 2001, the year of the WTO accession, does not change our conclusions.

Table 3: China's Accession to the World Trade Organization and Within-Firm Inequality

Panel A: Exports and CEO-to-Worker Pay Ratio

Dependent Variable (log)	Exports	CEO-to-Worker Pay Ratio	Exports	CEO-to-Worker Pay Ratio
	(1)	(2)	(3)	(4)
Treatment × Post	0.568***	0.125**	0.768***	0.076*
China WTO Accession	(0.120)	(0.060)	(0.112)	(0.043)
Treatment	Exporter to China 1998-2000		Exporter to China 1998-2000	
Sample	Manufacturing		All	
Year Fixed Effects	Yes	Yes	Yes	Yes
Firm Fixed Effects	Yes	Yes	Yes	Yes
Observations	8,000	8,000	13,000	17,000
R-squared	0.908	0.714	0.932	0.755

Panel B: Employment and Payroll

Dependent Variable (log)	Employment	Payroll	Employment	Payroll
	(1)	(2)	(3)	(4)
Treatment × Post	0.385***	0.406***	0.505***	0.500***
China WTO Accession	(0.067)	(0.067)	(0.061)	(0.062)
Treatment	Exporter to China 1998-2000		Exporter to China 1998-2000	
Sample	Manufacturing		All	
Year Fixed Effects	Yes	Yes	Yes	Yes
Firm Fixed Effects	Yes	Yes	Yes	Yes
Observations	8,000	8,000	17,000	17,000
R-squared	0.926	0.917	0.937	0.922

Note: The left-hand side variable for each of the regressions is the (log of) CEO-to-worker pay ratio. "Exporter" is the exporter indicator computed from LFTTD. Exports are dollar values of shipments from LFTTD. Employment is the total annual employment reported in LBD. Payroll is the total annual payroll reported in LBD. The unit of observation is firm-year and the time period spans 1992 through 2007. See Table A.1 for sector distribution of the sample. Robust standard errors are clustered at the year-sector level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

The pass-through of trade shocks to within-firm inequality takes place through firm size. Complementing the evidence in panel A that exports increased, panel B shows that China's accession to the WTO also led to increases in employment and payroll for firms with China-specific relationships. Columns 1 and 2 focus on the manufacturing sector and document that China's accession resulted in roughly 40% increases in both employment and payroll for those firms. Maintaining the same 1998-2000 treatment window and expanding the sample to all firms, as in columns 3 and 4, increases these estimates to roughly 50% increases in employment and payroll for the treated firms. For both sets of firms, the trade shocks increase employment and payroll by roughly the same magnitude, suggesting that the average firm wage is not responsive to the trade shocks. This in turn implies that the observed surge in CEO-to-worker pay ratio is driven by the fact that the trade shocks primarily increase executive compensation but not the average wage.

Taking the ratio of our estimates for trade-driven changes in inequality and firm size, we derive an implied elasticity: a 1% increase in firm size leads to a 0.2-0.3% increase in within-firm inequality and executive compensation. This range falls slightly below the elasticity of 0.4 that we estimated by regressing log size on log inequality directly in panel A of table 2. As we argued above, the workers' wages are unaffected by the trade shocks; hence, this elasticity also describes how CEO compensation changes with firm size, a relationship that is known as Roberts' Law (Roberts, 1956). In fact, Gabaix (2009) lists the standard range of Roberts' Law elasticities as 0.2-0.4, which encompasses our trade-driven estimates.

3 The Model

In this section, we build a model of heterogeneous firm in which international trade shapes within-firm inequality by changing firm size. The model setup is based on Helpman et al. (2004). We introduce occupational choice and executive compensation into the framework. The contribution of the model is two-fold. First, it offers a tractable framework to analyze the effects of trade on the CEO-to-worker pay ratio within each firm and overall income inequality. Second, the simple framework is also empirically relevant: it is able to generate income distribution and firm-size distribution with full support that closely resemble the data. Within this framework, we then carry out a quantitative analysis to evaluate the impacts of globalization on income inequality, both within the right-tail of the income distribution, and between the right-tail and the general population.

3.1 Model Setup

The model world consists of two countries indexed by i. Each country i is populated by individuals with measure n_i. People in each country are endowed with human capital x. As x uniquely identifies each individual, with a slight abuse of notations, we also use x as index for individuals within a country. The distribution of human capital in each country follows an exponential distribution with shape parameter λ. The cumulative distribution function (CDF) of human capital is as follows:

$$F(x) = 1 - e^{-\lambda x}.$$

We use the exponential distribution, together with other assumptions explained later in this section, to capture the structure and shape of the income distribution and the firm size distribution at the same time. We characterize the distributions in more detail when we present the analytical results in section 4.

An individual can choose between two careers. She can either work for an existing firm or she can create a new firm. If she chooses to be a worker, then her human capital directly translates into the amount of efficiency labor that will be inelastically supplied to the market. In this case, the individual's income will be $w_i x$, where w_i is the prevailing wage rate per efficiency unit of labor in country i. Individuals cannot move between countries and the wage rate w_i is determined in a country-wide competitive labor market.

The individual can also create a new firm to start producing a new variety of good. In doing so she becomes the founder and CEO of the firm. The productivity of the firm, denoted by $A_i(x)$, depends on the human capital of the founder and takes the following form:

$$A_i(x) = b_i e^x, \tag{3}$$

where b_i is the total factor productivity (TFP) in country i. With the assumption on the distribution of x, the above function implies that firm productivity, A_i, follows a Type-I Pareto distribution with location parameter b_i and shape parameter λ (see appendix for the proof). Subsequently this also implies that firm sales, employment, and profit distributions will also be Paretian.

The payoff to the founder and CEO of the firm is a function of the profit of the firm, denoted as $k(\pi) \leq \pi$, where π is the profit. For simplicity, we assume that the residual profit after the CEO compensation is distributed back to the entire population in country i evenly (i.e. all the people in the country own the firms through a mutual fund). This assumption does not affect the analysis of income inequality, and the main results of the paper do not change meaningfully if we relax this assumption.

Reflecting Roberts' Law (Roberts, 1956) from the corporate governance literature, we assume that $k(\pi)$ is exogenously determined, monotonically increasing, and regularly-varying in π. By definition, a function $k(\pi)$ is regularly-varying with tail index β if and only if for any $z > 0$, the following relationship holds:

$$\lim_{\pi \to \infty} \frac{k(z\pi)}{k(\pi)} = z^{\beta}.$$

Intuitively, regularly-varying functions are functions that behave like power functions at the limit.[16] In our context, the assumption of regular variation delivers the empirically robust Roberts' Law so CEO compensation is proportional to a power function of firm profits asymptotically. The assumption of regular variation also implies that the right-tail of the income distribution will exhibit Paretian behavior, though the vast majority of the distribution follows an exponential distribution — again, an empirically relevant result, which will be discussed in detail in the next section.

We show in appendix E how these stylized, tractable features of the labor market emerge from richer micro-foundations. In the extended model, CEOs and firms match in the market, and endogenously determine a compensation function for managerial talents, $k(x)$, much like in Gabaix and Landier (2008). In equilibrium, CEOs with higher talents will be matched with firms with higher productivity, and thus the compensation function will be monotonically increasing and regularly varying in both the managerial talent and the size of the firm. Positive assortative matching also implies that the matching pattern between CEOs and firms in equilibrium will be the same as if the best managers founded the best firms and remained as CEOs thereafter, the assumption that we relied on in the baseline model. As the endogenous labor market for CEOs delivers compensation functions and matching patterns identical to those exogenously assumed, the extension can be considered orthogonal to other parts of the model. For this very reason, we abstract away from a full-fledged labor market and compensation model for the CEOs in the baseline model, and refer the readers to appendix E for more details.

The production side of the economy is modeled after Melitz (2003), with firms that are heterogeneous in their productivity $A_i(x)$ each producing a single variety of a good indexed by x. Each firm produces a quantity $q_i(x)$ of its variety using the following production

[16] For more details, see Resnick (1987).

function:

$$q_i(x) = A_i(x) \cdot [L_i(x) - f_{ii}],$$

where $L_i(x)$ is the labor demand and f_{ii} is the fixed cost of production, paid in the units of labor of country i. The firms operate in a monopolistic competitive market and earn positive profit in equilibrium.

Firms in country i can export to country j by paying a fixed cost f_{ji}, denominated in units of labor, to set up the distribution network. Trading incurs an iceberg cost of $\tau_{ji} > 1$: in order to supply country j with one unit of good from country i, the firm needs to ship τ_{ji} units.

Individuals in country i consume a CES aggregate of all the varieties available in country i. Their utility function is as follows:

$$U_i = \left(\int_{m \in \Theta_i} q_i(m)^{\frac{\epsilon-1}{\epsilon}} dm \right)^{\frac{\epsilon}{\epsilon-1}},$$

where ϵ is the elasticity of substitution, and Θ_i is the set of goods that are available in country i.

3.2 Solution and Equilibrium Conditions

The solution to the firm's problem is similar to Melitz (2003). Denote the total spending in country i as H_i and the ideal price index as P_i. The maximum profit a firm in country i can earn in its domestic market is:

$$\pi_{ii}(x) = \frac{H_i}{\epsilon} \left[\frac{\epsilon - 1}{\epsilon} \frac{P_i}{w_i} \right]^{\epsilon-1} A_i(x)^{\epsilon-1} - f_{ii} w_i.$$

The *additional* profit a firm in country i can earn from exporting to country j is:

$$\pi^e_{ji}(x) = \frac{H_j}{\epsilon} \left[\frac{\epsilon - 1}{\epsilon} \frac{P_j}{\tau_{ji} w_i} \right]^{\epsilon-1} A_i(x)^{\epsilon-1} - f_{ji} w_i, \quad (4)$$

The details of the solution to the firm's problem can be found in Appendix C.

Similar to Melitz (2003), under standard parameter restrictions, firms sort into two groups. All the firms founded in country i serve the domestic market first. Moreover, the least productive firms only serve the domestic market. The more productive firms serve the domestic market and the foreign market through export. Denote the human capital of the founder of the least productive exporting firm in country i as x^e_{ji}, the cutoff must be the solution to the following equation respectively:

$$\pi^e_{ji}(x^e_{ji}) = 0. \tag{5}$$

The condition means that the marginal exporter earns zero profit from exporting.

The solution of the occupational choice problem is a single cutoff rule. There exists a human capital level x^*_i in country i such that all the individuals with human capital smaller than x^*_i choose to be workers and all the other individuals choose to create firms. The cutoff x^*_i is the solution to the following equation:

$$k(\pi(x^*_i)) = w_i x^*_i, \tag{6}$$

which requires that in equilibrium the founder of the marginal firm to be indifferent between creating a new firm or working for an existing firm. The sufficient and necessary condition for the existence of the solution is that $k(\pi_i(0)) < 0$, which means that the individual with the least amount of human capital must find creating a new firm unprofitable.

Figure 1 presents the solution in a simple setting where $k(\pi) = \pi$. The solid line is the income of a worker as a function of his/her human capital. The dashed line is the income of a CEO as a function of his/her human capital. Under the assumption that $k(\pi(0)) < 0$, the two curves cross once and only once at the cutoff human capital level x^*_i.

The equilibrium of the world economy is a vector of wages, $\{w_i\}$, a vector of the occupational choice cutoffs $\{x^*_i\}$, a vector of exporting cutoffs $\{x^e_{ji}\}$, a vector of ideal price levels $\{P_i\}$, and a vector of total expenditures $\{H_i\}$ such that for $i = 1, 2$ and $j = 1, 2$:

1. Every individual in country i maximizes their income by solving the occupational choice problem (equation (6) holds).

2. Every firm optimally chooses to be a non-exporter or exporter, (equations (5) holds).

3. Total income equals to total expenditure in each country:

$$H_i = n_i w_i \int_0^{x^*_i} x f_i(x) dx + n_i \int_{x^*_i}^{\infty} \pi_i(x) f_i(x) dx. \tag{7}$$

4. Aggregate price level and the individual prices satisfy the rational expectation condi-

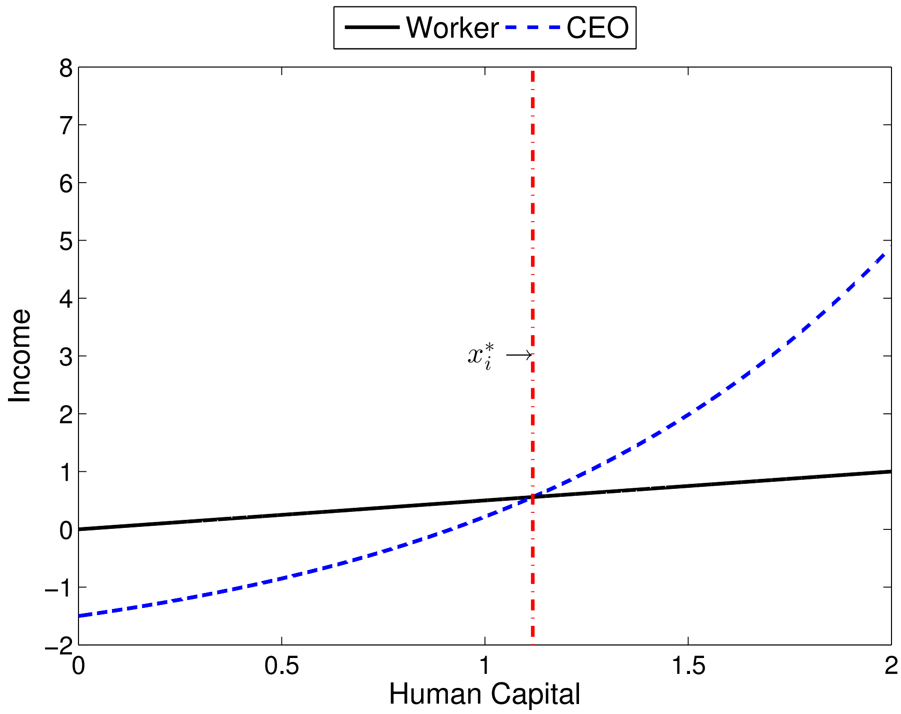


Figure 1: Solution of the Occupational Choice Problem

The graph plots the solution of the occupational choice problem. The black solid line is the income of a worker, and the blue dashed line is the income of a CEO. The vertical line indicates the cutoff human capital that is indifferent between being a worker or a CEO. This graph assumes that $k(\pi) = \pi$.

tion:

$$P_i = \left(\int_{m \in \Theta_i} p(m)^{1-\epsilon} dm \right)^{\frac{1}{1-\epsilon}}. \tag{8}$$

5. Labor market clears in each country.

Equation (7) is the income-expenditure identity in country i. In equilibrium, the total expenditure in country i must equal the total income in country i, which is the sum of all the wage and profit income[17]. Equation (8) is the definition of the ideal price index, which is the cost of one unit of utility in country i. Appendix C provides the details on these two equilibrium conditions, as well as the details on the labor market clearance condition.

[17]The CEO compensation function does not enter the total income function, because the difference between profit and CEO compensation at a given firm will be distributed back to the individuals in country i, which implies that we only need to consider total profit when accounting for total income in a given country.

4 Analytical Results

4.1 Firm Size Distribution and Income Distribution

As we detailed in the previous section, the distribution of firm productivity arises from the distribution of entrepreneurs' human capital; this productivity distribution in turn leads to plausible and tractable distributions of firm sales, employment and profits. Specifically, the productivity distribution in country i follows a Type-I Pareto distribution with shape parameter λ and location parameter $b_i e^{x_i^*}$, where x_i^* is the marginal entrepreneur. Firm sales are linear functions of $A^{\epsilon-1}$. As a result, the distribution of sales follows a Type-I Pareto distribution with shape parameter $\lambda/(\epsilon-1)$. Moreover, as noted in di Giovanni et al. (2011), international trade systematically changes the size distribution of firms. In our framework, this influence of international trade on the distribution is reflected in the location parameters: the location parameters are small for domestic and large for exporting firms. Firm employment and profit are affine functions of $A^{\epsilon-1}$ due to the fixed costs of operating and exporting. They follow Type-II Pareto distributions with shape parameter $\lambda/(\epsilon-1)$. As in the distribution of sales, location parameters in the distributions of employment and profits vary by the market size accessible to a firm. Appendix C provides details on the distributions of firms.

Individual income is ranked by occupations: the workers earn the lowest income, followed by the CEOs at domestic firms, and the CEOs at exporting firms. The income distribution follows a two-class structure. All the workers earn the same wage rate per efficiency labor unit; therefore, their income distribution is exponential with a shape parameter λ/w_i. The income of the CEOs depends on the CEO compensation function. By assumption, the compensation function $k(\pi)$ is monotonically increasing in π and regularly varying. Under these two assumptions, the income distribution of the CEOs adopts the following CDF:

$$U(y) = 1 - y^{-\frac{\lambda}{\beta(\epsilon-1)}} R(y), y > 0,$$

where y is the income, β is the tail index of $k(\pi)$, $\frac{\lambda}{\beta(\epsilon-1)}$ is the shape parameter of the distribution, and $R(y)$ is a slowly-varying function.[18] Distributions with this form of CDF are Pareto-Type distributions and exhibit fat-tail behavior at the right end similar to Type-I Pareto distributions. Appendix C provides details on the derivation of the income distributions of different groups of individuals.

[18]Slowly-varying functions are regularly-varying functions with tail index of 1. Intuitively, slowly-varying functions are functions that behave like linear functions at the limit.

4.2 Partial Equilibrium

The main mechanism of the model is most clearly demonstrated in partial equilibrium with wages, prices and total expenditures fixed at their autarky levels: following an opening to trade, the most productive firms export, grow larger, and the compensation of the exporting CEOs far outpaces the domestic wages, leading to increased inequality.

In figure 2 we present these partial equilibrium results for a simplified model where the CEO compensation equals profits, $k(\pi) = \pi$. The solid black line and the dashed blue lines are the same as in figure 1: they are respectively the incomes of workers and CEOs in autarky for the home country. When the world opens up to trade, only the most productive firms export. In the graph, the right end of the CEO income function tilts up into the red circled line, which is the income of CEOs at the exporting firms. The shaded area between the red circled line and the blue dashed line is the extra profit (and extra compensation to the CEO) earned in the foreign country. In this simple case, all the benefits of globalization are claimed by the CEOs at the exporting firms, and none of the benefits trickle down to the workers in those firms. At the aggregate level, top income shares will be higher because the CEOs at the exporting firms are originally the richest people in autarky.

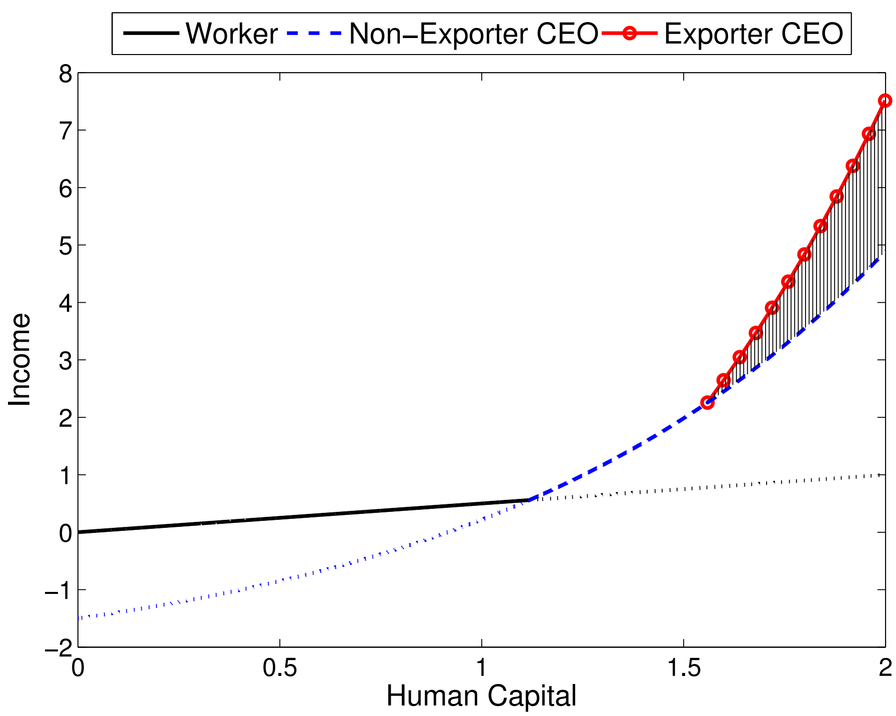


Figure 2: Trade and Top Income Shares in Partial Equilibrium

This graph plots the income of different individuals against their human capital for different occupations under autarky and under trade. The black solid line is the income of a worker. The blue dashed line is the income of CEOs at non-exporting firms. The red circled line is the income of CEOs at exporting firms. The shaded area is the extra profit earned from exporting. This partial equilibrium assumes that $k(\pi) = \pi$ and that wage, total expenditure, and prices are all fixed. It also abstracts away from FDI.

4.3 General Equilibrium

The main mechanism discussed in partial equilibrium above persists in general equilibrium as well. We first present a simple result characterizing the cross-sectional intra-firm inequality of the model in general equilibrium:

Proposition 1 *If the set of exporting firms in country i is non-empty, then the average CEO-to-worker pay ratio among domestic firms is strictly smaller than the average CEO-to-worker pay ratio among exporting firms.*

Proof See Appendix D.

Proposition 1 replicates in general equilibrium the empirical findings from section 2. If an econometrician observes the model world and estimates equation (1) without any size control, she will find that the CEO-to-worker pay ratio is significantly higher among firms that sell to the foreign market than those who do not. In addition, in general equilibrium, the CEO-to-worker pay ratio is proportional to the size of the firm. Therefore, if the econometrician can also observe the size of the firm and controls for it when estimating equation (1), the observed between-group difference will disappear, just the same as we observed in the U.S. data.

In the next proposition, we show that the cutoff points of human capital among different groups of firms — x_i^* for firms that produce domestically and x_{ji}^e for exporters — are sufficient statistics for the profit-to-wage ratios, which in turn shape the within-firm inequality measured as CEO compensation relative to worker wages.

Proposition 2 *In general equilibrium, the domestic-profit-to-wage ratio, defined as*

$$\frac{\pi_{ii}(x)}{w_i} = \frac{H_i}{w_i \epsilon} \left(\frac{P_i}{w_i} \frac{\epsilon - 1}{\epsilon} \right)^{\epsilon - 1} A_i(x)^{\epsilon - 1} - f_{ii},$$

will be lower when x_i^* is higher; The exporting-profit-to-wage ratio, defined as

$$\frac{\pi_{ji}^e(x)}{w_i} = \frac{H_j}{w_i \epsilon} \left(\frac{P_j}{\tau_{ji} w_i} \frac{\epsilon - 1}{\epsilon} \right)^{\epsilon - 1} A_i(x)^{\epsilon - 1} - f_{ji},$$

will be lower when x_{ji}^e is higher.

Proof See Appendix D.

Intuitively, as the trade costs τ_{ji} decrease, bilateral trade between i and j increases. The increased access to a foreign market makes exporting profitable for more firms, lowering the productivity cutoff for exporting x_{ji}^e. Proposition 2 then establishes that the exporting-profit-to-wage ratio will be higher among all the exporters as a result of the lower trade costs. Consequently, those whose income is linked to the profit of the firm—the top executives—will see their income increasing faster than the income of the workers. Trade liberalization also puts competitive pressures on the least productive domestic firms, leading them to exit and leading the domestic-production cutoff x_i^* to rise. Higher x_i^* in turn leads to lower CEO-to-worker pay ratio among the domestic firms. This proposition suggests that the top executives at the exporting firms stand to benefit from from trade liberalization, which might lead to higher top income shares at the aggregate level. We formally establish this result in the next proposition.

Proposition 3 *In a symmetric-country setup of the model, if $\tau_{ji} = \tau_{ij}$ drops, then there exists a percentile $p^* \in (0, 100)$ such that the top p^*-percent income share will be higher. Specifically:*

$$p^* = 100 \times (e^{\lambda x_{ji}^e}),$$

where x_{ji}^e is the exporting cut-off before the changes in τ_{ji} and τ_{ij}

Proof See Appendix D.

Proposition 3 establishes that bilateral trade liberalization leads to higher income concentration at the right tail of the income distribution. Put differently, CEOs of exporting firms benefit more from trade than both the CEOs of domestic firms and the workers. As the CEOs of the exporting firms were already richer than the other groups of people before the trade liberalization, lower $\tau_{ij} = \tau_{ji}$ will lead to higher income shares at the top. Outside of a symmetric country setup, analytical results on top income shares are difficult to establish; for this reason, we next turn to the quantification of our model to study the relationship between globalization and top income shares.

5 Quantitative Analysis

In this section, we quantify the impact of trade liberalizations on top income inequality in general equilibrium. We first extend the benchmark model to incorporate multinational firms (MNEs), a choice motivated both by the relevance of MNEs for understanding international flows and by the fact that their CEOs are also well-paid relative to their workers, as per appendix table B.1. We then calibrate the model to resemble the U.S. economy in the 2000s, and show that the model provides a reasonably good approximation for the U.S. income distribution. We then study how different measures of income inequality respond to changes in trade barriers, and show that globalization might be responsible for a substantial part of the surge in top income shares in recent decades. In the end we show that the main results of the model are robust to changes in certain parameter values.

5.1 Multinational Firms

As multinational firms are important players in both international trade and capital flows, we first extend the model to allow for MNEs before we carry out the quantitative analysis. In addition to exporting, the firms in country i can also serve country j via horizontal foreign direct investment (FDI), as in Helpman et al. (2004). In order to serve country j from country i through FDI, the firm needs to pay the fixed overhead costs g_{ji} in units of labor in country i. The labor costs are interpreted as the overhead costs of starting operation, as well as the costs introduced by policy barriers. The *additional* profit a firm in country i can earn from FDI in country j is:

$$\pi_{ji}^{f}(x) = \frac{H_j}{\epsilon}\left[\frac{\epsilon-1}{\epsilon}\frac{P_j}{w_j}\right]^{\epsilon-1} A_i(x)^{\epsilon-1} - g_{ji}w_i. \tag{9}$$

Subject to some standard parameter restrictions, firms sort into three groups in the extended model. All the firms founded in country i serve the domestic market first. Moreover, the least productive firms only serve the domestic market. The more productive firms serve the domestic market and the foreign market through export. The most productive firms serve the domestic market and the foreign market through FDI. Denote the human capital of the CEO in the least productive MNE in country i as x_{ji}^{f}. The cutoff between exporters and MNEs must be the solution to the following equation:

$$\pi_{ji}^{e}(x_{ji}^{f}) = \pi_{ji}^{f}(x_{ji}^{f}), \tag{10}$$

which says that the marginal MNE finds it equally profitable to serve the foreign market by FDI and by exporting.

Through proposition 4, we show that the cutoff x_{ji}^{f} for serving the foreign market through FDI is a sufficient statistics for the ratio of FDI profits to the wage ratio:

Proposition 4 *In general equilibrium, the FDI-profit-to-wage ratio, defined as:*

$$\frac{\pi_{ji}^{f}(x)}{w_i} = \frac{H_j}{w_i\epsilon}\left(\frac{P_j}{w_j}\frac{\epsilon-1}{\epsilon}\right)^{\epsilon-1} A_i(x)^{\epsilon-1} - g_{ji},$$

will be lower when x_{ji}^{f} is higher.

Proof See Appendix D.

As with the cutoffs for domestics production and exporting, we can use this relationship to understand the impact of FDI liberalization on inequality by tracking the changes in x^f_{ji}.

5.2 Calibration

We interpret the two countries in the model world as the United States and the rest-of-the-world (ROW). We treat 109 economies combined as the ROW. These countries, together with the U.S., are responsible for around 74 percent of the world population and 82 percent of the world GDP in 2008. The selection of countries is due to data availability, and the countries included in ROW are reported in Table B.4.[19]

In our measure of population, n_i, we want to account for differences in worker productivity across countries, difference that arise from the variation in both human capital and the physical capital associated with each worker. As a result, we follow the methods outlined in Caselli (2005) and first compute the "quality-adjusted workforce" using the Penn World Table 7.0 and the educational attainment data from Barro and Lee (2010). We then augment this measure of total workforce with the estimated capital stock and arrive at the final measure of the size of "population." For details on the population measures, see Appendix F.

With this measure of population, we then calibrate the country TFP b_i to match the relative size of the United States and the ROW. We normalize U.S. TFP to 1 and report the calibrated b_i for ROW in Table B.5. Furthermore, we set the elasticity of substitution to 4 so that the average markup charged by firms is 33 percent. This level of mark-up is in the middle of plausible estimates, and we provide robustness checks with ϵ between 2 and 6 in a later section.[20] The shape parameter of the human capital distribution, λ, is set to 3.18. This implies that the Pareto shape parameter of the firm employment distribution is $\lambda/(\epsilon - 1) = 1.06$, the estimation provided by Axtell (2001).

We calibrate the fixed costs of operation and export using the Doing Business database from the World Bank following the methods outlined in di Giovanni and Levchenko (2012, 2013). Specifically, we use the days of starting a business in the U.S. as the raw measure of the fixed costs of operation in the home country. The fixed costs of operation in the ROW

[19]A country is included in the sample if and only if its data from 1988 to 2008 are available both in Penn World Table 7.0 and Barro and Lee (2010).

[20]For example, Domowitz et al. (1988) estimated the average markup for U.S. manufacturing firms to be 0.37. Rotemberg and Woodford (1991) used steady-state markups between 0.2 and 0.6, while Feenstra and Weinstein (2010) estimated the average markup to be 0.3 in 2005 in the U.S. The elasticity of substitution used here is slightly lower than the estimates based on gravity equations, which are usually between 5 and 10, as reported by Anderson and van Wincoop (2004). Robustness checks show that the main results of the paper hold true with higher levels of ϵ.

are the average across the rest 109 countries weighted by GDP. We use the *Trading across Borders* module of the Doing Business Indicators database to measure the fixed costs of international trade. Define ϕ_{ij} as the sum of days required to export a 20-foot dry-cargo container from country i and to import the same kind of container into country j. The fixed cost of exporting from the U.S. to the ROW is computed as the weighted average of $\phi_{\text{i,US}}, i = 1, 2 \cdots, 109$:

$$f_{21} = \frac{\sum_{i=1}^{109} E_{\text{i,US}} \cdot \phi_{i,US}}{\sum_{i=1}^{109} E_{\text{i,US}}},$$

where the weight, $E_{\text{i,US}}$, is the export from the U.S. to country i. Similarly, the fixed cost of export from the ROW to the U.S. is:

$$f_{12} = \frac{\sum_{i=1}^{109} E_{\text{US,i}} \cdot \phi_{US,i}}{\sum_{i=1}^{109} E_{\text{US,i}}},$$

where the weight, $E_{\text{US,i}}$, is the export from country i to the U.S. The f_{ij} matrix at this stage is measured in the unit of time. At the end, we normalize the entire f_{ij} matrix so that around 0.83 percent of individuals in the U.S. choose to create firms. This statistics matches the ratio of chief executives to working population in 2000 Public Use Microdata Series (PUMS) 5 percent sample obtained from IPUMS.[21]

To capture differences in ownership structures of firms, we use the following functional form of $k(\pi)$ as CEO compensation:

$$k(\pi) = \begin{cases} \pi & \text{if} \quad \pi \leq \alpha \\ \alpha^{1-\beta}\pi^{\beta} & \text{if} \quad \pi > \alpha \end{cases}, \tag{11}$$

This function is monotonically increasing in π and regularly varying; therefore, all the analytical results in Section 4 carry over. Intuitively, the function captures the idea that firms with profit less than or equal to α are "sole proprietorship" firms: the founder and CEO owns the firm and claims all the profit. Firms with profit larger than α are "corporations," and the founder can only claim a proportion of the profit. The power function form for larger firms implies that the right tail of the income distribution follows a Pareto distribution with tail index $\frac{\lambda}{(\epsilon-1)\beta}$.

As noted in Section 3, equation (11) is based on the empirical findings in the literature that CEO compensation is proportional to the power function of the firm size, $k \sim \pi^{\beta}$, oth-

[21]This statistics measures chief executives, not self-employed to working population ratio, which around 10.9 percent as reported in Hipple (2010). See Ruggles et al. (2010) for details.

erwise known as the "Roberts law" (Roberts, 1956). This function also arises naturally as an equilibrium compensation function from a matching model where the managers with higher ability are matched with larger and more productive firms in equilibrium. Specifically, this function is a special case of the duo-scaling equation in Gabaix and Landier (2008), where α is the size of the reference firm. Within the context of this paper, the reference firm is the smallest corporation in each country. The calibration strategy described below ensures that the smallest firm in the model is always smaller than α in the benchmark model. This further implies that both types of firms exist in equilibrium.

We calibrate the ownership threshold α to match the ratio of sales of all the corporations to the sales of all the firms; this ratio is 62 percent in the U.S. in 2007.[22] We calibrate β to match the right tail index of the U.S. income distribution. Drăgulescu and Yakovenko (2001b) documents that the Pareto index of the U.S. income distribution is around 1.7. This implies that in this model, conditional on the tail index of the firm size distribution, β is $\frac{1.06}{1.7} \approx 0.747$.

We impose an upper bound, s, on the human capital distribution to eliminate unrealistically large corporations. We calibrate s to match the highest CEO-to-worker pay ratios in the data. We first compute the ratio between the highest CEO compensation in Execu-Compustat and the average U.S. wage from national income and product accounts (NIPA) in each year between 1992 and 2007[23]. We then set $s = 3.249$ so that the same ratio in the model is matched to the median of the data sequence, which is around 2,903.

We assume that both the iceberg trade costs and the fixed costs of starting foreign subsidiaries are symmetric: $\tau_{12} = \tau_{21}$ and $g_{12} = g_{21}$. We then jointly calibrate the two cost parameters, $\{\tau_{21}, g_{21}\}$, to match the exports-to-GDP ratio and the multinational-firm-sales-to-GDP ratio in the U.S. in year 2008. The first moment condition can be directly estimated using GDP data from NIPA. The second moment condition come from the Bureau of Economic Analysis's *Direct Investment and Multinational Corporations* data set.[24] These two parameters have to be jointly calibrated because iceberg trade costs affect not only the volume of trade but also the multinational sales through the extensive margin. Similarly,

[22]The sales of U.S. firms by legal form come from the *Statistics of U.S. Businesses, 2007* from the Census Bureau. The definition of "corporation" in this paper follows the legal form of "corporation" used by the Census. The other legal forms in the Census definition are classified as "proprietorship", which includes "S-corporations", "tax-exempt corporations", "partnership", "sole proprietorship", "other" and "tax-exempt other". The receipts of "government" are subtracted from the total firm sales.

[23]The wage data comes from NIPA Table 6.6A-D. The census does not allow disclosure of extreme values (maximum and minimum) that involve confidential data. Therefore we use the ratio between CEO compensation and the average U.S. wage instead of the CEO-to-worker pay ratio at the firm level in the empirical part.

[24]We use "All non-bank foreign affiliates" sales data up to 2008 as the estimate for the sales of multinational firms.

the fixed costs of FDI affect the volume of trade as well through the extensive margin. At the end we have $\tau_{21} = 1.720$ and $g_{21} = 1020$. All the above parameters are reported in Table 4.

Table 4: Calibration Targets and Results

Parameter	Benchmark	Target/Source
λ	3.81	Axtell (2001)
ϵ	4.0	Average mark-up
α	23.2	Corporate sales as a percentage of all firms sales
β	0.747	Tail index of income dist., Drăgulescu and Yakovenko (2001b)
f_{11}	6.0	World Bank Doing Business Index
f_{12}	19.6	World Bank Doing Business Index
f_{21}	24.6	World Bank Doing Business Index
f_{22}	38.9	World Bank Doing Business Index
f-Scale	0.756	Percentage. of chief execu. in work force.
n_{ROW}	6.0	Caselli (2005), Barro and Lee (2010)
b_{ROW}	0.58	Relative country size
s	3.249	Highest-CEO-to-average-wage ratio among public firms
τ	1.720	Export-GDP ratio in 2008
g	1020	Multinational-sales-GDP ratio in 2008

Note: λ is the shape parameter of the exponential distribution. ϵ is the elasticity of substitution in the utility functions. α is the size of the smallest public firm. β is the tail index of the compensation function. f_{ij} is the fixed cost of exporting from country j to country i. f-Scale is the normalizing factor of the entire f_{ij} matrix. We divide the f_{ij} matrix by this number. n_i is the measure of capital-adjusted endowment of human capital in country i. b_i is the TFP in country i. s is the upper bound of human capital distribution. See Section 5.2 and the appendix for the details of calibration. See Table B.5 for the calibrated values of τ, g and TFP by year used in the counter-factual.

5.3 Model Fit

Even though it is calibrated to the *tail* index of U.S. income distribution, the model generates a good fit for the *overall* U.S. income distribution in general equilibrium. Figure 3 compares the model-generated income shares with the data in 2008.[25] The model provides a good approximation of the U.S. income distribution for the right tail. For example, the top 0.01 percent income share is 3.4 percent in the data and 4.2 percent in the model in 2008. The top 5 percent income share is 33.8 percent in the data and 29.6 percent in the model. Outside of the top income decile, the model also captures the overall shape of the income distribution reasonably well. The top 25 and 50 percent income shares in the model and the data only differ within a few percentage points. Overall, the difference between the model and the data for the top income shares reported in Figure 3 is around 7.8 percent when measured in Euclidean 2-norm.

[25] The data for income shares above the top 10 percent come from the updated Table A.1 in Piketty and Saez (2003). The income share outside of the top 10 percent comes from the Tax Foundation report (Greenberg,

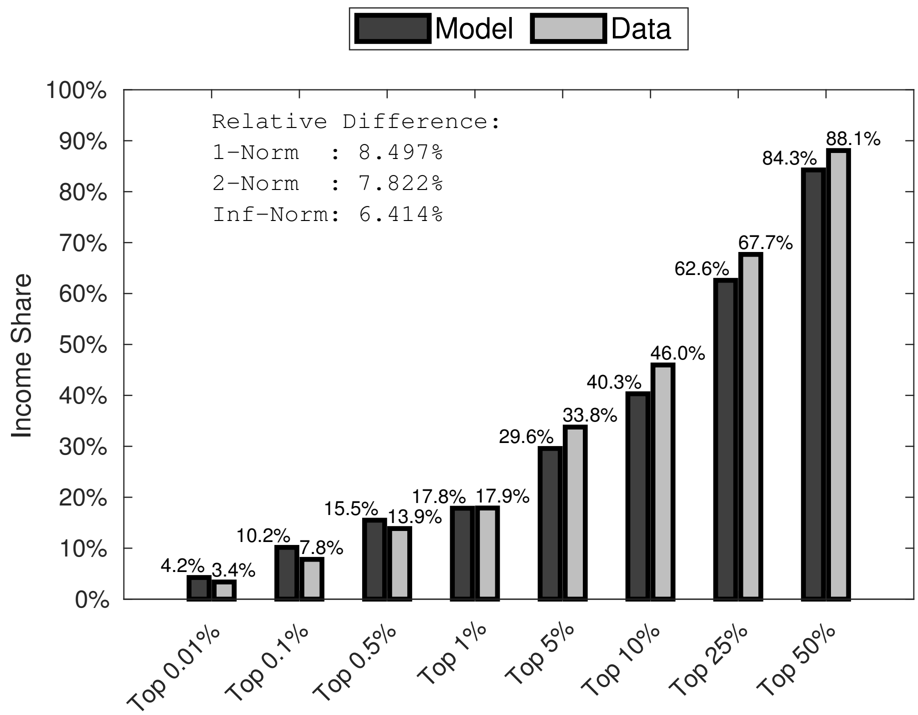


Figure 3: Top Income Shares: Model vs. Data (2008)

Note: This graph compares the top income shares between the model and the data in 2008. The top income shares in the model are described by the dark grey bars and those in the data described by light gray bars. The parameters behind the model simulation can be found in Section 5.2. The source of data is the updated Table A.1 from Piketty and Saez (2003). The average difference between the model and the data across the six top income shares is measured in Euclidean 2-norm. The differences are reported in percentage terms.

The model also compares favorably to the other moments of the data not targeted in the calibration; table 5 presents these comparisons for the mean-median ratio of the U.S. income distribution, the workers' share of income, and the CEO-to-worker pay ratio. The mean-to-median ratio of the U.S. economy in the model is 2.79, and the counterpart in the data is 1.61(Rodriguez et al., 2002). The second row in table 5 compares the workers' share of income in the model and the data. In the model the corresponding statistics is computed as the total wage payment to workers (CEO not included) divided by total output. In the data the statistics is computed as wage compensation divided by the gross domestic income of the private sector.[26] Again, the model closely resembles the data: the workers' share of income is 0.76 in the model, and 0.71 in the data. The last row compares the CEO-to-worker pay ratio. The model statistics is computed for the sample of "public" firms whose profit is higher than α. The counter-part in the data is based on the dataset

2017), which is in turn based on IRS tax return data.

[26]These data come from NIPA table 1.10. The gross domestic income of the private sector is defined as compensation of employees plus net operating surplus of private enterprises.

described in Section 2. In the model the CEO-to-worker pay ratio is 95 while in the data it is 89.

Table 5: Model Fit, Additional Measures

Moments	Model	Data
Mean-to-median ratio, income	2.70	1.61
Workers' share of income	0.760	0.711
CEO-worker pay ratio	95	89

Note: The Mean-to-median ratio and the percentile location of the mean come from Rodriguez et al. (2002). The workers' share of income is computed from NIPA. Table 1.10. The CEO-worker pay ratio is computed in Section 2.

5.4 Openness and Income Inequality

While the benchmark calibration used the iceberg trade costs τ and the fixed cost of starting foreign subsidiaries g to match the moments of trade volume and multinational sales in the data, we now examine how different measures of income inequality vary with τ and g. The first set of results compare the autarky equilibrium with the benchmark model, and the second set of results report the sensitivity of income inequality to continuous changes in the openness of trade.

Autarky and Trade We first show that opening to trade widens within-firm inequality. To do so, we compare the income of different individuals between autarky and the benchmark model. In "autarky," we set τ and g matrices high enough such that no trade and foreign investment takes place, while keeping all the other parameters the same as in the benchmark model. The first three panels in Figure 4 compare the income of the CEO and a worker with average human capital across three different firms in autarky and in trade. The firm in panel (a) is a domestic firm in trade equilibrium, the firm in panel (b) an exporter, and the firm in panel (c) a multinational firm.[27] The income of the average worker increases by around 9.1 percent from 0.22 to 0.24 in all three firms between autarky and trade. However, different CEOs see different income paths. The CEO at the domestic firm sees his/her income decrease by around 4.6 percent, the CEO at the exporting firm sees his/her income increase by around 23.3 percent, while the CEO at the multinational firm sees his/her income surge by as much as 225 percent. As a result, trade widens within-firm inequality for the large firms that sell to ROW: the CEO-to-worker pay ratio increases from 340 to 388 in the exporting firm, and from 928 to 2,769 in the multinational firm.

[27]To keep the results comparable between this section and the robustness check sections, we report the income of the CEO from the largest domestic, exporting, and multinational firm respectively in each graph.

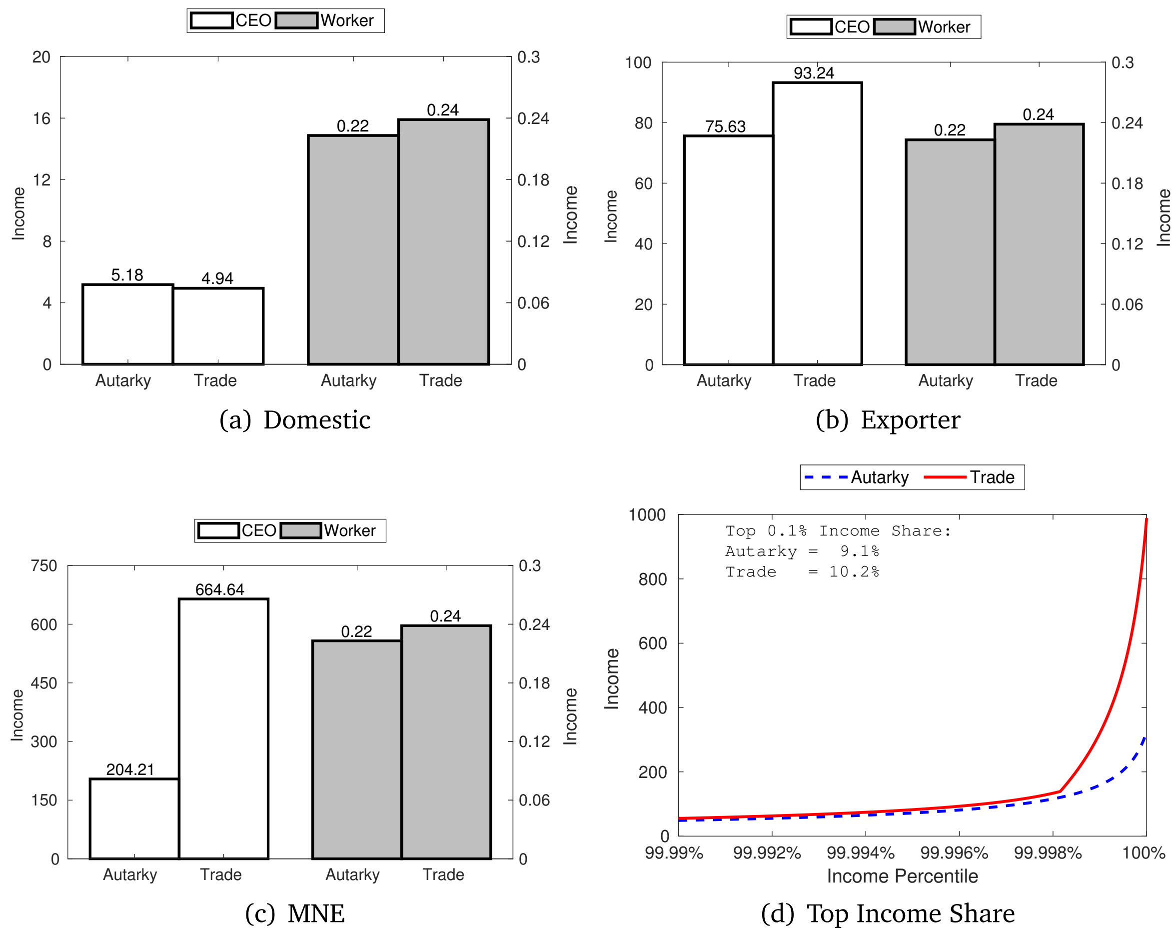


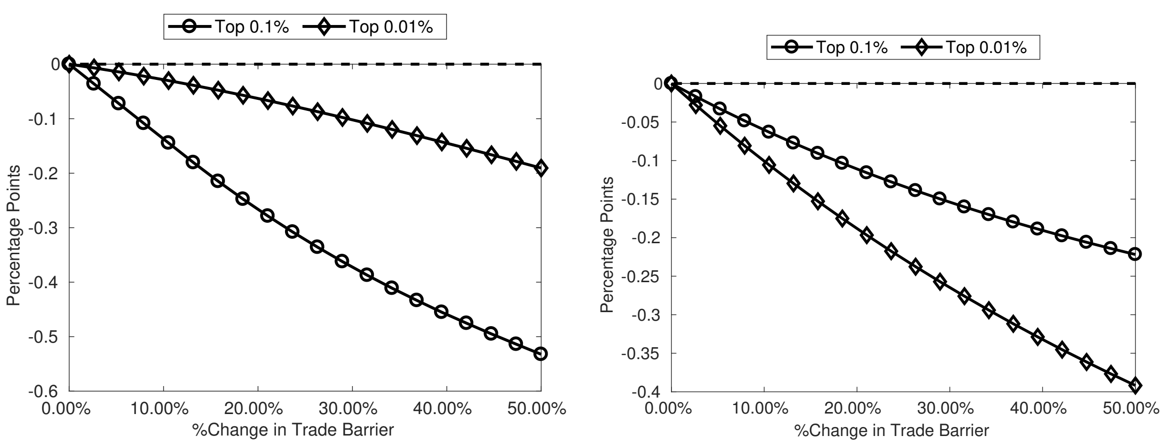
Figure 4: Income Inequality between Autarky and Trade, Benchmark Model

Note: The first three panels of the figure compares the income of the CEO and a worker with average endowment of human capital at three different firms in the economy. The last panel plots the income of top 0.1 percent in autarky v.s. in trade. "Autarky" means both τ and g are set to a large number so trade and FDI fall to 0. "Trade" means the benchmark model when both τ and g are calibrated so the exports-to-GDP ratio and multinational-sales-to-GDP ratio match the U.S. data in 2008.

Higher within-firm inequality translates into higher top income shares. The last panel in figure 4 compares the income of the top 0.1 percent of the population between autarky and the benchmark model. The income distribution is already skewed to the right in autarky, with the top 0.1 percent of the population claiming around 9.1 percent of total income. In trade equilibrium, the distribution is even more skewed to the right, with the top 0.1 percent income share increasing to 10.2 percent. This is a 1.1 percentage point change in absolute income shares, or a 12 percent increase in relative terms. In comparison, the top 0.1 percent income share increased by 2.6 percentage points between 1988 and 2008 in the U.S. data. Overall, the model seems to be able to explain a significant proportion of the change in top income share using the change in the volume of trade and FDI sales.

Top Income Shares, τ, and g In the next set of simulations, we study how different income shares respond to gradual changes in τ and g. We first gradually increase τ from the benchmark value, $\tau = 1.72$, by 50 percent to $\tau = 2.08$, while keeping all the other parameters at the benchmark value. As τ increases, the exports-to-GDP ratio drops from 0.129 (2008 value) to 0.042, which is roughly the level in early 1970s. Panel (a) of figure 5 presents how top 0.1 and top 0.01 income shares in the U.S. respond to changes in τ. Higher trade barriers hurt the top earners more than the rest of the distribution and lead to lower top income shares. For example, the top 0.1 percent income share drops by 0.53 percentage point, and the top 0.01 income share drops by 0.19 percentage point. Similarly, Panel (b) in the same figure presents the changes in income shares responding to the changes in g. Again, higher fixed costs to set-up foreign subsidiaries hurt the top income earners more: top 0.1 percent income share decreases by 0.22 percentage point, while the top 0.01 percent income share decreases by 0.39 percentage point, when g is 50 percent higher than the benchmark model.

Top Income Shares between 1988 and 2008 To quantify the impact of globalization on top income shares, we calibrate the model to match data on trade flows, multinational sales, and GDP and then compare the predicted income shares to those in the data. Specifically, we calibrate τ and g to match the export-to-GDP ratio and the multinational-sales-to-GDP ratio, and b_i to match the GDP ratio between ROW and the U.S. in each year between 1988 and 2008. All the other parameters are fixed at the benchmark value. The



(a) τ

(b) g

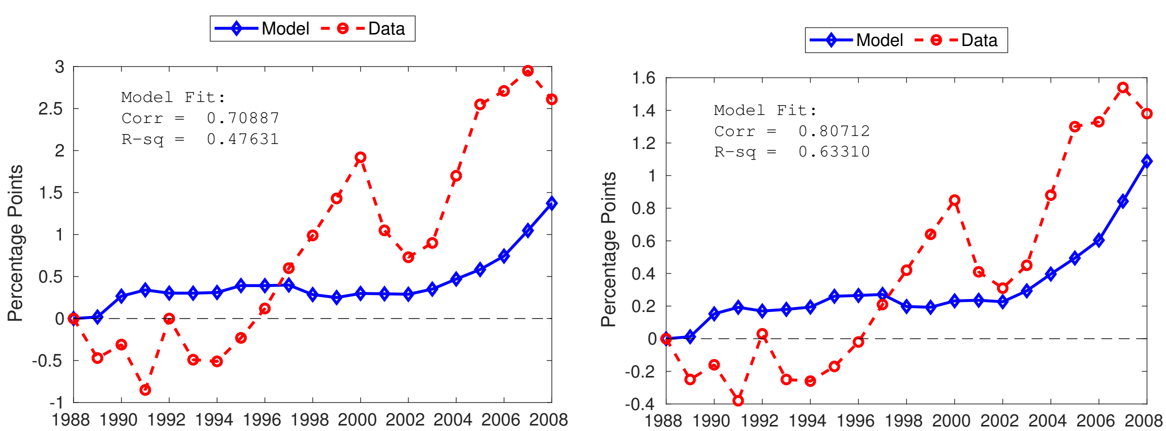
Figure 5: Income Shares and Barriers to Trade, Model Simulations

Note: This figure plots how income shares respond to changes in trade barriers τ and g. The vertical axis is the change in income shares as compared to the benchmark model. The horizontal axis is the percentage changes in τ and g as compared to the benchmark model.

values of τ, g and b_i are reported in Table B.5. Conditional on the calibrated τ, g, and b_i in each year, we solve the general equilibrium of the model, compute the measures of income inequality, and compare them to the data.

The model captures changes in top income shares between 1988 and 2008: the correlation between the annual changes in top 0.1 percent income shares in the model and the data is 0.71, and the adjusted R-squared of regressing the data series on the model series is 0.48. Panel (a) in figure 6 compares the data and model series over the 20-year period. The red dashed line is the change in the income share data between the year on the x-axis and 1988, expressed in percentage points, with the data coming from Table A.1 in Piketty and Saez (2003) updated through 2008. For example, the last point on this curve indicates that compared to 1988, the top 0.1 percent income share in 2008 is 2.61 percentage points higher. The blue solid line is the same measure in the model. Each point on the blue solid line is based on the top income share computed with the calibrated τ, g, and b_i in that year. The last point on the graph with the parameters calibrated to the moments in 2008 is the benchmark model.

Our model explains roughly half of the changes in top 0.1 percent income shares in the data. For example, between 2008 and 1988 the top 0.1 percent income share increased by 2.61 percentage points in the data and 1.37 percentage point in the model, indicating



(a) Top 0.1 Percent (b) Top 0.01 Percent

Figure 6: Top Income Share and Globalization over the Years

Note: This graph shows the change in top 0.1 percent and top 0.01 percent income shares in percentage points between 1988 and 2008. In the model simulation τ and g are calibrated to match the imports-to-GDP ratio and multinational-sales-to-GDP ratio in each year. For other model parameters behind this simulation, see Section 5.2. The source of the data is Table A.1 in the updated tables of Piketty and Saez (2003). Two measures of model fit are computed: the Pearson correlation between the two curves and the adjusted R-squared of estimating a linear relationship with data sequence on the left-hand-side and model sequence on the right (with constant term).

that 1.37/2.61≈ 52 percent of the change in top income shares can be explained using the changes in trade volumes and relative productivity. This result suggests that a large proportion of the observed change in aggregate income inequality can be explained through the channel of within-firm inequality: better access to foreign markets benefits the top executives more than it benefits the average workers, widening the income gap between the rich and the poor.

The explanatory power of the model varies from period to period. During the first period, from the beginning of the sample to around 1994, the top income shares fluctuate greatly from year to year in the data. This variation is largely driven by the short and long term effects of the 1986 Tax Reform Act.[28] This tax reform drastically changed the marginal tax rates and tax brackets for the top income earners, thus changing the tax reporting incentives. The short-term consequences of the 1986 TRA are reflected in the sharp increase in top income shares measured in the tax return data between 1986 and 1988 (not shown in the graph). The long-term consequences of the tax reform are less clear, but they can still be observed in the volatility of the data curve in Figure 6 before 1994. By contrast, the model economy exhibits a steady increase in income shares driven by the slow increases in trade and multinational sales. The discrepancy between the model and the data is expected because the model does not consider various effects of income tax. In the second phase, starting from 1994 until the 2001-2002 stock market crash, we start to observe a rapid increase in the top income share in the data, but only a modest increase in the model. The surge in top income shares in the data can probably be attributed to the rapid economic growth and the stock market boom. In the model world where no equity market exists, top income shares only respond to the changes in the volumes of trade and multinational sales, which grow slowly during this period. For example, the trade-to-GDP ratio in the U.S. only increased by around 0.15 percent point each year between 1994 and 2002. The low explanatory power of the model is again, expected, because the model is not designed to capture capital gains in the stock market. In the last phase from 2002 onwards, the explanatory power of the model is high. This is a period during which the trade-to-GDP ratio increases at the fastest pace (1.32 percentage points per year) after World War II. As a result, the trade-induced inequality increases rapidly in the model, matching the concurrent surge in top income shares in the data to a large extent.

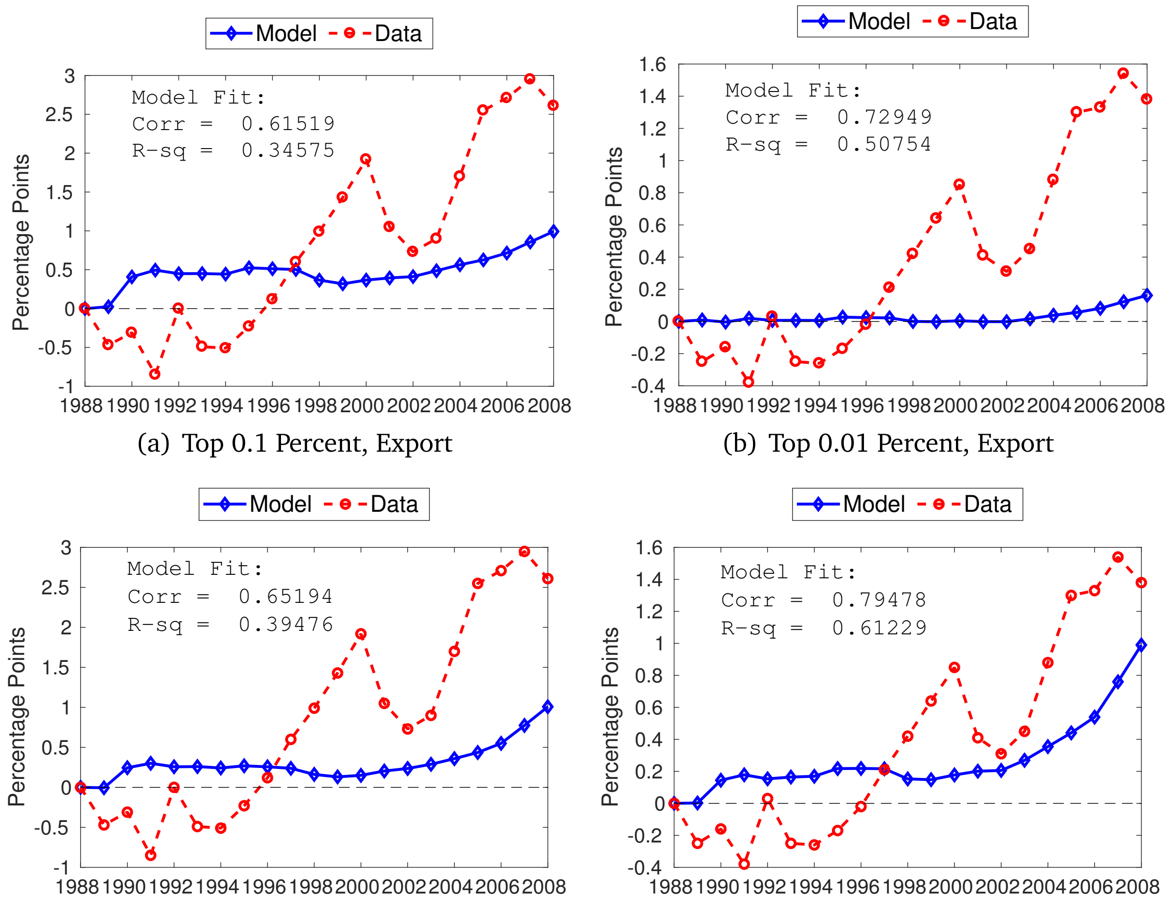
Repeating this analysis for the top 0.01 percent of the income distributions returns similar results as shown in panel (b) of figure 6. Between 1988 and 2008, the income share of the top 0.01 percent increased by 1.38 percentage points in the data, while it increased by 1.08 percentage points in the model; this suggests that the model can explain

[28] See Slemrod (1996) and Poterba and Feenberg (2000) for details.

a much higher ($1.08/1.38 \approx$ 78) percent of the change in the data in the top 0.01 percent as compared to the top 0.1 percent. With the model designed to explain the income of top executives in large corporations—executives who happen to occupy the pinnacle of the income pyramid—the explanatory power of the model declines as we move down the income ladder. For example, other occupations such as working professionals are among the top 0.1 or 1 percent of the income ladder in the real world, and they are missing in the model. The lower we move down the income ladder, the more frequent are these cases, and the lower the explanatory power of the model will be. It is important to understand how globalization affects different occupations differently, however, this is beyond the scope of this paper. The model does not attempt to provide a comprehensive theory to explain the surge of top income shares in developed countries. Instead, it highlights a particular channel through which globalization can affect the top income earners differently from the way it affects the general population.

The two channels of globalization, exporting and multinational sales, exert roughly equal influence on the top 0.1 percent income share. Figure 7 reports two counter-factual simulations in which we only allow one channel of globalization to move while fixing the other parameters. With the cost of starting foreign subsidiaries g_{ij} fixed, the movements in trade costs τ_{ij} can generate a 0.99 percentage point surge in the top 0.1 percent income share between 1988 and 2008. The movements in g_{ij} generate a similar percentage (1.05 percentage points) in the top 0.1 percent income share. At the top 0.01 percent, the reductions in g are more effective than those in τ (0.97 v.s. 0.16 percentage points), probably due to the higher concentrations of CEOs from the multinational firms within the top 0.01 percent.

Lastly, we show that changes in relative TFP across countries cannot explain the dynamics of top income shares alone without the expansion of the volume of trade and multinational sales. We run two counterfactual simulations to highlight this point. In the first simulation, we fix both τ and g to their benchmark values, and allow only the TFP vector b_i to vary from year to year. Conditional on year-specific b_i, we solve the model and compute the top income shares for each year, and compare them to the data. Without the expansion of the volume of trade and multinational sales, top income shares in the model do not follow the data as shown in the two two panels of Figure 8. The top 0.1 percent income share barely moves over time, and the top 0.01 income share actually decreases when τ and g are fixed at the benchmark value. In the second counter-factual, we do exactly the opposite exercise: we fix TFP at the 1988 level and allow τ and g to move. The results reported in the bottom two panels of figure 8 are basically identical to the baseline simulations in figure 6. This confirms the message from the top two panels:



(a) Top 0.1 Percent, Export

(b) Top 0.01 Percent, Export

(c) Top 0.1 Percent, FDI

(d) Top 0.01 Percent, FDI

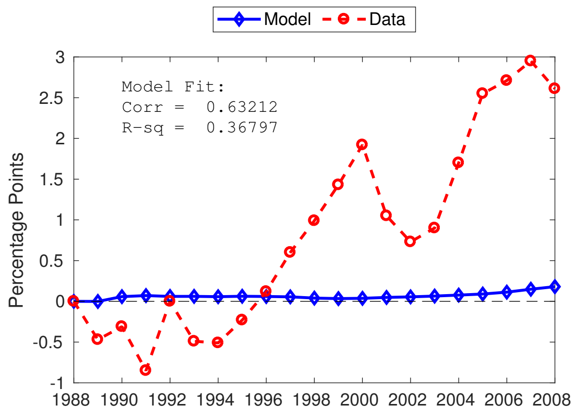
Figure 7: Exporting and FDI Liberalization

Note: This graph shows the change in top 0.01 percent and top 0.1 percent income shares in percentage points between 1988 and 2008 while we only allow for export (τ) or FDI (g) liberalization separately. For more details, see notes to Figure 6.

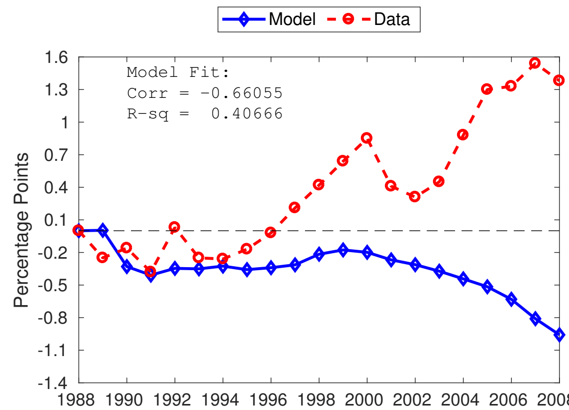
it is the the evolution of trade barriers, not the relative productivity that drives the pattern of top income shares.

5.5 Robustness Checks

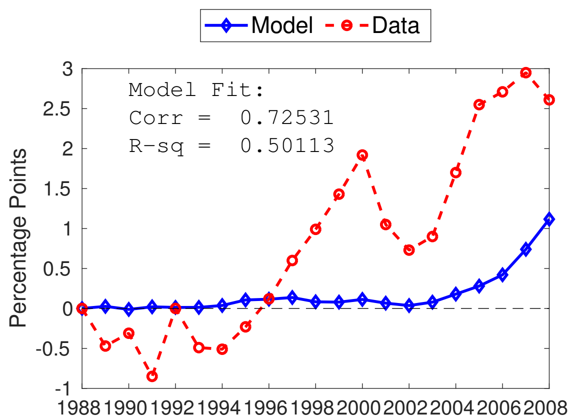
In this section, we show that the earlier analysis is robust to different values of the elasticity ϵ and the implied markup. In the benchmark model we calibrate $\epsilon = 4$ to capture the average markup. In this section we set ϵ to 2 and 6 and repeat the earlier analysis. In each of the robustness checks we re-calibrate every parameter to match the same moments as in the benchmark model; the re-calibrated parameters are reported in Table 6.



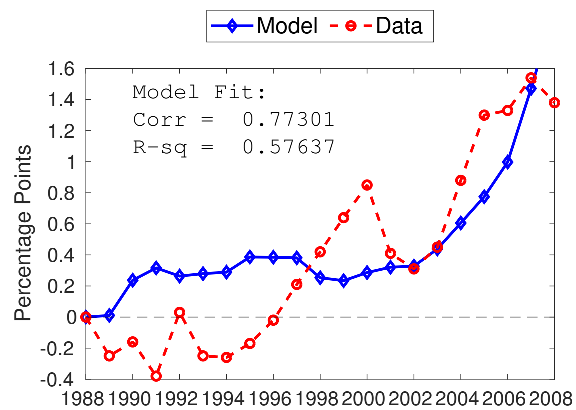
(a) Top 0.1 %, Only TFP Changes



(b) Top 0.01 %, Only TFP Changes



(c) Top 0.1 Percent, No TFP Changes



(d) Top 0.01 Percent, No TFP Changes

Figure 8: The Effects of TFP Changes

Note: This graph shows the change in top 0.1 percent and top 0.01 percent income shares in percentage points between 1988 and 2008. The change in the model is shown on the left axis, and the change in the data is shown on the right axis. In the model simulation, τ and g matrices are fixed at 1988 level, while TFP varies from year to year. For other model parameters behind this simulation, see Section 5.2. The source of the data is Table A.1 in the updated tables of Piketty and Saez (2003). Two measures of model fit is computed: the Pearson correlation between the two curves and the adjusted R-squared of estimating a linear relationship with data sequence on the left-hand-side and model sequence on the right (with constant term).

In general, when the elasticity of substitution is higher, the markup and profit margins of the firms decrease, the income distribution is less concentrated in the hands of the executives, and top income shares are less responsive to changes in trade barriers. Figure B.2 in the appendix reports the results when $\epsilon = 6$. The main results of the benchmark model carry through in this case with a smaller magnitude. In this case, the real income of workers increase by around 4.7 percent between autarky and trade, while the CEO at a multinational firm sees his/her income increasing by approximately 181 percent. The impact of trade can also be observed at the aggregate level: top 0.01 percent income share

Table 6: Calibration Targets and Results

Parameter	Benchmark	High ϵ	Low ϵ	Target/Source
λ	3.81	5.3	1.06	Axtell (2001)
ϵ	4.0	6.0	2.0	Average mark-up
α	23.2	29.5	461.1	Corporate sales as a percentage of all firms sales
β	0.747	0.747	0.747	Tail index of income dist., Drăgulescu and Yakovenko (2001b)
f_{11}	6.0	6.0	6.0	World Bank Doing Business Index
f_{12}	19.6	19.6	19.6	World Bank Doing Business Index
f_{21}	24.6	24.6	24.6	World Bank Doing Business Index
f_{22}	38.9	38.9	38.9	World Bank Doing Business Index
f-Scale	0.756	0.0476	10.56	Percentage. of chief execu. in work force.
n_{ROW}	6.0	6.0	6.0	Caselli (2005), Barro and Lee (2010)
b_{ROW}	0.58	0.58	0.47	Relative country size
s	3.249	2.202	8.72	Highest-CEO-to-average-wage ratio among public firms
τ	1.720	1.566	3.323	Export-GDP ratio in 2008
g	1020	3548	702	Multinational-sales-GDP ratio in 2008

Note: λ is the shape parameter of the exponential distribution. ϵ is the elasticity of substitution in the utility functions. α is the size of the smallest public firm. β is the tail index of the compensation function. f_{ij} is the fixed cost of exporting from country j to country i. f-Scale is the normalizing factor of the entire f_{ij} matrix. We divide the f_{ij} matrix by this number. n_i is the measure of capital-adjusted endowment of human capital in country i. b_i is the TFP in country i. s is the upper bound of human capital distribution. See Section 5.2 and the appendix for the details of calibration. See Table B.5 for the calibrated values of τ, g and TFP by year used in the counter-factual.

increases from 3.5 to 3.7 percentage points. Figure B.3 in the appendix reports the results when $\epsilon = 2$. Again, the main results of the benchmark model are preserved and even strengthened in this case due to the same reason outlined above. Between autarky and trade, the real income of the workers increases by 39 percent, while the income of the CEO at the multinational firm increases by 211 percent. At the aggregate level, the top 0.01 percent income share increases from 5.0 to 8.0 percentage points between autarky and trade.

6 Conclusion

This paper studies the relationship between globalization and income inequality with a special focus on the gap between the rich and the poor. Empirically, this paper presents a new fact that within-firm inequality is higher among the firms that have access to global markets. On average, the CEO-to-worker pay ratio is about 50 percent higher among the exporting firms than among domestic firms. The differences in within-firm inequality are mainly driven by differences in firm size. Using China's 2001 accession into the WTO as a trade shock, we also show that the U.S. firms with prior linkage to the Chinese market experienced higher exports and within-firm inequality during the years after China's accession using a difference-in-difference method.

This paper presents a new framework to study the distributional effect of trade. It merges the heterogeneous firms trade model with a model of occupational choice and executive compensation. The key mechanism to generate higher within-firm inequality among exporters and MNEs is through the size effect. On the one hand, CEO compensation is positively linked to the performance of the firm, and only the large and productive firms find it profitable to sell to the global markets. On the other hand, the wage rate is determined in a countrywide labor market and is not linked to each specific firm. These two forces imply that within-firm inequality is higher among the firms that have access to the global markets. We analytically show that trade liberalization leads to higher top income shares in general equilibrium. Using counterfactual analysis, we argue that the changes in trade barriers are able to quantitatively explain a large fraction of the surge in top income shares in the U.S. data.

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Online Appendix

A Data Descriptions

A.1 Publicly-Traded Firms

The empirical evidence on public firms is based on a linked data set that has three components. In this appendix we describe the details of the dataset.

The ExecuCompustat provides data on executive compensation. It reports the total realized and estimated compensation of the CEO, CFO, and three other highly paid executives of U.S. public firms in the S&P Composite 1500 Index from 1992 onward.[29] The executive compensation consists of salary, bonus, stock options, long term incentive plans (LTIPs), restricted stock awards, and all others. "Realized" compensation (variable name: TDC2) measures the value of stock option awards at the time of execution, while "estimated" compensation (variable name: TDC1) measures the value of stock options at the time of granting using the Black-Scholes formula.[30]

The confidential Census Bureau databases provide the other key variables needed to measure within-firm inequality and exporting status. The LBD is compiled from the Census Bureau's Business Register, which covers the universe of U.S. firms at the establishment level. We aggregate it up to the firm level and extract annual employment and payroll variables, which are used to compute the average non-executive wage for each firm in a given year. The LBD is linked to the last component of the data set, the LFTTD, using the methods described in McCallum (2013). The LFTTD records the universe of individual international trade transactions made by U.S. firms based on the data collected by U.S. Customs from 1992 onward. It links each export transaction to the U.S. exporting firm and thus provides the base to identify exporting firms in each year. The final linkage between ExecuCompustat and the linked LBD-LFTTD is done through the Compustat-SSEL Bridge provided by the Census Bureau. Table A.1 and A.2 provide summary statistics of the combined data set.

[29] The Securities and Exchange Commission (SEC) requires public firms to disclose the total compensation of at least five said executives starting from 1992. Any firm that was once included in the S&P 1500 Index is included in the sample, even if the firm is later dropped from the index. The S&P 1500 Index is the union of three commonly used indices: S&P 500 (LargeCap), S&P MidCap 400 Index, and S&P SmallCap 600 Index. This index covers approximately 90 percent of the total U.S. public firm capitalization.

[30] In 2006, the SEC changed the disclosure rule on executive compensation, which makes the raw data before and after 2006 not directly comparable. The ExecuCompustat data set takes this into account when constructing TDC1 and TDC2 so these two variables can be used for the entire sample.

Table A.1: Sector Composition: Public Firm Sample

Sector	Matched Data Percent	Matched Data N.Obs.	ExecuCompustat Percent	ExecuCompustat N.Obs.
Mineral & Construction	4.39%	751	5.44%	1876
Manufacturing	46.15%	7892	42.51%	14649
Transportation, Communications and Utilities	10.79%	1845	11.24%	3873
Wholesale and Retail Trade	12.36%	2113	11.49%	3960
Finance, Insurance and Real Estate	13.91%	2379	15.28%	5265
Services	12.40%	2121	14.03%	4835
Other	0.71%	122	0.69%	239
Total	100.00%	17223	100.00%	34697

Note: This table reports the sectoral composition of the firm-year observations in the linked ExecuCompustat-LBD-LFTTD data set and compares the distribution with the original ExecuCompustat data set. The sector definition is based on a one-digit SIC code.

Table A.2: Summary Statistics: Public Firm Sample

Mean	Exporters	Non-Exporters	Overall
CEO Compensation, Estimated	4487.7	3254.3	4197.1
CEO Compensation, Realized	4662.4	3340.4	4350.8
CEO-to-worker Pay Ratio, Estimated	91.9	80.8	89.3
CEO-to-worker Pay Ratio, Realized	91.8	79.6	88.9
N. Observations	13169	4054	17223

Note: This table reports the mean of key variables of the linked ExecuCompustat-LBD-LFTTD data set. The unit of observation is firm-year. Executive compensations are measured in thousands of U.S. dollars. For the difference between estimated and realized compensation, see Section 2.

A.2 Privately-Held Firms

The evidence on privately-held firms in the US is based on the linked CIQ-LBD-LFTTD dataset. In this appendix we describe the details of the datasets.

To construct the dataset, we start with executives working in private U.S. firms between 2003 and 2007 from the CIQ data. This yields a data set that contains around 33,000 individuals working in 3,849 privately held firms and 11,706 firm-year level observations. We then link this data set to the Standard Statistical Establishment List (SSEL) in the Census Bureau. Unlike the ExecuCompustat, where the bridge files exist and firms can be matched using standardized identifiers, the CIQ data have not been linked to the census data sets before. Therefore, we carry out a fuzzy match based on name, street address, and zip code. We require that the weighted similarity has to be at least 95 percent for two entries to be considered a match and then hand-screen all the matched records to eliminate obvious errors. The matched CIQ records are then linked with LBD-LFTTD constructed by McCallum (2013).

Table A.3 summarizes the results of the fuzzy merge and compares the distribution of firms across sectors in the linked data set and the original CIQ data. The linked data set contains 6,002 firm-year observations and 2202 unique firms. A total of 3,366 firm-year observations and 1,207 unique firms are exporting firms, while the remaining 2,636 observations with 9,95 unique firms are non-exporters. Overall, 51 percent of the CIQ records are matched with the census data. The sectoral distribution of the CIQ is preserved in the linked data set. For example, manufacturing firms constitute 33.8 percent in the linked data and 34.4 percent in the original data; financial firms are responsible for 22.0 percent in the linked data and 18.9 percent in CIQ.

Instead of the CEO-to-worker pay ratio, we construct the ratio between the highest-paid executive and the non-executive wage as the benchmark measure of intra-firm inequality. The CIQ data does not report standardized job titles, and therefore, constructing the CEO title from the raw data would introduce unnecessary noise. Nevertheless, most of the highest-paid executives are indeed CEOs: in ExecuCompustat, more than 98 percent of the highest-paid executives are the CEOs. There is no strong reason to believe that this ratio will be significantly different in the CIQ sample.

The summary statistics of the top-1-to-worker pay ratio are reported in Table A.4. Overall, within-firm inequality is lower among private firms than among public firms. The top-1-to-worker pay ratio is 37.6 in the private firm sample compared with 89 in the public firm sample. Again, the top-1-to-worker pay ratio varies with exporting status. The ratio is 41.3 among exporters and only 32.8 among non-exporters.

Table A.3: Sector Composition: Private Firm Sample

	Matched Data		Capital IQ	
Sector	Percent	N.Obs.	Percent	N.obs.
Mineral & Construction	3.32%	199	4.13%	483
Manufacturing	33.86%	2032	34.44%	4032
Transportation, Communications and Utilities	10.71%	643	10.23%	1197
Wholesale and Retail Trade	9.30%	558	9.18%	1075
Finance, Insurance and Real Estate	21.98%	1319	18.85%	2206
Services	19.99%	1200	21.80%	2552
Other	0.85%	51	1.38%	161
Total	100.00%	6002	100.00%	11706

Note: This table reports the sectoral composition of the firm-year observations in the linked CIQ-LBD-LFTTD data set and compares the distribution with the original Capital-IQ data set. The sector definition is based on one-digit SIC code.

Table A.4: Summary Statistics: Private Firm Sample

Mean	Exporters	Non-Exporters	Overall
Top 1 Compensation, Estimated	2626.9	1731.2	2233.5
Top 1 Compensation, Realized	2157	1522.1	1878.2
Top-1-to-worker Pay Ratio, Estimated	49.8	36.7	44
Top-1-to-worker Pay Ratio, Realized	41.3	32.8	37.6
N. Observations	3366	2636	6002

Note: This table reports the mean of key variables of the linked CIQ-LBD-LFTTD data set. The unit of observation is firm-year. Executive compensations are measured in thousands of U.S. dollars. For the difference between estimated and realized compensation, see Section 2.

A.3 Multinational Firms

The evidence on multinational firms is based on the same dataset as our baseline estimation. The multinational firm indicators are constructed from the geographic segment data in Compustat. We classify a firm-year observation as multinational if a U.S. firm reports the existence of a non-domestic geographic segment, such as a foreign division. The multinational indicators from segment data are then linked with the ExecuCompustat-LBD. The resulting data set contains 12,943 firm-year observations and 1,606 unique firms. Out of these firm-year observations, 5,885 records are classified as non-MNE and the rest 7,058 as MNE. On average, the CEO-to-worker pay ratio is 87.4 among the non-MNE group and 100.0 among the MNE group.

B Additional Tables and Figures

B.1 Additional Evidence on Export Status

To complement section 2.2, we present additional evidence of the robust correlation between participation in international markets and within-firm inequality. In panel A of Table B.1, we show that exporting status is positively correlated with within-firm inequality even when CEO compensation is measured by its subcomponents: CEO salary, bonus, and stock & options. Column (6) shows that the key correlation is also positive when we measure inequality relative to the compensation of the top 5 executives. In panel B we first modify estimating equation (1) to include different forms of fixed effects, firm-specific time trends, and we employ different forms of clustering; the core positive relationship between exporting status within-firm inequality persists. In column (5) we show that multinational firms have 23.6% higher within-firm inequality than non-multinationals. Panel C uses the data on compensation within privately-held firms to document a positive relationship between exporting status and different measures of executive compensation among private firms. Table B.2 replicates table 2 while replacing employment and payroll with sales and assets as measures of firm size.

Table B.1: Robustness: Within-Firm Inequality and Export Status

Panel A: Public Firms	Log CEO-to-Worker Pay Ratio					
	(1)	(2)	(3)	(4)	(5)	(6)
Exporter	0.507***	0.486***	0.213***	0.508***	0.855***	0.477***
	0.030	(0.029)	(0.023)	(0.035)	(0.071)	(0.027)
CEO Compensation	Baseline (Actual)	Estimated	Salary	Bonus	Stock & Options	Top 5 Executives
Sample	All	All	All	All	All	All
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Group Fixed Effects	Sector	Sector	Sector	Sector	Sector	Sector
Observations	17,000	17,000	17,000	13,000	17,000	16,000
R-squared	0.270	0.266	0.370	0.340	0.182	0.341

Panel B: Public Firms	Log CEO-to-Worker Pay Ratio				
	(1)	(2)	(3)	(4)	(5)
Exporter	0.507***	0.537***	0.507***	0.087***	
	0.030	(0.032)	(0.047)	(0.028)	
MNE					0.236***
					(0.028)
Robustness	Baseline	Year×Sector Fixed Effects	Cluster at Firm Level	Firm-Specific Time Trend	Multinational Enterprise
Sample	All	All	All	All	All
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes
Group Fixed Effects	Sector	Sector	Sector	Sector	Sector
Observations	17,000	17,000	17,000	17,000	13,000
R-squared	0.270	0.413	0.270	0.962	0.277

Panel C: Private Firms	Log Highest-Paid-Executive-to-Worker Pay Ratio					
	(1)	(2)	(3)	(4)	(5)	(6)
Exporter	0.411***	0.442***	0.168***	0.313***	0.544***	0.390***
	0.055	(0.052)	(0.036)	(0.086)	(0.103)	(0.054)
Executive Compensation	Actual	Estimated	Salary	Bonus	Stock & Options	Top 5 Executives
Sample	All	All	All	All	All	All
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Group Fixed Effects	Sector	Sector	Sector	Sector	Sector	Sector
Observations	6,000	6,000	5,000	4,000	5,000	5,000
R-squared	0.402	0.363	0.497	0.388	0.393	0.429

Table B.2: Robustness: Within-Firm Inequality, Export Status, and Firm Size

Panel A: Within-Firm Inequality and Firm Size in the United States

Dependent Variable	Log CEO-to-Worker Pay Ratio			
	(1)	(2)	(3)	(4)
Log Sales	0.423***	0.437***		
	(0.010)	(0.007)		
Log Assets			0.427***	0.425***
			(0.009)	(0.007)
Sample	Manufacturing	All	Manufacturing	All
Year Fixed Effects	Yes	Yes	Yes	Yes
Group Fixed Effects	Sector	Sector	Sector	Sector
Observations	8,000	17,000	8,000	17,000
R-squared	0.417	0.439	0.407	0.428

Panel B: Within-Firm Inequality and Export Status, Controlling for Firm Size

Dependent Variable	Log CEO-to-Worker Pay Ratio			
	(1)	(2)	(3)	(4)
Exporter	0.047	0.024	0.295***	0.062**
	(0.091)	(0.025)	(0.079)	(0.025)
Log Sales	0.422***	0.436***		
	(0.010)	(0.007)		
Log Assets			0.424***	0.420***
			(0.011)	(0.007)
Sample	Manufacturing	All	Manufacturing	All
Year Fixed Effects	Yes	Yes	Yes	Yes
Group Fixed Effects	Sector	Sector	Sector	Sector
Observations	8,000	17000	8,000	17000
R-squared	0.417	0.439	0.407	0.428

Note: The left-hand side variable for each of the regressions is the (log of) CEO-to-worker pay ratio. "Exporter" is the exporter indicator computed from LFTTD. Exports are dollar values of shipments from LFTTD. Sales are the total annual sales reported in COMPUSTAT. Assets are the total assets reported in COMPUSTAT. The unit of observation is firm-year and the time period spans 1992 through 2007. See Table A.1 for sector distribution of the sample. Robust standard errors are clustered at the year-sector level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

B.2 Additional Evidence on the Trade Shock

To highlight the source and timing of our identification, we compare across different periods the within-firm inequality for firms with and without China-specific trade relationships. To that effect, we plot in Figure B.1 the coefficients γ_p measuring the period-p difference in within-firm inequality from a pooled regression of the following form:

$$\text{Outcome}_{\text{it}} = \delta_0 + \mathbf{d'}_1 \cdot \mathbf{f} + \mathbf{d'}_2 \cdot \mathbf{y} + \sum_{p=1}^{P} \gamma_p \text{Treatment}_i \times \text{Period}_p + \epsilon_{it}, \tag{12}$$

where Period_p partitions our sample into consecutive three-year blocks of time and Treatment_t is an indicator for firms that exported to China between 1999 and 2001.[31] Prior to China's WTO accession, the relative within-firm inequality γ_p is not statistically distinguishable from zero. Nonetheless, over the pre-WTO period, the point estimates of γ_p increase from 3% at the start to 13% just before the WTO accession. The impact of the WTO accession is driven by the 2005-2007 period when the treated firms have 25% higher inequality—a differential effect that can also be statistically distinguished from zero.

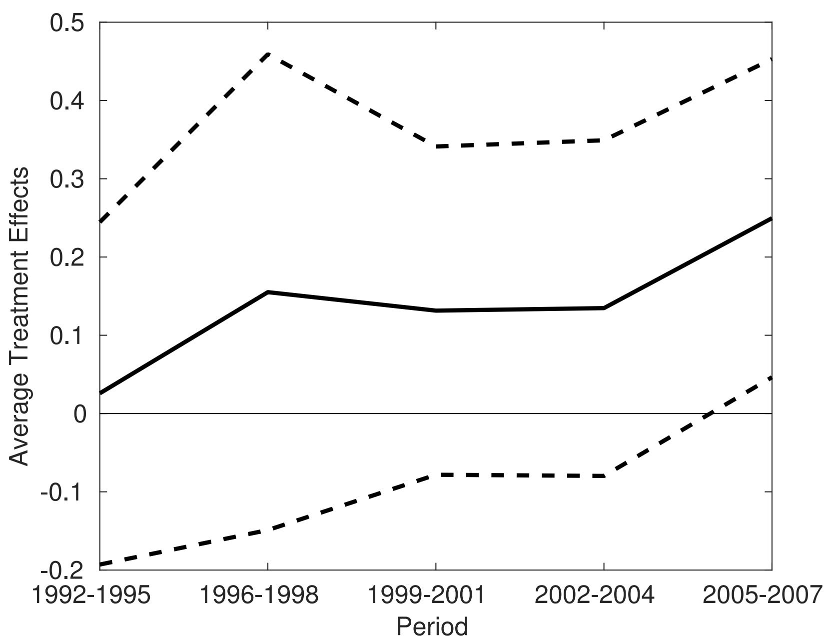


Figure B.1: Average Treatment Effect for CEO-to-Worker Pay Ratios across Time

Note: This figure plots estimated regression coefficients γ_p of the period-by-period difference in within-firm inequality for firms that exported to China between 1999 and 2001 relative to the control group. The dashed lines are 95 percent confidence intervals.

[31]More detailed definitions of time periods would not have permitted us to disclose all coefficients from regression (12).

To allay potential concerns about the timing of the trade shock, we repeat the earlier analysis using a window that includes 2001, the year of the WTO accession, into the definition of the treatment. The results are qualitatively and quantitatively similar to those from the baseline table 3. Specifically, in table B.3 we redefine the treated firms to be those that exported to China in the period 1999-2001 instead of the period 1998-2000. For manufacturing firms with this pre-existing China-specific relationship, China's accession to the WTO led to a 77.9% increase in exports and an 11.2% increase in the CEO-to-worker pay ratio. When we include firms in all sectors, we estimate a 43.9% increase in exports and a 10.3% increase in within-firm inequality. Taking the ratio of our estimates for trade-driven changes in inequality and firm size, we–as based on table 3–derive an elasticity implying that a 1% increase in firm size leads to a 0.2-0.3%.

Table B.3: China's Accession to the World Trade Organization and Within-Firm Inequality
Robustness: Including Accession Year 2001 in Treatment Definition

Panel A: Exports and CEO-to-Worker Pay Ratio

Dependent Variable (log)	Exports	CEO-to-Worker Pay Ratio	Exports	CEO-to-Worker Pay Ratio
	(1)	(2)	(3)	(4)
Treatment × Post	0.779***	0.112*	0.439***	0.103*
China WTO Accession	(0.122)	(0.063)	(0.111)	(0.053)
Treatment	Exporter to China 1999-2001		Exporter to China 1999-2001	
Sample	Manufacturing		All	
Year Fixed Effects	Yes	Yes	Yes	Yes
Firm Fixed Effects	Yes	Yes	Yes	Yes
Observations	8,000	8,000	13,000	17,000
R-squared	0.909	0.714	0.930	0.755

Panel B: Employment and Payroll

Dependent Variable (log)	Employment	Payroll	Employment	Payroll
	(1)	(2)	(3)	(4)
Treatment × Post	0.594***	0.601***	0.321***	0.326***
China WTO Accession	(0.070)	(0.072)	(0.052)	(0.054)
Treatment	Exporter to China 1999-2001		Exporter to China 1999-2001	
Sample	Manufacturing		All	
Year Fixed Effects	Yes	Yes	Yes	Yes
Firm Fixed Effects	Yes	Yes	Yes	Yes
Observations	8,000	8,000	17,000	17,000
R-squared	0.927	0.919	0.936	0.921

Note: The left-hand side variable for each of the regressions is the (log of) CEO-to-worker pay ratio. "Exporter" is the exporter indicator computed from LFTTD. Exports are dollar values of shipments from LFTTD. Employment is the total annual employment reported in LBD. Payroll is the total annual payroll reported in LBD. The unit of observation is firm-year and the time period spans 1992 through 2007. See Table A.1 for sector distribution of the sample. Robust standard errors are clustered at the year-sector level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

B.3 Additional Information on the Calibration

Table B.4: Countries Included in Calibration

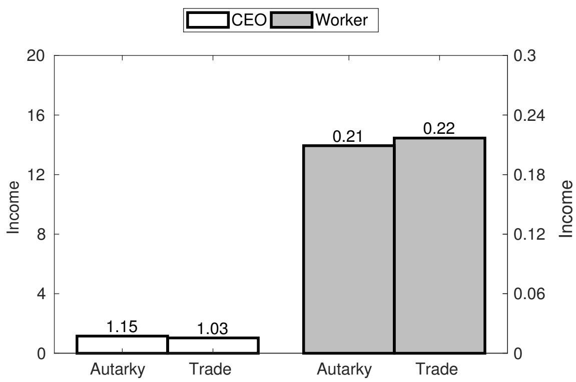
Afghanistan	Cote d'Ivoire	Iraq	Nepal	Spain
Albania	Denmark	Ireland	Netherlands	Sri Lanka
Algeria	Dominican	Israel	New Zealand	Sudan
Argentina	Ecuador	Italy	Nicaragua	Sweden
Australia	Egypt	Jamaica	Niger	Switzerland
Austria	El Salvador	Japan	Norway	Syria
Bangladesh	Fiji	Jordan	Pakistan	Tanzania
Belgium	Finland	Kenya	Panama	Thailand
Benin	France	Korea	Papua New Guinea	Togo
Bolivia	Germany	Laos	Paraguay	Tonga
Botswana	Ghana	Lesotho	Peru	Trinidad &Tobago
Brazil	Greece	Malawi	Philippines	Tunisia
Bulgaria	Guatemala	Malaysia	Poland	Turkey
Burundi	Guyana	Maldives	Portugal	Uganda
Cameroon	Haiti	Mali	Romania	United Arab Emirates
Canada	Honduras	Mauritania	Rwanda	United Kingdom
Central African	Hong Kong	Mauritius	Saudi Arabia	United States
Chile	Hungary	Mexico	Senegal	Uruguay
China	Iceland	Mongolia	Sierra Leone	Venezuela
Colombia	India	Morocco	Singapore	Vietnam
Congo	Indonesia	Mozambique	Slovak	Zambia
Costa Rica	Iran	Namibia	South Africa	Zimbabwe

Note: This table reports the list of countries (110 in total) included in the calibration. All the countries except the U.S. are included in ROW. The GDP and population data are based on Penn World Table 7.0 in the year 2008. GDP is in the unit of constant 2005 international dollar and calculated as the product of *RGDPL* and *POP*.

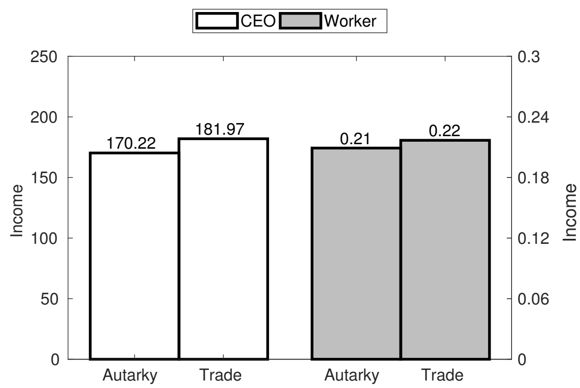
Table B.5: τ, g, and TFP

	τ	g	TFP, ROW
1988	1.930	6389.846	0.406
1989	1.906	6363.507	0.405
1990	1.911	4204.818	0.463
1991	1.896	3831.308	0.476
1992	1.891	4110.471	0.466
1993	1.894	4019.989	0.467
1994	1.873	4024.921	0.463
1995	1.834	3662.035	0.468
1996	1.826	3686.147	0.465
1997	1.808	3742.491	0.461
1998	1.830	4336.815	0.444
1999	1.832	4447.511	0.438
2000	1.812	4197.577	0.442
2001	1.854	3915.460	0.453
2002	1.884	3808.301	0.460
2003	1.878	3361.962	0.470
2004	1.843	2880.914	0.482
2005	1.821	2481.549	0.494
2006	1.797	2063.574	0.514
2007	1.760	1440.825	0.546
2008	1.720	1020.479	0.577

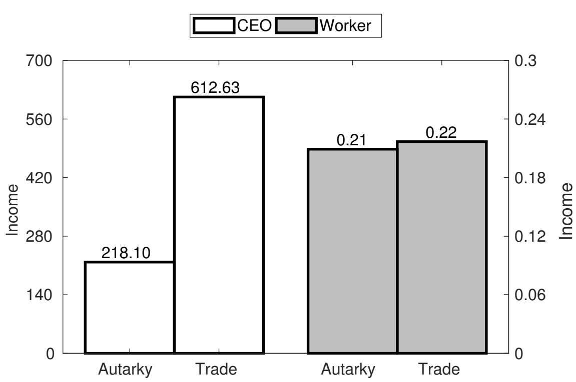
Note: This table reports the calibrated trade cost τ, g, and the estimated TFP. The τ and g matrices are assumed to be symmetric. The calibrated τ and g assume that the TFP for both countries is fixed at the 1988 level. The TFP reported is calculated to match the GDP ratio between the U.S. and ROW in each year. The TFP in the U.S. is always normalized to 1.



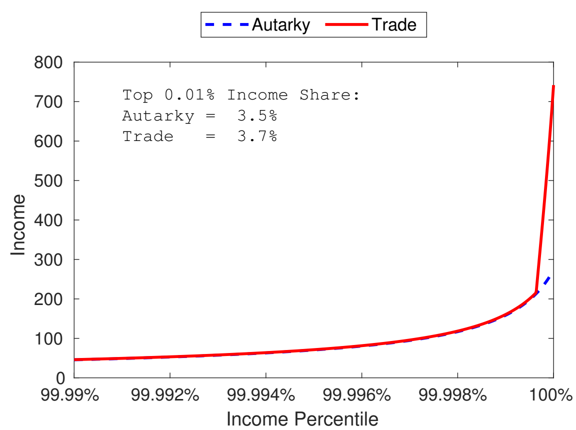
(a) Domestic Firms



(b) Exporting Firms



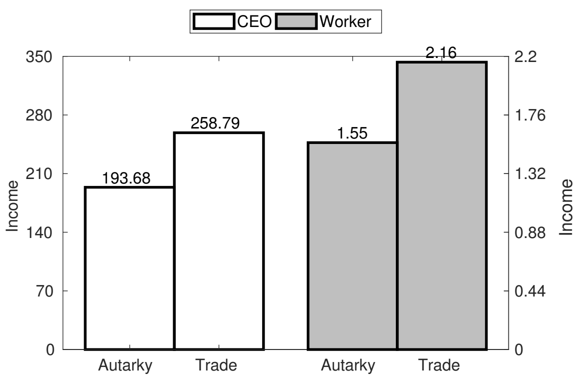
(c) MNE



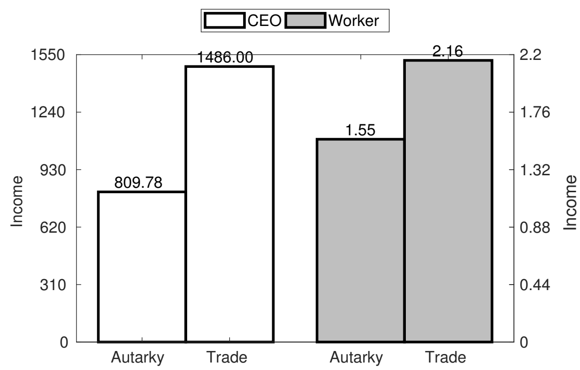
(d) Top Income Share

Figure B.2: Income Inequality Between Autarky and Trade, $\epsilon = 6$

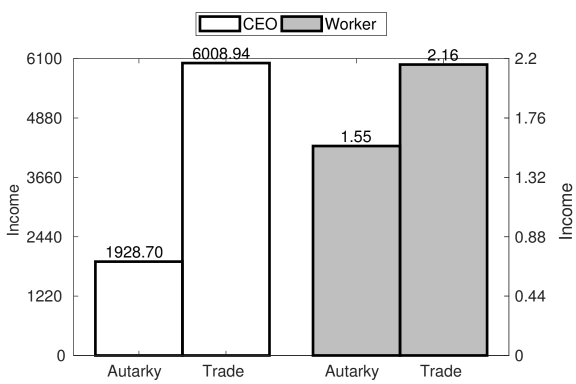
Note: This figure plots how income inequality changes between autarky and trade for the case when $\epsilon = 6$. For more details, see the notes to Figure 4.



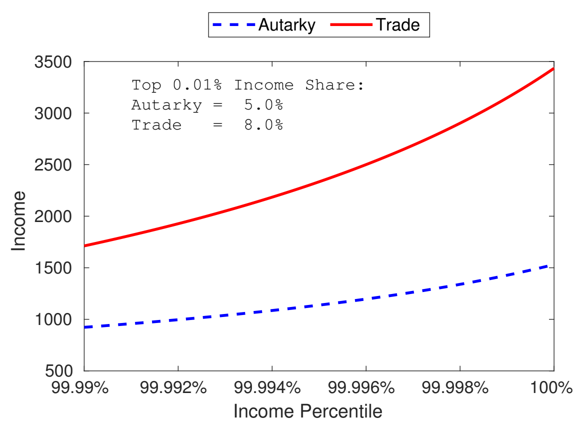
(a) Domestic Firms



(b) Exporting Firms



(c) MNE



(d) Top Income Share

Figure B.3: Income Inequality Between Autarky and Trade, $\epsilon = 2$

Note: This figure plots how income inequality changes between autarky and trade for the case when $\epsilon = 2$. For more details, see the notes to Figure 4.

C Details of the Model

C.1 The Firm's Problem

Denote the total expenditure in country i as H_i, the ideal price level as P_i. If a firm in country j wants to sell to the market i, denote the price of the good as $p_{ij}(x)$ and the marginal cost (iceberg cost included) of selling to market i as $M_{ij}(x)$. The firm solves the following problem:

$$\begin{aligned} \max_{q_{ij}(x)} \quad & p_{ij}(x)q_{ij}(x) - M_{ij}(x)q_{ij}(x), \\ \text{s.t.} \quad & p_{ij}(x) = H_i^{\frac{1}{\epsilon}} P_i^{\frac{\epsilon-1}{\epsilon}} q_{ij}(x)^{-\frac{1}{\epsilon}}, \end{aligned}$$

where the constraint of the maximization problem is the inverse of the derived demand function from solving the consumer's problem in market i.

The solution of the above maximization problem is

$$q_{ij}(x) = H_i P_i^{\epsilon-1} \left(\frac{\epsilon}{\epsilon-1} M_{ij}(x) \right)^{-\epsilon}, \tag{13}$$

$$p_{ij}(x) = \frac{\epsilon}{\epsilon-1} M_{ij}(x). \tag{14}$$

Equation (14) is the result of plugging equation (13) into the inverse derived demand function.

The marginal cost of supplying to market i depends on the productivity of the firm, as well as the method through which the firm chooses to serve market i. If market i is served by a domestic firm or by an exporter in country j, then:

$$M_{ij}(x) = \frac{\tau_{ij} w_j}{A_j(x)}.$$

In the special case of $i = j$, market i is served by the domestic firm in country i:

$$M_{ii}(x) = \frac{w_i}{A_i(x)}.$$

If market i is served by an MNE founded in country j, then

$$M_{ij}(x) = \frac{w_i}{A_j(x)}.$$

The sales to market i, $\sigma_{ij}(x)$ is therefore

$$\sigma_{ij}(x) = p_{ij}(x)q_{ij}(x) = H_i P_i^{\epsilon-1} \left(\frac{\epsilon}{\epsilon - 1} M_{ij}(x) \right)^{1-\epsilon}.$$

To supply $q_{ij}(x)$ to market i, the labor used in production is

$$L_{ij}(x) = H_i P_i^{\epsilon-1} \left(\frac{\epsilon}{\epsilon - 1} M_{ij}(x) \right)^{\epsilon} \frac{\tau_{ij}}{A_j(x)},$$

with the understanding that when $i = j$, $\tau_{ij} = 1$.

The profit earned in market i before the fixed cost is

$$[p_{ij}(x) - M_{ij}(x)]q_{ij}(x) = \frac{H_i}{\epsilon} P_i^{\epsilon-1} \left(\frac{\epsilon}{\epsilon - 1} M_{ij}(x) \right)^{1-\epsilon}$$

To ensure that firms sort into non-exporters, exporters, and multinational firms by productivity, we impose the following assumption similar to the one used in Helpman et al. (2004):

$$\frac{g_{ji}}{f_{ji}} \geq \left(\frac{\tau_{ji} w_i}{w_j} \right)^{\epsilon-1}$$

This equation implies that only the most productive firms will engage in FDI, while the other productive firms choose export over FDI.

A similar restriction needs to be imposed to ensure the separation of the domestic firms: we need to make sure that in equilibrium, not all the firms choose to sell to the foreign market. In a Melitz model, this condition can be written down explicitly. Unfortunately, it is not possible to do so for this paper. The reason is that x_i^* does not admit a closed-form solution. Nevertheless, characterization of the restriction is still possible. Generally, we need the market size of the home country to be above a certain level relative to the foreign country, or the variable trade cost to be above a certain level, so the firms in the home country will not find exporting to the foreign country too easy. In all the results presented in this paper, the separation of firms into domestic and exporting/multinational firms is checked and ensured.

C.2 The Equilibrium Conditions

The first three equilibrium conditions on cutoff human capital levels are self-evident. Here we explain the other two equilibrium conditions in detail. In this section, we derive the equilibrium conditions under truncation.

Income-Expenditure Identity The third equilibrium condition, equation (7), requires that the total expenditure and total income in country i must be the same:

$$H_i = n_i w_i \int_0^{x_i^*} x f_i(x) dx + n_i \int_{x_i^*}^{\infty} \pi_i(x) f_i(x) dx. \tag{15}$$

Total expenditure is denoted as H_i. Total income consists of two parts: the total labor income and the total profits. The CEO compensation function, $k(\pi)$, does not enter the accounting equation. The difference between the profit and the CEO compensation at each firm is distributed to all the individuals in the same country, and therefore $k(\pi)$ does not matter for total income.

The total labor income is easy to compute. It is the wage rate $w(i)$ times the total labor supply:

$$w_i \cdot \left(n_i \int_0^{x_i^*} x f_i(x) dx \right) = w_i n_i \frac{\lambda}{1 - e^{s_i \lambda}} \int_0^{x_i^*} x e^{-\lambda x} dx, \tag{16}$$

$$= \frac{w_i n_i}{(1 - e^{-\lambda s_i} \lambda)} \left[e^{-\lambda x_i^*} (-\lambda x_i^* - 1) + 1 \right], \tag{17}$$

$$= w_i n_i \frac{F(x_i^*)}{\lambda} - \frac{n_i x_i^* e^{-\lambda x_i^*}}{1 - e^{-\lambda s_i}}, \tag{18}$$

$$= w_i \cdot \underbrace{\left\{ \frac{n_i}{\lambda} [F(x_i^*) - x_i^* f(x_i^*)] \right\}}_{\text{Labor Supply}}, \tag{19}$$

where $f(.)$ is the PDF of the truncated exponential distribution. The part in the curly brackets is the total labor supply in country i.

The total profit in country i is composed of three parts: the profit earned in the home country i, the profit earned in the other country j through export, and the profit earned in country j through FDI. This three-part separation is not the same as separating the profits into firms in the three corresponding groups. The difference is that, the profits earned in the home country i includes the profits from all the firms, as the exporters and MNEs also sell to the home market.

The total profit earned in the home market i is

$$n_i \int_{x_i^*}^{s} \frac{H_i}{\epsilon} P_i^{\epsilon - 1} \left(\frac{\epsilon}{\epsilon - 1} w_i \right)^{1-\epsilon} (b_i e^x)^{\epsilon - 1} f_i(x) dx - n_i f_{ii} w_i [1 - F(x_i^*)].$$

The total profit earned in the foreign market though exporting is

$$n_i \int_{x_{ji}^e}^{x_{ji}^f} \frac{H_j}{\epsilon} P_j^{\epsilon-1} \left(\frac{\epsilon}{\epsilon-1}\tau_{ji} w_i\right)^{1-\epsilon} (b_i e^x)^{\epsilon-1} f_i(x) dx - n_i f_{ji} w_i [F(x_{ji}^f) - F(x_{ji}^e)],$$

and the total profit earned in the foreign market through FDI is

$$n_i \int_{x_{ji}^f}^{s} \frac{H_j}{\epsilon} P_j^{\epsilon-1} \left(\frac{\epsilon}{\epsilon-1} w_j\right)^{1-\epsilon} (b_i e^x)^{\epsilon-1} f_i(x) dx - n_i g_{ji} w_i [1 - F(x_{ji}^f)].$$

The total profit in country i is the summation over these three parts. The income-expenditure identity here does not imply trade balance, as it usually does in a Melitz model. What it does imply is trade and financial balance. Trade in equilibrium is almost surely unbalanced, and the gap will be offset by the differences in capital flow: the differences between the profits the domestic MNEs collected from abroad and the foreign MNEs collected from the home market.

Ideal Price Level Equation (8) is the definition of the ideal price level in country i:

$$P_i = \left(\int_{m \in \Theta_i} p(m)^{1-\epsilon} dm\right)^{\frac{1}{1-\epsilon}}. \tag{20}$$

What needs further explanation is the set of goods available in country i: Θ_i. This set is the union of three mutually exclusive subsets: (1) the goods provided by all the firms created in country i, (2) the goods provided by all the exporting firms in country j, and (3) the goods provided by all the MNEs in country j. The price for every single variety in each of the subsets is a constant mark-up over the marginal cost in that subset. The marginal cost for goods in different subsets can be found in Appendix C.1. The ideal price level is a CES integration of all the individual prices over the set Θ_i.

After decomposing the set Θ_i into the three subsets mentioned above, the ideal price level can be expressed based on the firm productivity distribution directly:

$$P_i^{1-\epsilon} = \left\{ \sum_{j=1}^{2} \left[n_j \left(\frac{\epsilon}{\epsilon-1}\tau_{ij} w_j\right)^{1-\epsilon} \int_{x_{ij}^e}^{x_{ij}^f} b_i e^x f(x) dx + n_j \left(\frac{\epsilon}{\epsilon-1} w_i\right)^{1-\epsilon} \int_{x_{ij}^f}^{s} b_i e^x f(x) dx \right] \right\}.$$

Note that when $i = j$, $x_{ij}^e = x_i^*$. The first part in the square bracket includes all the goods provided by domestic firms, domestic exporters, and foreign exporters. The second part in the square bracket includes all the goods provided by the domestic and foreign MNEs.

Labor Market Clearing Condition The labor market clearing condition in country i requires that total supply of efficiency labor equals to total demand. Total supply equals the integral of x from 0 to x_i^* over the density function $f(x)$. Total labor demand is more complicated. It has four parts:

1. The labor used in the production of all the goods supplied to the home market i and exported to the foreign market j by the firms founded in country i:

$$L_i^{(1)} = n_i \sum_{j=1}^{2} \int_{x_{ji}}^{x_{ji}^f} \frac{H_j}{P_j^{1-\epsilon}} \left(\frac{\epsilon}{\epsilon - 1} \frac{\tau_{ji} w_i}{A_i(x)} \right)^{-\epsilon} \frac{\tau_{ji}}{A_i(x)} f(x) dx.$$

2. The labor used in fixed costs of operation and export incurred for the production in part 1:

$$L_i^{(2)} = n_i \sum_{j=1}^{n} f_{ji} \int_{x_{ji}}^{x_{ji}^f} f(x) dx.$$

3. The labor used in fixed costs for the goods supplied to country j through FDI by the firms created in country i:

$$L_i^{(3)} = n_i \sum_{j=1}^{2} g_{ji} \int_{x_{ji}^f}^{\infty} f(x) dx.$$

4. The labor used in the production of the goods supplied to country i by the foreign subsidiaries in country i from the firms founded in country j:

$$L_i^{(4)} = \sum_{j=1}^{2} n_j \int_{x_{ij}^f}^{\infty} \frac{H_i}{P_i^{1-\epsilon}} \left(\frac{\epsilon}{\epsilon - 1} \frac{w_i}{A_i(x)} \right)^{-\epsilon} \frac{1}{A_i(x)} f(x) dx.$$

C.3 Firm Size Distributions

In this appendix, we derive the CDF of firm productivity, sales, profit, and employment distributions for different groups of firms.

C.3.1 Productivity Distribution

The human capital, x, in country i is distributed exponentially with the following CDF:

$$F(x) = 1 - e^{-\lambda x},$$

and the firm founded by the individual with human capital x has the following productivity:

$$A_i(x) = b_i e^x.$$

Note that the marginal individual between entrepreneur and worker has human capital x^*, and thus will create a firm with productivity:

$$A_i(x^*) = b_i e^{x^*}.$$

For simplicity of notation we denote the lowest firm productivity as A_i^*. This implies that the human capital distribution underlying all the entrepreneurs is a shifted exponential distribution with the following CDF:

$$F^*(x) = 1 - e^{-\lambda(x-x^*)}.$$

The CDF of the firm productivity distribution conditional on the lower bound A_i^*, denoted as $F_A(y)$, can be derived as follows:

$$\begin{aligned} F_A(y) &= \Pr(A_i(x) \leq y) = \Pr(b_i e^x \leq y) = \Pr(e^x \leq \frac{y}{b_i}), \\ &= \Pr(x \leq \log(y/b_i)) = F^*(\log(y/b_i)), \\ &= 1 - e^{-\lambda[\log(y/b_i) - x^*]}, \\ &= 1 - b_i^\lambda e^{\lambda x^*} y^{-\lambda}, \\ &= 1 - (A^*)^\lambda y^{-\lambda}, \end{aligned}$$

which is the CDF of a Type-I Pareto distribution with location parameter $A^* = b_i x^*$ and shape parameter λ. This CDF is shared by all the firms in country i whether they are non-exporting firms, exporting firms, or multinational firms.

Truncation If the exponential distribution is truncated from above at s, then the CDF of the human capital distribution for all entrepreneurs will be:

$$F(x) = \frac{1 - e^{-\lambda(x-x^*)}}{1 - e^{-\lambda s}}, x \in [x^*, s].$$

Given the same functional form of firm productivity, the CDF of the productivity distribution can be derived using similar methods outlined above. The distribution can be verified to be a truncated Pareto distribution,

$$F_A(y) = \frac{1-(A^*)^\lambda y^{-\lambda}}{1-b_i^\lambda u_i^{-\lambda}}, y \in [b_i, u_i],$$

where u_i is the country-specific upper bound of firm productivity:

$$u_i = b_i e^s.$$

In the rest of the this appendix, we use the original distribution without truncation.

C.3.2 Sales Distribution

The sales from country j to country i is derived in Appendix C.1 and repeated here:

$$p_{ij}(x)q_{ij}(x) = H_i P_i^{\epsilon-1}\left(\frac{\epsilon}{\epsilon-1}M_{ij}(x)\right)^{1-\epsilon}, \tag{21}$$

where $M_{ij}(x)$ is the marginal cost of production conditional on the mode of access (export or multinational production). Based on the market-specific sales, we derive the firm sales. We denote sales for a firm with CEO human capital x in country i as $\sigma_i(x)$ and rewrite it as a linear function of $A_i(x)^{\epsilon-1}$:

$$\sigma_i(x) = \Sigma_i(x)A_i(x)^{\epsilon-1}.$$

$\Sigma_i(x)$ summarizes the market size accessible to the firm. It is a step function depending on x:

$$\Sigma_i(x) = \begin{cases} H_i\left(\frac{P_i}{w_i}\frac{\epsilon-1}{\epsilon}\right)^{\epsilon-1} & , x \in [x_i^*, x_{ji}^e), \\ H_i\left(\frac{P_i}{w_i}\frac{\epsilon-1}{\epsilon}\right)^{\epsilon-1} + H_j\left(\frac{P_j}{\tau_{ji}w_i}\frac{\epsilon-1}{\epsilon}\right)^{\epsilon-1} & , x \in [x_{ji}^e, x_{ji}^f), \\ H_i\left(\frac{P_i}{w_i}\frac{\epsilon-1}{\epsilon}\right)^{\epsilon-1} + H_j\left(\frac{P_j}{w_j}\frac{\epsilon-1}{\epsilon}\right)^{\epsilon-1} & , x \in [x_{ji}^f, \infty). \end{cases}$$

The first line is the market accessible to the non-exporters, the second line the exporters, and the last line the multinational producers. The general formula for the CDF of the sales distribution is

$$
\begin{aligned}
F_\sigma(y) &= \Pr(\sigma < y), \\
&= \Pr(\Sigma_i(x) A_i(x)^{\epsilon-1} < y) = \Pr\left(A_i(x) < \left(\frac{y}{\Sigma_i(x)}\right)^{\frac{1}{\epsilon-1}}\right), \\
&= F_A\left(\left(\frac{y}{\Sigma_i(x)}\right)^{\frac{1}{\epsilon-1}}\right) = 1 - (A_i^*)^\lambda \left(\frac{y}{\Sigma_i(x)}\right)^{\frac{-\lambda}{\epsilon-1}}, \\
&= 1 - \left(\frac{\Sigma_i(x)}{(A_i^*)^{1-\epsilon}}\right)^\theta y^{-\theta},
\end{aligned}
$$

where

$$
\theta = \frac{\lambda}{\epsilon - 1}.
$$

The above equation defines Type-I Pareto distribution with shape parameter $\frac{\lambda}{\epsilon-1}$ and location parameter $\Sigma_i(x)(A_i^*)^{\epsilon-1}$. The location parameter differs by $\Sigma_i(x)$. The non-exporting firms have the smallest $\Sigma_i(x)$ and therefore the lowest location parameter. The exporting firms have higher $\Sigma_i(x)$ and the multinational firms have the highest $\Sigma_i(x)$. Note that within the same group (non-exporters, exporters, and multinationals), $\Sigma_i(x)$ is the same for all the firms.

C.3.3 Profit Distribution

The profit earned in each market is provided in Appendix C.1. Based on the market-specific profit, the firm profit can be written as an affine function of $A_i(x)^{\epsilon-1}$:

$$
\pi_i(x) = \Pi_i(x) A_i(x)^{\epsilon-1} - C_i(x).
$$

Similar to the sales distribution, $\Pi_i(x)$ takes three values depending on x:

$$
\Pi_i(x) = \begin{cases}
\frac{H_i}{\epsilon}\left(\frac{P_i}{w_i}\frac{\epsilon-1}{\epsilon}\right)^{\epsilon-1} & , x \in [x_i^*, x_{ji}^e), \\
\frac{H_i}{\epsilon}\left(\frac{P_i}{w_i}\frac{\epsilon-1}{\epsilon}\right)^{\epsilon-1} + \frac{H_j}{\epsilon}\left(\frac{P_j}{\tau_{ji} w_i}\frac{\epsilon-1}{\epsilon}\right)^{\epsilon-1} & , x \in [x_{ji}^e, x_{ji}^f), \\
\frac{H_i}{\epsilon}\left(\frac{P_i}{w_i}\frac{\epsilon-1}{\epsilon}\right)^{\epsilon-1} + \frac{H_j}{\epsilon}\left(\frac{P_j}{w_j}\frac{\epsilon-1}{\epsilon}\right)^{\epsilon-1} & , x \in [x_{ji}^f, \infty).
\end{cases}
$$

The first line is the market size accessible to a domestic firm. The second line is the market size for exporting firms, and the third line is the market size for multinational firms. Similarly, the fixed cost term $C_i(x)$ depends on the type of the firm

$$C_i(x) = \begin{cases} w_i f_{ii} & , x \in [x_i^*, x_{ji}^s), \\ w_i(f_{ii} + f_{ji}) & , x \in [x_{ji}^e, x_{ji}^f), \\ w_i(f_{ii} + g_{ji}) & , x \in [x_{ji}^f, \infty). \end{cases}$$

The distribution function of π takes the following general formula

$$\begin{aligned} F_\pi(y) = \Pr(\pi \leq y) &= \Pr(\Pi_i(x) \cdot A_i(x)^{\epsilon-1} - C_i(x) \leq y), \\ &= \Pr\left(A_i(x) \leq \left(\frac{y + C_i(x)}{\Pi_i(x)})\right)^{\frac{1}{\epsilon-1}}\right), \\ &= 1 - b_i^\lambda \left(\frac{y + C_i(x)}{\Pi_i(x)})\right)^{\frac{-\lambda}{\epsilon-1}} = 1 - \left(\frac{y + C_i(x)}{\Pi_i(x) b_i^{\epsilon-1}}\right)^{-\frac{\lambda}{\epsilon-1}}, \\ &= 1 - \left(1 + \frac{y + \mu_i(x)}{\chi_i(x)}\right)^{-\theta}, \end{aligned}$$

where

$$\begin{aligned} \mu_i(x) &= \chi_i(x) - C_i(x), \\ \chi_i(x) &= \Pi_i(x) \cdot (A_i^*)^{\epsilon-1}, \\ \theta &= \frac{\lambda}{\epsilon - 1}. \end{aligned}$$

This equation is the CDF of a Type-II Pareto distribution as defined in Arnold (1985). The shape index of the firm profit distribution is $\theta = \frac{\lambda}{\epsilon-1}$. The two location parameters $\mu_i(x)$ and $\chi_i(x)$ depend on the market that the firm can access to.

C.3.4 Employment Distribution

Employment distribution is similar to the profit distribution. Market-specific employment is provided in Appendix C.1 and here we aggregate it up to firm-level employment. For each firm the employment, $L_i(x)$, can be written as an affine function of $A_i(x)^{\epsilon-1}$:

$$L_i(x) = \Lambda_i(x) A_i(x)^{\epsilon-1} + T_i(x).$$

$\Lambda_i(x)$, again, summarizes the market size accessible to a firm x and is a step function that takes three values:

$$\Lambda_i(x) = \begin{cases} \frac{H_i}{P_i^{1-\epsilon}} \left(\frac{1}{w_i}\frac{\epsilon-1}{\epsilon}\right)^{\epsilon} & , x \in [x_i^*, x_{ji}^e), \\ \frac{H_i}{P_i^{1-\epsilon}} \left(\frac{1}{w_i}\frac{\epsilon-1}{\epsilon}\right)^{\epsilon} + \frac{H_j}{P_j^{1-\epsilon}} \left(\frac{1}{w_i}\frac{\epsilon-1}{\epsilon}\right)^{\epsilon} \tau_{ji}^{1-\epsilon} & , x \in [x_{ji}^e, x_{ji}^f), \\ \frac{H_i}{P_i^{1-\epsilon}} \left(\frac{1}{w_i}\frac{\epsilon-1}{\epsilon}\right)^{\epsilon} + \frac{H_j}{P_j^{1-\epsilon}} \left(\frac{1}{w_j}\frac{\epsilon-1}{\epsilon}\right)^{\epsilon} & , x \in [x_{ji}^f, \infty). \end{cases}$$

$T_i(x)$ is the labor used as fixed cost of operation, export, and multinational production:

$$T_i(x) = \begin{cases} f_{ii} & , x \in [x_i^*, x_{ji}^s), \\ f_{ii} + f_{ji} & , x \in [x_{ji}^e, x_{ji}^f), \\ f_{ii} + g_{ji} & , x \in [x_{ji}^f, \infty). \end{cases}$$

Because both the employment and the profit are affine transformations of $A_i(x)^{\epsilon-1}$, the steps to derive the general formula of CDF are exactly the same. In the end, employment distributions are also Type-II Pareto distributions with shape parameter θ. The two location parameters depend on the market size accessible to the firm as well.

C.4 Income Distribution

The equilibrium income distribution in the model follows a two-class structure: the worker's income distribution follows an exponential distribution, and the CEO's income follows various Pareto-Type distributions. In this appendix, we present the details of the income distributions of the model.

Workers Workers in country i receive w_i for each unit of efficiency labor supplied to the market. The income for a worker with human capital x is $w_i x$, which follows an exponential distribution, same as x. The shape parameter of the income distribution is $\frac{\lambda}{w_i}$. The CDF of the distribution is

$$\begin{aligned} V(y) = \Pr(w_i x \leq y) &= \Pr(x \leq \frac{y}{w_i}), \\ &= 1 - e^{-\frac{\lambda}{w_i} y}. \end{aligned}$$

CEOs If $k(\pi)$ is monotonic and regularly varying with tail index β, then the CEO income follows a Pareto-Type distribution with shape parameter θ/β. Given a compensation function $k(\pi)$, the CDF of the CEO income is

$$U(y) = \Pr(k(\pi) \leq y) = \Pr(\pi \leq k^{-1}(y)) = F_\pi(k^{-1}(y)),$$

where $k^{-1}(y)$ is the inverse of $k(\pi)$ and $F_\pi(\cdot)$ is the CDF of firm profit distribution derived in Appendix C.3. The inverse function exists because $k(\pi)$ is monotonic. Because $k(\pi)$ is a regularly varying function with tail index β, the inverse function $k^{-1}(\cdot)$ is also a regularly varying function with tail index $1/\beta$ (Proposition 0.8.5, Resnick (1987)).

The survival function of π is a regularly varying function, with tail index $-\theta$ as well. To see this:

$$\lim_{\pi\to\infty} \frac{1 - F_\pi(\eta\pi)}{1 - F_\pi(\pi)} = \frac{\left(1 + \frac{\eta\pi+\mu}{\chi}\right)^{-\theta}}{\left(1 + \frac{\pi+\mu}{\chi}\right)^{-\theta}} = \eta^{-\theta}.$$

The composition of two regularly varying functions is a regularly varying function, and the tail index of the composition function is the product of the two indices (Proposition 0.8.4, Resnick (1987)). Therefore $1 - U(y)$, as the composition of $k^{-1}(y)$ and $1 - F_\pi(\pi)$, is a regularly varying function with tail index $-\frac{\theta}{\beta}$. This defines $y = k(\pi)$ as a Pareto-Type distribution with shape parameter $\frac{\theta}{\beta}$ (Definition 7.25, Gulisashvili (2012)). Moreover, the CDF of $k(\pi)$ can be re-written as:

$$U(y) = 1 - y^{-\theta/\beta} R(y),$$

where $R(y)$ is a slowly varying function:

$$\lim_{y\to\infty} \frac{R(\eta y)}{R(y)} = 1.$$

Example The CEO compensation function is

$$k(\pi) = \alpha^{1-\beta}\pi^\beta = \alpha^{1-\beta}\left(\Pi \cdot A^{\epsilon-1} - C\right)^\beta.$$

The CDF of $k(\pi)$ is

$$\begin{aligned} U(y) = \Pr(k \leq y) &= \Pr(\alpha^{1-\beta} \left(\Pi \cdot A^{\epsilon-1} - C\right)^{\beta} \leq y), \\ &= \Pr\left(A^{\epsilon-1} \leq \frac{y^{\frac{1}{\beta}}\alpha^{\frac{\beta-1}{\beta}} + C}{\Pi}\right), \\ &= 1 - b^{\lambda}\left(\frac{y^{\frac{1}{\beta}}\alpha^{\frac{\beta-1}{\beta}} + C}{\Pi}\right)^{-\frac{\lambda}{\epsilon-1}}. \end{aligned}$$

Using the general result proved above, it is trivial to show that $k(\pi)$ follows a Pareto-Type distribution. Here we follow a different route and prove directly that the survival function $1 - U(y)$ is a regularly varying function. To see this:

$$\begin{aligned} \lim_{y\to\infty} \frac{1-U(\eta y)}{1-U(y)} &= \lim_{y\to\infty}\left(\frac{\eta^{\frac{1}{\beta}} y^{\frac{1}{\beta}}\alpha^{\frac{\beta-1}{\beta}} + C}{y^{\frac{1}{\beta}}\alpha^{\frac{\beta-1}{\beta}} + C}\right)^{-\frac{\lambda}{\epsilon-1}}, \\ &= \lim_{y\to\infty}\left(\frac{\eta^{\frac{1}{\beta}} + \frac{C}{y^{\frac{1}{\beta}}\alpha^{\frac{\beta-1}{\beta}}}}{1 + \frac{C}{y^{\frac{1}{\beta}}\alpha^{\frac{\beta-1}{\beta}}}}\right)^{-\frac{\lambda}{\epsilon-1}}. \end{aligned}$$

As $y \to \infty$, $y^{\frac{1}{\beta}} \to \infty$, therefore

$$\lim_{y\to\infty} \frac{1-U(\eta y)}{1-U(y)} = \eta^{-\frac{\lambda}{\beta(\epsilon-1)}},$$

which defines $1 - U(y)$ as a regularly varying function with index $-\frac{\lambda}{\beta(\epsilon-1)}$. This further implies that the income distribution function of CEOs in corporations can be expressed as

$$U(y) = 1 - y^{-\frac{\lambda}{\beta(\epsilon-1)}} R(y).$$

The income distribution of the CEOs at sole proprietorship firms is the same as the profit distribution and therefore is Type-II Pareto.

See Feller (1966), Resnick (1987), and Gulisashvili (2012) for more details on regularly varying functions and Pareto-Type distributions.

D Proofs

For completeness, we provide another proposition to establish the ranking in the extended model with multinational firms. We then provide the proof for this proposition along side with proposition 1:

Proposition 5 *If the sets of exporting firms and multinational firms in country i are non-empty, then the average CEO-to-worker pay ratio among domestic firms is strictly smaller than the average CEO-to-worker pay ratio among exporting firms, which in turn is strictly smaller than the average CEO-to-worker pay ratio among multinational firms.*

D.1 Proof of Proposition 1 and 5

The least productive CEOs manage the domestic firms, which implies that, on average, they receive the lowest compensation among all the CEOs. The more productive CEOs manage the exporting firms, and the most productive CEOs manage the multinational firms. Since wage is equalized across the firms, the ranking of the CEO-to-worker pay ratio is the same as the ranking of the CEO income. ∎

D.2 Proof of Proposition 2

Profit-to-wage ratios in this model only depends on the cutoff human capitals in general equilibrium. This property can be exploited to gain some insight into the basic mechanism of the model without quantification.

Domestic Profit The profit-to-wage ratio in the domestic market is the profit earned from the domestic market divided by domestic wage. This part of profit is earned by the domestic firms, the exporters, and the MNEs created in the home country.

The profit-to-wage ratio is

$$\frac{\pi_{ii}(x)}{w_i} = \frac{H_i}{w_i\epsilon}\left(\frac{P_i}{w_i}\frac{\epsilon-1}{\epsilon}\right)^{\epsilon-1} A_i(x)^{\epsilon-1} - f_{ii}.$$

From the cutoff condition of the marginal firm, we know:

$$\frac{H_i}{w_i\epsilon}\left(\frac{P_i}{w_i}\frac{\epsilon-1}{\epsilon}\right)^{\epsilon-1} b_i^{\epsilon-1}e^{(\epsilon-1)x_i^*} - f_{ii} = x_i^*,$$

and therefore

$$\frac{H_i}{w_i \epsilon}\left(\frac{P_i}{w_i}\frac{\epsilon-1}{\epsilon}\right)^{\epsilon-1} = \frac{x_i^* + f_{ii}}{b_i e^{(\epsilon-1)x_i^*}}. \tag{22}$$

Plug this into the first equation, we have

$$\frac{\pi_{ii}(x)}{w_i} = (x_i^* + f_{ii})e^{(\epsilon-1)(x-x_i^*)} - f_{ii}.$$

The partial derivative of this ratio with respect to x is positive, so in general, the profit-to-wage ratio is higher when the firm is more productive and larger. All the general equilibrium movements affect this ratio through the only endogenous variable in this equation: the cutoff value x_i^*. The cutoff human capital is a measure of the competitiveness of the home market in general equilibrium: it will be higher when the market is more competitive due to highly productive foreign firms entering. The partial derivative of this ratio with respect to x_i^* is

$$\frac{\partial}{\partial x_i^*}\left(\frac{\pi_{ii}(x)}{w_i}\right) = e^{(\epsilon-1)(x-x_i^*)}[1-(\epsilon-1)(x_i^* + f_{ii})]. \tag{23}$$

The sign of this derivative is the same as $[1-(\epsilon-1)(x_i^* + f_{ii})]$. We claim that this sign is always negative under the assumption that the least productive individual in country i must not find creating a new firm profitable. This restriction is imposed to guarantee the existence and uniqueness of the occupational choice cutoff in the paper. This assumption means:

$$\frac{H_i}{\epsilon}P_i^{\epsilon-1}w_i^{1-\epsilon}\left(\frac{\epsilon-1}{\epsilon}\right)^{\epsilon-1}A_i(0)^{\epsilon-1} - f_{ii}w_i < 0,$$

$$f_{ii} > \frac{H_i}{\epsilon w_i}^{\epsilon-1}\left(\frac{\epsilon-1}{\epsilon}\frac{P_i}{w_i}\right)^{\epsilon-1}A_i(0)^{\epsilon-1}.$$

Plug equation (22) into the above inequality, we have

$$f_{ii} > \frac{x_i^* + f_{ii}}{A_i(x_i^*)^{\epsilon-1}}A_i(0)^{\epsilon-1}$$

$$f_{ii} > \frac{x_i^*}{e^{(\epsilon-1)x_i^*} - 1}.$$

Now we need to prove

$$x_i^* + f_{ii} > \frac{1}{\epsilon - 1}. \tag{24}$$

To do this, we define

$$m(x_i^*) = x_i^* + \frac{x_i^*}{e^{(\epsilon-1)x_i^*} - 1} - \frac{1}{\epsilon - 1}.$$

It is easy to show that $m(x_i^*)$ is monotonically increasing,

$$\frac{\partial m(x_i^*)}{\partial x_i^*} = 1 + \frac{e^{(\epsilon-1)x_i^*}(1 + (\epsilon-1)x_i^*) - 1}{(e^{(\epsilon-1)x_i^*} - 1)^2} > 0,$$

because

$$((\epsilon - 1)x_i^* > 0) \wedge (e^{(\epsilon-1)x_i^*} > 1).$$

Therefore, the minimum of $m(x^*)$ is obtained at $x_i^* = 0$, which is precisely 0. To see this, we need to apply L'Hôpital's rule to the second term at $x_i^* = 0$:

$$\begin{aligned}\lim_{x_i^* \to 0} m(x^*) &= x_i^* + \frac{1}{e^{(\epsilon-1)x_i^*}(\epsilon - 1)} - \frac{1}{\epsilon - 1},\\ &= \frac{1}{\epsilon - 1} - \frac{1}{\epsilon - 1} = 0.\end{aligned}$$

This implies that for all possible values of $x_i^* \in [0, \infty)$, equation (24) is true and therefore the profit-to-wage ratio decreases with x_i^*.

Exporting Profits The profits earned from exporting to the foreign country, divided by local wage, is

$$\frac{\pi_{ji}^e(x)}{w_i} = \frac{H_j}{w_i \epsilon} \left(\frac{P_j}{\tau_{ji} w_i} \frac{\epsilon - 1}{\epsilon} \right)^{\epsilon - 1} A_i(x)^{\epsilon - 1} - f_{ji}.$$

Similar to the domestic profit, the cutoff human capital of the marginal exporter is a sufficient statistics for the size of the foreign market and the marginal cost of accessing to that market. To see this, we start with the cutoff condition:

$$\frac{H_j}{\epsilon}\left(\frac{P_j}{\tau_{ji}w_i}\frac{\epsilon-1}{\epsilon}\right)^{\epsilon-1}A_i(x_{ji}^e)^{\epsilon-1}-f_{ji}w_i=0,$$
$$\frac{H_j}{w_i\epsilon}\left(\frac{P_j}{\tau_{ji}w_i}\frac{\epsilon-1}{\epsilon}\right)^{\epsilon-1}=\frac{f_{ji}}{b_i e^{(\epsilon-1)(x-x_{ji}^e)}}.$$

Plugging the above equation into the original profit-to-wage ratio, we have:

$$\frac{\pi_{ji}^e(x)}{w_i}=f_{ji}[e^{(\epsilon-1)(x-x_{ji}^e)}-1].$$

This ratio depends positively on x and negatively on x_{ji}^e. x_{ji}^e is a measure of the access to the foreign market: it will be lower (easier to access) when τ_{ji} is lower, or the foreign market is larger (H_j or P_j higher). When τ_{ji} is lower, the profit-to-wage ratio from the exporting market will be higher. ∎

D.3 Proof of Proposition 3

If $\tau_{ji}=\tau_{ij}$ drops, then x_{ji}^e will be lower and x_i^* will be higher. Proposition 2 implies that $\frac{\pi_{ii}(x)}{w_i}$ will be lower, which futher implies that the income ratio between CEOs at the domestic firms and the workers will be smaller. Proposition 2 also implies that $\frac{\pi_{ji}^e(x)}{w_i}$ will be higher as a result. Note that the ratio between the profit of the exporting firms and wage rate is the sum of the domestic and the export ratios:

$$\frac{\pi_{ii}(x)+\pi_{ji}^e(x)}{w_i}=\frac{H_i}{w_i\epsilon}\left(\frac{P_i}{w_i}\frac{\epsilon-1}{\epsilon}\right)^{\epsilon-1}A_i(x)^{\epsilon-1}-f_{ii}+\frac{H_j}{w_i\epsilon}\left(\frac{P_j}{\tau_{ji}w_i}\frac{\epsilon-1}{\epsilon}\right)^{\epsilon-1}A_i(x)^{\epsilon-1}-f_{ji}.$$

The symmetry assumption implies that H, P and w will be equalized across countries, and so will their partial derivative with respect to τ_{ji} and τ_{ij}:

$$\frac{\partial\left(H_iP_i^{\epsilon-1}w_i^{-\epsilon}\right)}{\partial\tau_{ji}}=\frac{\partial\left(H_jP_j^{\epsilon-1}w_i^{-\epsilon}\right)}{\partial\tau_{ij}}$$

It is also straight forward to show that the partial derivative must be positive in general equilibrium, otherwise, there will be negative aggregate gains from trade.

The above observations imply that the sign of

$$\frac{\partial\left(\frac{\pi_{ii}(x)+\pi_{ji}^e(x)}{w_i}\right)}{\partial\tau_{ji}}$$

is always positive independent of $A_i(x)$, because $\tau_{ji}^{1-\epsilon}$ will be higher if τ_{ji} is lower. The intuition is simple: the income ratio between CEOs at the exporting firm and the workers will be higher following bilateral trade liberalizations.

The income ratio between the CEOs at the exporting firms and the domestic firms will also be higher because $\frac{\pi_{ii}(x)}{w_i}$ is lower and $\frac{\pi_{ii}(x)+\pi^e_{ji}(x)}{w_i}$ is higher as shown above.

Proposition 1 implies that the any CEO at the exporting firms earn higher income that the CEOs at the domestic firms and the workers. Now consider any individual with $x > x^e_{ji}$. After the changes in τ_{ji}, the income gap between him and all the individuals below x^e_{ji} will be wider. This directly implies that the income share for all the individuals with $x > x^e_{ji}$ will be higher if τ_{ji} is lower, and thus p^* can be computed as the survial function of the human capital distribution:

$$p^* = 100 \times (1 - F(x^e_{ji})) = 100 \times (e^{\lambda x^e_{ji}}) \quad \blacksquare$$

D.4 Proof of Proposition 4

FDI Profits The profits earned from FDI to the foreign country, divided by local wage, is:

$$\frac{\pi^f_{ji}(x)}{w_i} = \frac{H_j}{w_i\epsilon}\left(\frac{P_j}{w_j}\frac{\epsilon-1}{\epsilon}\right)^{\epsilon-1} A_i(x)^{\epsilon-1} - g_{ji}.$$

From the FDI cutoff condition, we know

$$\frac{H_j}{w_i\epsilon}\left(\frac{P_j}{w_j}\frac{\epsilon-1}{\epsilon}\right)^{\epsilon-1} A_i(x^f_{ji})^{\epsilon-1} = \frac{H_j}{w_i\epsilon}\left(\frac{P_j}{\tau_{ji}w_i}\frac{\epsilon-1}{\epsilon}\right)^{\epsilon-1} A_i(x^f_{ji})^{\epsilon-1} + (g_{ji} - f_{ji}),$$

$$\frac{H_j}{w_i\epsilon}\left(\frac{P_j}{w_j}\frac{\epsilon-1}{\epsilon}\right)^{\epsilon-1} = \left[f_{ji}\frac{A_i(x^f_{ji})^{\epsilon-1}}{A_i(x^e_{ji})^{\epsilon-1}} + g_{ji} - f_{ji}\right]\frac{1}{A_i(x^f_{ji})^{\epsilon-1}}.$$

Therefore

$$\frac{\pi^f_{ji}(x)}{w_i} = f_{ji}e^{(\epsilon-1)(x-x^e_{ji})} + (g_{ji} - f_{ji})e^{(\epsilon-1)(x-x^f_{ji})} - g_{ji}.$$

This profit-to-wage ratio decreases with x^f_{ji}:

$$\frac{\partial\frac{\pi^f_{ji}(x)}{w_i}}{\partial x^f_{ji}} = e^{(\epsilon-1)(x-x^f_{ji})}(g_{ji} - f_{ji})(1-\epsilon) < 0. \quad \blacksquare$$

E A Model for the CEO Market

In this section we extend the benchmark model to allow for a labor market for CEOs, and an endogenously-determined CEO compensation function. The model here closely follows the work of Gabaix and Landier (2008). The key message of the extended model is, as long as the CEO contributes to the productivity of the firm, the equilibrium compensation function will satisfy the key assumptions that were used to exogenously define the compensation functions in the benchmark model.

Instead of allowing the individuals to create firms, we start by assuming that there exists a continuum of potential firms with different innate productivity, denoted and indexed by $\phi \in \Phi$, where Φ is a subset of real numbers. A firm needs to hire a CEO in order to operate. A potential CEO comes from the pool of candidates who are differentiated by their human capital x. The distribution of x follows the same exponential distribution as in the benchmark model. The final productivity of the firm depends on both the innate productivity of the firm, and the ability of the CEO. Following the notation of the benchmark model, the final productivity of the firm is:

$$A(\phi, x) = \phi \cdot b \cdot e^{x},$$

where b denotes the TFP of the country. CEO receives compensation k from the firm. The compensation as a function of talent, $k(x)$, will be determined in equilibrium. Following the notation of the benchmark model, the profit of the firm in this extension can be written as:

$$\pi(\phi, x) = \tilde{H} A(\phi, x)^{\epsilon-1} - fw - k(x),$$

where $\tilde{H}$ describes the size of the markets to which the firm has access:

$$\tilde{H} = \frac{H}{\epsilon} P^{\epsilon-1} w^{-\epsilon} \left(\frac{\epsilon}{\epsilon - 1} \right)^{1-\epsilon}.$$

When the firm determines which CEO to hire, it takes the market price of talent, $k(x)$ as given. The first order condition of the firm is:

$$\tilde{H}(\epsilon - 1) A(\phi, x)^{\epsilon} A(\phi, x)' = k'(x)$$

which is essentially balancing the benefit of hiring a slightly better CEO with the extra cost of doing so. The solution to the differential equation of $k'(x)$ is:

$$k(x) = \tilde{H}b(\epsilon - 1)\int_{\underline{x}}^{\infty} \phi(x)e^{x(\epsilon-1)}dx + C, \tag{25}$$

where $\phi(x) : \mathcal{R} \rightarrow \Phi$ is the equilibrium mapping between CEO with talent x and the firm with productivity ϕ. C is the integration constant, which can be pinned down by the outside option of the least talented CEO, $\underline{x}$:

$$C = \underline{x}w.$$

It is impossible to exactly solve equation (25) without specifying the functional form of $\phi(x)$. However, without a closed-form solution we can still establish a couple of properties of $k(x)$. Gabaix and Landier (2008) characterized $k(x)$ by re-mapping x and ϕ into sequential indices, and utilizing an approximate spacing function of x. Specifically, they showed that equation (25) can approximately obtain a closed form solution if x follows an exponential distribution, up to a slowly varying function. Their key insights are two-folds. First, efficient market implies that in equilibrium there must be assortative matching between firms and CEOs, and thus $\phi(x)$ must be monotonically increasing in x. This implies that $k(x)$ must be monotonically increasing in x as well. Further more, when x follows an exponential distribution, the spacing function of x is regularly varying. This implies that in equilibrium, $k(x)$ must be regularly varying as well.

The arguments above establish that in equilibrium, the endogenously-determined $k(x)$ must be 1) monotonically increasing in x, and 2) regularly varying in x. These two results are precisely the assumptions that we made in the benchmark model, where $k(x)$ is exogenously imposed on the market. Moreover, it shows that even if we separate CEOs and founders, and model the market between CEO talents and firms, the end result in terms of the compensation scheme and matching pattern, will not change.

F Calibration

The measure of population are computed following the method in Caselli (2005). The computation is based on Penn World Table 7.0, and all undefined variable names in italics are the standard variable names in PWT. We first compute real GDP in year t, Y_t, as

$$Y_t = pop_t \cdot rgdpl_t.$$

The number of workers, L_t, is backed out by

$$L_t = Y_t / rgdpwok_t.$$

This raw measure of the stock of work-force is first adjusted by human capital. Using years of school attainment for both males and females 25 years old and above from Barro and Lee (2010), we construct human capital h_t as

$$h_t = e^{\phi(c_t)},$$

where c_t is the years of schooling and $\phi(c_t)$ is piece-wise linear:

$$\phi(c_t) = \begin{cases} 0.134 * c & \text{if} \quad c_t \leq 4 \\ 0.134 * 4 + 0.101 * (c_t - 4) & \text{if} \quad 4 < c_t \leq 8 \\ 0.134 * 4 + 0.101 * 4 + 0.068 * (c_t - 8) & \text{if} \quad 8 < c_t \end{cases}.$$

Because the year of schooling data are only available at five-year intervals, linear interpolation is used to fill in the gap years. c_t is a slow-moving variable; therefore, linear interpolation can provide reasonably smooth estimations.

To construct the stock of physical capital in each year, we first compute investment in each year as

$$I_t = Y_t * \mathrm{ki_t}/100,$$

and then back out the initial capital stock using perpetual inventory method. We assume that capital and output grow at the same rate, and the depreciation rate is 6 percent per year. The initial capital stock when $t = 0$ is

$$K_0 = I_0/(g_k + 0.06),$$

where g_k is the average growth rate of GDP in the first 10 years of data. Given the initial capital stock, the sequence of capital stock in year t is computed as

$$K_t = (1 - 0.06)K_{t-1} + I_t.$$

With a computed sequence of physical capital, the final measure of population year t,

n_t, is computed as

$$n_t = K_t^a (h_t L_t)^{1-a},$$

where $a = 1/3$. The number of n used in the benchmark calibration is the average between 1988 and 2008.