The Pro-Competitive Consequences of Trade in Frictional Labor Markets*

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What are the pro-competitive consequences of trade *in frictional labor markets*? This paper develops and estimates a dynamic general equilibrium trade model to show that the interplay between endogenously variable markups in product markets and frictions in labor markets has important implications for aggregate as well as distributional consequences of trade. In particular, I show that once markups are allowed to respond to trade liberalization, unemployment and residual wage inequality rise almost three times more than in a model with constant markups (in the steady state). The presence of labor market frictions makes the pro-competitive gains from trade liberalization negative.

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1 Introduction

A large body of literature explores the responses of markups to trade liberalization, and whether they increase or decrease the gains from trade (Edmond et al., 2015; Arkolakis et al., 2019). The consequences of trade-induced changes in markups *in frictional labor markets* and their welfare implications are, however, less explored. This is an important question due to the rising importance of trade (restrictions), market power and markups, and labor market imperfections. This paper shows that the interplay between variable markups in product markets and frictions in labor markets has important implications for aggregate as well as distributional consequences of trade, which are less studied.[1] In particular, a downward pressure on markups induced by foreign competition would increase firms' responsiveness to their idiosyncratic shocks thereby increasing unemployment and wage inequality in frictional labor markets.

I develop and estimate a dynamic general equilibrium model of international trade featuring endogenously variable markups to show that trade-induced changes in markups have important impacts on labor market outcomes in a frictional labor market. In particular, I show that once markups are allowed to respond to trade liberalization, unemployment and residual wage inequality rise almost three times more than in a model with constant markups (in the steady state). The surge in unemployment caused by variable markups tends to reduce the pro-competitive gains from trade in the steady state.[2] Interestingly, I show that while abstracting from labor market frictions in my framework implies positive pro-competitive gains from trade liberalization, taking labor market frictions into account makes the pro-competitive gains from trade liberalization *negative*, i.e., the steady-state welfare gains are smaller under variable markups than those under constant markups.

In the model, an endogenous measure of firms operate in a small open economy, each subject to idiosyncratic productivity shocks. Firms use intermediate inputs and hire (multiple) homogeneous workers to produce their differentiated products, subject to vacancy posting costs, firing costs, and matching frictions. These frictions create rents from worker-firm matches, and a standard bargaining game determines how they are divided up. Firms sell their products in oligopolistically competitive markets à la Atkeson and Burstein (2008), and therefore larger firms have more market power and charge higher markups, as is common in this class of models.

The link between openness, markups, and labor market outcomes in the model comes from that trade liberalization increases competition in product markets thereby raising demand elas-

[1] As Arkolakis et al. (2019), for example, mention, their study "has little to say about how variable markups may affect the distributional consequences of trade, alleviate misallocations between oligopolistic sectors, or worsen labor market distortions."

[2] Following Arkolakis et al. (2019), by the *pro-competitive gains from trade* I mean the differential welfare implications of trade when markups are variable and when they are constant.

ticities and putting a downward pressure on markups.[3] This in turn increases labor elasticities of revenue which makes firms' employment decisions more responsive to their idiosyncratic shocks. More responsiveness to shocks makes the firm size distribution more dispersed by shifting employment toward larger firms that, due to labor market frictions, pay higher wages. As jobs get more concentrated in high-paying firms, more individuals decide to search for jobs in the labor market, which in turn reduces the labor market tightness and increases unemployment. Furthermore, in a less tight labor market it is more likely for firms to fill vacancies, which further increases firms' responsiveness to idiosyncratic shocks thereby reinforcing the effects on the size distribution and unemployment. In addition, a more dispersed firm size distribution along with the fact that larger firms pay higher wages raises residual wage inequality.

My focus on the response of demand elasticities to openness is supported by various studies in the empirical trade literature.[4] To further motivate my key mechanism that links labor elasticities of revenue with firms' employment responsiveness to shocks, Section 2 reports a variety of reduced-form suggestive evidence. In particular, I divide firms into different size bins and show that estimated labor elasticities of revenue as well as job turnover rates for all size bins rise after trade liberalization in Colombia;[5] a rise in job turnover indicates that firms adjust their employment more frequently. Moreover, the size bins with a larger increase in labor elasticities of revenue also experience a larger rise in their job turnover rates.

I also demonstrate a positive cross-firm size correlation between estimated labor elasticities of revenue and rates of job turnover. In line with the literature (e.g., Haltiwanger et al. (2013) for US; Coşar et al. (2016) for Colombia; Dix-Carneiro et al. (2021) for Brazil), I show that larger firms provide more stable jobs, i.e., they have lower job turnover rates. Moreover, I document that larger firms have lower labor elasticities of revenue.[6] Hence, this paper provides

[3]Throughout this paper, demand elasticity refers to the price elasticity of demand.

[4]The large literature that studies the impact of international trade on demand elasticities and markups in various countries suggests that import competition tends to increase demand elasticities and to reduce markups, see e.g., Eslava et al. (2004) for Colombia, Roberts and Tybout (1996) for Mexico, Colombia, Chile, and Morocco, De Melo and Urata (1986) for Chile, Harrison (1994) for Cote d'Ivoire, Krishna and Mitra (1998) for India, Kim (2000) for Korea, Bottasso and Sembenelli (2001), Konings et al. (2005) for Bulgaria and Romania, Badinger (2007) for European countries, Levinsohn (1993) for Turkey, Edmond et al. (2015) for Taiwan, Arkolakis et al. (2019), MacKenzie (2021), and Atrianfar and Firooz (2019). Some studies define markup as price over marginal cost, while others define it as total revenue over total variable costs. I use the former definition in this paper. De Loecker et al. (2016) who study trade liberalization in India note that trade liberalization affects Indian firms' markups through two competing forces: higher competition as well as lower input costs. They show that while firms charge higher markups after trade liberalization, markups fall conditional on input costs. Tybout (2003) reviews this literature and concludes that price-cost margin falls by trade exposure. Eslava et al. (2004) estimate demand elasticities faced by Colombian manufacturing plants and show that demand elasticities fall by trade openness.

[5]Job turnover is defined as the sum of job creation (total number of jobs created) and job destruction (total number of jobs destroyed).

[6]This is in line with the literature documenting that larger firms charge higher markups, e.g., Atkin et al. (2015) for Pakistan, De Loecker and Warzynski (2012) for Slovenia, De Loecker et al. (2016) for India, and Edmond et al. (2015) for Taiwan.

a new explanation for the size-stability relationship: Larger firms provide more stable jobs, partly because they have smaller labor elasticities of revenue which implies less responsiveness to shocks (see Section 2.1 for a simple model).

Using my quantitative model, I explore how variable markups can influence trade-induced changes in labor market outcomes in a frictional labor market thereby affecting the pro-competitive gains from trade. To this end, I compare the counterfactual outcomes of my baseline, variable-markup model to those of a restricted version with constant markups. I first fit both models to the same data moments from Colombian plant-level data in the pre-trade liberalization episode. Importantly, both models have the same (ex-post) trade elasticity and imply the same increase in export (and import) share of revenue in a counterfactual trade liberalization exercise. I show that taking variable markups into account increases trade-induced unemployment and residual wage inequality by almost three times. In particular, my counterfactual exercises show that, under variable (constant) markups, Colombia's reduction in import tariffs in early 1990s increases unemployment rate and residual wage inequality in the steady state by 16.2% (5.8%) and 9% (3.8%), respectively. The counterfactual outcomes under variable markups are more consistent with changes in size distribution, unemployment, and residual wage inequality observed in Colombia after trade liberalization.[7]

The surge in unemployment in the variable-markup model reduces the measure of produced varieties, which increases the price index and puts a downward pressure on welfare. In addition to this unemployment effect, variable markups in my model also affect welfare consequences of trade through two other forces that are standard in the literature. On the one hand, Home producers' markups fall and become less dispersed. Moreover, employment shifts toward larger, under-producing firms that charge higher markups. This effect, as in Edmond et al. (2015), tends to reduce misallocation arising from markups and to generate pro-competitive gains from trade liberalization, i.e., increasing welfare consequences of trade relative to the constant-markup model.

On the other hand, however, as emphasized by Arkolakis et al. (2019), Foreign firms charge higher markups after trade liberalization, which tends to reduce the pro-competitive gains from trade. Overall, my counterfactual exercises imply that the pro-competitive "gains" from trade liberalization in a frictional labor market are quite negative: While Colombia's trade liberalization in the 1990s raises its real income by 1.7% (in the steady state) under constant markups, accounting for variable markups reduces these gains to only 0.3%. That is taking variable markups into account reduces the gains from trade liberalization by 80%.

[7]The implications of the model are also broadly in line with what is documented in the literature. For instance, the literature documents that after adopting outward-oriented trade policies, several Latin American countries experienced higher (within-industry) job reallocations (Haltiwanger et al., 2004) and the associated negative consequences for workers, including higher unemployment rates (de Desarrollo, 2004) and higher wage inequality (Attanasio et al., 2004).

To emphasize the role of search frictions in driving these negative pro-competitive gains from trade liberalization, it is important to show that this result is indeed due to labor market frictions, not due to Foreign firms charging higher markups. To this end, I shut down search frictions in the labor market in both constant- and variable-markup models, and perform the same trade liberalization counterfactual exercise. Both models again imply the same (ex-post) trade elasticity and generate the same increase in export share of revenue in the steady state, similar to the models with search frictions. Interestingly, in this world without labor market frictions, the pro-competitive gains from trade liberalization are positive: While the steady-state real income rises by 2.5% in the variable-markup model, it rises by 2% in the constant-markup model. These positive pro-competitive gains from trade liberalization in a frictionless labor market are consistent with Edmond et al. (2015), as my model structure without search frictions is broadly in line with theirs.

We can therefore conclude that while abstracting from labor market frictions in my framework implies positive pro-competitive gains from trade liberalization, taking labor market frictions into account makes the pro-competitive gains from trade liberalization *negative*. That is accounting for variable markups in a frictional labor market substantially reduces the gains from trade liberalization. In the language of Arkolakis et al. (2019), I show that the pro-competitive gains from trade liberalization can be even more "elusive" in the presence of labor market frictions.

This paper contributes to several strands of literature. First, this work contributes to the literature on the effects of trade openness in the presence of frictional labor markets (Davidson et al., 1999, 2008; Egger and Kreickemeier, 2009; Davis and Harrigan, 2011; Amiti and Davis, 2011; Fajgelbaum, 2013). More specifically, since the formulation in this paper uses random search and wage bargaining, this paper is relatively close to Helpman and Itskhoki (2010), Helpman et al. (2010), Felbermayr et al. (2011), Coşar et al. (2016), Helpman et al. (2017), Dix-Carneiro et al. (2021), and Ruggieri (2018). I contribute to this literature by exploring the impacts of trade-induced changes in markups in frictional labor markets. I show that variable markups substantially magnify the link between trade and labor market outcomes. By showing that variable markups can raise unemployment in frictional labor markets which affects welfare implications of trade, this paper also contributes to the literature quantifying the pro-competitive gains from trade (e.g., Edmond et al., 2015; Arkolakis et al., 2019). My paper complements these studies by focusing on how variable markups interact with labor market frictions, which in turn has important aggregate and distributional consequences.

The theoretical link between international trade, demand elasticity, and labor market outcomes dates back (at least) to Rodrik (1997), who argues that globalization, through offshoring, makes labor demand more elastic, which in turn increases wage volatility. Slaughter (2001) documents that demand elasticity for production labor in most of the U.S. manufacturing industries between 1961 to 1991 has risen, which is partly due to international trade. De Loecker et al. (2020) state that the fall in workers flow in the U.S. economy over the past few decades is consistent with the rise in average markups. Decker et al. (2020) document that the downward trend in job reallocation in the U.S. is due to lower responsiveness of firms to the shocks, which might be due to globalization.[8] I contribute to this literature by examining the quantitative importance of trade-induced changes in demand elasticities (i) in frictional labor markets, and (ii) in a general equilibrium setting.

By quantifying that one main underlying mechanism that influences firms' responsiveness to shocks and firm size distribution is changes in markups (and labor elasticities of revenue), this paper contributes to the literature that studies patterns and underlying forces of job turnover (e.g., Davis and Haltiwanger, 1992; Haltiwanger and Vodopivec, 2002; Coşar et al., 2016) as well as the vast literature on firm dynamics, e.g., Jovanovic (1982), Hopenhayn (1992), Hopenhayn and Rogerson (1993), Ericson and Pakes (1995), Klette and Kortum (2004), Cooper et al. (2007), Luttmer (2007), Rossi-Hansberg and Wright (2007), Elsby and Michaels (2013), Coşar et al. (2016), Arkolakis (2016), and Decker et al. (2020) among others.[9]

Finally, this paper contributes to the literature that quantifies labor or capital adjustment costs (e.g., Cooper and Haltiwanger, 2006; Cooper et al., 2007; Coşar et al., 2016; David and Venkateswaran, 2019). As pointed out, for example, by David and Venkateswaran (2019), adjustment costs would be overestimated if other sources of frictions or distortions are ignored.[10] Using a structural model, this paper shows that imposing constant markups would overestimate the importance of labor market frictions by 11%: Without markup adjustments, limited hiring and firing responses to idiosyncratic shocks are likely to be attributed entirely to input market frictions.

Although this paper studies the consequences of trade liberalization, the mechanism in-

[8]The mechanism in Decker et al. (2020) is different from the one in this paper. Decker et al. (2020) argue that, due to globalization, firms may respond to shocks partly via adjusting labor working in their production lines outside the U.S. As they don't observe firms' workforce who work abroad, they say one might conclude firms are less responsive to shocks. They also examine the link between import penetration and firms' responsiveness and find a mixed result suggesting that, as they note, this is an important line of future research.

[9]There is a distinction between worker reallocation and job reallocation emphasized in this literature. Both in my model and in my data, I measure job reallocation, not worker reallocation. Davis and Haltiwanger (1992) report a major fraction (35-56%) of worker reallocation in the U.S. is accounted for by job reallocation, and even a larger fraction is documented by Haltiwanger and Vodopivec (2002) for Estonia (about two-thirds). In this paper, I focus on the effect of demand elasticity on job (i.e., employment opportunities within firms) turnover, which leads to worker turnover. Since worker flows are not observed in my plant-level data, the only source of worker reallocation in my model is assumed to be job reallocation. Indeed, worker reallocation and job reallocation are equivalent in my model.

[10]David and Venkateswaran (2019) show that a large portion of capital misallocation is due to the capital tax (wedge), an exogenous object in their model, which is correlated with productivity. As a result, high productivity firms do not react much to productivity shocks. In my model, however, the (labor) wedge is an endogenous/variable object, sourced from variable markups. Moreover, this wedge reacts to trade-induced changes in the product market competition.

troduced here is not confined to international economics; any policy that enhances product market competition would potentially influence demand elasticities faced by firms, which in turn influences labor market outcomes. Moreover, the insights provided in this paper are not limited to the labor market studies; changes in demand elasticities would influence not only the employment decisions of firms, but also their other decision variables like investment.

The rest of this paper is organized as follows. Section 2 presents a simple theory to highlight the link between labor elasticities of revenue and firms' responsiveness to shocks. Moreover, to support the essential mechanism of the paper, I provide some reduced-form suggestive evidence from Colombian economy. Section 3 describes the environment, lays out the quantitative model, and defines the stationary equilibrium of the model. Section 4 discusses the calibration procedure, provides the intuition behind the moments targeted to learn about model parameters, and performs counterfactual exercises. Section 5 concludes.

2 The Main Mechanism

This section explains and provides suggestive evidence for the main mechanism introduced in this paper that links labor elasticity of revenue with firms' employment responsiveness to their shocks. First, I provide a simple model to show that firms' employment responsiveness to shocks is a function of the labor elasticity of revenue. Then, I use Colombian manufacturing plant-level data to show that there is a positive association between labor elasticity of revenue and job turnover.

2.1 A Simple Model

Although the full model developed in Section 3 is a dynamic general equilibrium trade model with labor market frictions, here, to fix the idea and show the main mechanism, I employ a static model with a competitive labor market. Consider an economy with price-setter firms which face the demand elasticity σ:

$$q = Bp^{-\sigma} \ , \tag{1}$$

where q is the quantity demanded, p is the price charged by the firm, and B is the aggregate demand shifter. Assume the following production function:

$$q = \phi l^{\psi} \ , \tag{2}$$

where ϕ is firm's productivity and l is labor. To measure firms' employment responsiveness to shocks in what follows, it is important to note that ψ is the labor elasticity of output *after all* *factors of production are optimized out and expressed in terms of labor.*[11]

Based on equations (1) and (2), one can write firm's revenue function as

$$R = Al^{\zeta} \ , \tag{3}$$

where $A \equiv B^{\frac{1}{\sigma}}\phi^{\frac{\sigma-1}{\sigma}}$ is the revenue productivity residual, or the firm's revenue shock, and $\zeta \equiv \psi(\frac{\sigma-1}{\sigma})$ is the labor elasticity of revenue, again after all factors of production are optimized out and expressed in terms of labor. The labor elasticity of revenue consists of the labor elasticity of output ψ and the demand elasticity σ. The labor elasticity of revenue rises with demand elasticity; the intuition is that for a firm that faces a more-elastic demand curve, changes in labor (and therefore quantity) result in larger changes in revenue, since price is less responsive.

Using the first order condition of the firm's profit maximization problem, one easily shows:

$$\frac{dl/l}{dA/A} = \frac{1}{1-\zeta} \ , \tag{4}$$

where I call the left-hand side the firm's employment responsiveness to revenue shocks A (*responsiveness*, hereafter). Equation (4) implies that firms' responsiveness increases with labor elasticity of revenue.[12] This is because as labor elasticity of revenue rises, the marginal revenue product of labor changes more slowly with labor, and firms therefore respond more (in terms of employment) to shocks. The next section provides some suggestive evidence that firms with higher labor elasticity of revenue are more responsive to their shocks and have higher job turnover rates.

An immediate implication of equation (4) is that when firms face a more-elastic demand curve, they would become more responsive (in terms of employment) to their idiosyncratic shocks, because price would be less responsive to changes in quantity.[13] In the full model developed in Section 3, demand elasticity σ (and therefore, labor elasticity of revenue ζ) is a firm-level endogenous equilibrium object that responds to the level of competition in the market. By influencing the degree of product market competition, trade liberalization affects demand elasticities that firms face, which in turn changes firms' responsiveness to shocks

[11] Note that one can also introduce some *fixed* factors, like capital, into the production function, assuming that they are fixed and do not respond to shocks. The measurement exercise in the next section takes into consideration this alternative approach as well.

[12] I assume $\zeta < 1$. Section 2.2 estimates labor elasticity of revenue and shows this is indeed the case for manufacturing plants in Colombia.

[13] Appendix A takes an alternative perspective and uses labor demand function to relate output demand elasticity to firms' responsiveness to shocks. To elaborate, instead of arguing that labor elasticity of revenue is affected by changes in output demand elasticity, Appendix A shows that, as emphasized in the literature, labor demand elasticity responds to changes in output demand elasticity. These two perspectives are closely connected since labor elasticity of revenue and labor demand elasticity are two sides of the same coin.

thereby influencing various labor market outcomes.

2.2 Suggestive Evidence

In this section, I use Colombia Annual Manufacturing Survey to support the essential mechanism of this paper which links labor elasticity of revenue to firms' responsiveness to their shocks. The data cover all manufacturing plants with at least 10 employees, from 1983-1991 and 1992-2012.[14,15] This section presents three suggestive evidence. First, I show that larger firms have smaller labor elasticities of revenue, and adjust their labor less frequently, i.e., they have lower job turnover rates. Hence, there is a positive association between job turnover and labor elasticity of revenue across the firm size distribution. The second suggestive evidence shows that labor elasticities of revenue rise after trade liberalization in Colombia and this increase is positively associated with the rise in job turnover. Moreover, I show that firms which experience a larger rise in labor elasticity of revenue after trade liberalization also experience a larger increase in job turnover rates. The last evidence documents that firms with higher labor elasticity of revenue are more responsive to their revenue shocks.[16]

Suggestive Evidence 1 *Larger firms have smaller labor elasticities of revenue, and adjust their labor less frequently (i.e., they have lower job turnover rates). Hence, there is a positive association between labor elasticity of revenue and job turnover across the firm size distribution.*

To present this evidence, I divide plants into 40 employment bins, and estimate the revenue function separately for each employment bin j:[17]

$$\log(R_{ijt}) = \zeta_j \ \log(l_{ijt}) + \log(A_{ijt}) + \varepsilon_{ijt} \ , \tag{5}$$

where R_{ijt} and l_{ijt} are, respectively, revenue and employment of plant i in employment bin j at time t. A_{ijt} is the transmitted part of revenue shocks, while ε_{ijt} are transitory i.i.d. shocks.[18] The objects of interest are the labor elasticities of revenue ζ_j.

[14] This is a plant-level data set. In what follows, however, I use the words "firm" and "plant" interchangeably. Moreover, I winsorize the data at 1 and 99 percent.

[15] Special thanks to Jim Tybout who provided me with the 1983-1991 data. The data from 1992-2012 are from Colombia National Administrative Department of Statistics (DANE). Moreover, note that since the plant IDs before 1991 are not generated by DANE, I cannot link the plants before 1991 to those after 1992.

[16] Since both labor elasticity of revenue and firms' responsiveness are endogenous variables, all suggestive evidence presented in this section are correlations, i.e., I do not claim to establish any causal link in this section.

[17] In supporting my mechanism, one advantage of estimating labor elasticity of revenue instead of demand elasticity (or labor elasticity of output) is that the former can be more credibly estimated without observing price and quantity separately, a common issue in estimating production or demand functions.

[18] I call A the "revenue shocks" since it may contain productivity as well as demand-side shocks. This is also called revenue productivity residual and estimated in the literature, e.g., Gopinath et al. (2017), Decker et al. (2018), and Foster et al. (2017).

There are six categories of workers employed at plants: unskilled workers, apprentices, foreign technicians, local technicians, skilled workers, and management staff. To control for worker heterogeneity/productivity to the extent possible, I use *effective labor* to measure plant-level employment throughout this paper. To measure effective labor, I first calculate the average wage of each type of workers across all plants and all time periods. Then, each type of worker is weighted by its average wage relative to the average wage of unskilled workers. The sum of these weighted workers is the plant-level effective labor.

In estimating the revenue function (5), I employ the control function approach in Levinsohn and Petrin (2003) to solve the simultaneity problem between revenue shocks and labor input;[19] Appendix B reports the results using Ackerberg et al. (2015) methodology as a robustness check. In line with my structural model in Section 3, I treat labor as a *dynamic* input, i.e., labor is a state variable since it is subject to adjustment costs. Finally, I use material usage as the proxy variable.[20]

As discussed before, the revenue function (5) assumes that *all* factors of production except labor are *static* (i.e., freely adjustable) and are optimized out.[21] As an alternative, Appendix B estimates labor elasticities of revenue by including capital, which is assumed to be *fixed*, and all other factors of production except labor are assumed to be static and optimized out.[22] Notice that estimating the labor elasticity of revenue that is informative for firms' responsiveness to shocks needs at least one of the aforementioned assumptions about capital (and other production inputs). This is because if more than one production input is assumed to be dynamic, one needs to explicitly model the factor adjustment costs to be able to back out the labor elasticity of revenue. Under these two alternative assumptions, I estimate the labor elasticity of revenue ζ_j, and the results are very similar.

I calculate job turnover rate for each employment bin j in year t as

$$\mathrm{JT}_{jt} = \frac{\sum_{i \in c} |l_{ijt} - l_{ijt-1}| + \sum_{i \in exit} l_{ijt-1}}{(L_{jt-1} + L_{jt})/2} \times 100 \ , \tag{6}$$

where i denotes plants, c is the set of continuing plants, and L_{jt} is total employment for employment bin j at time t. The terms in the numerator measure employment adjustment by

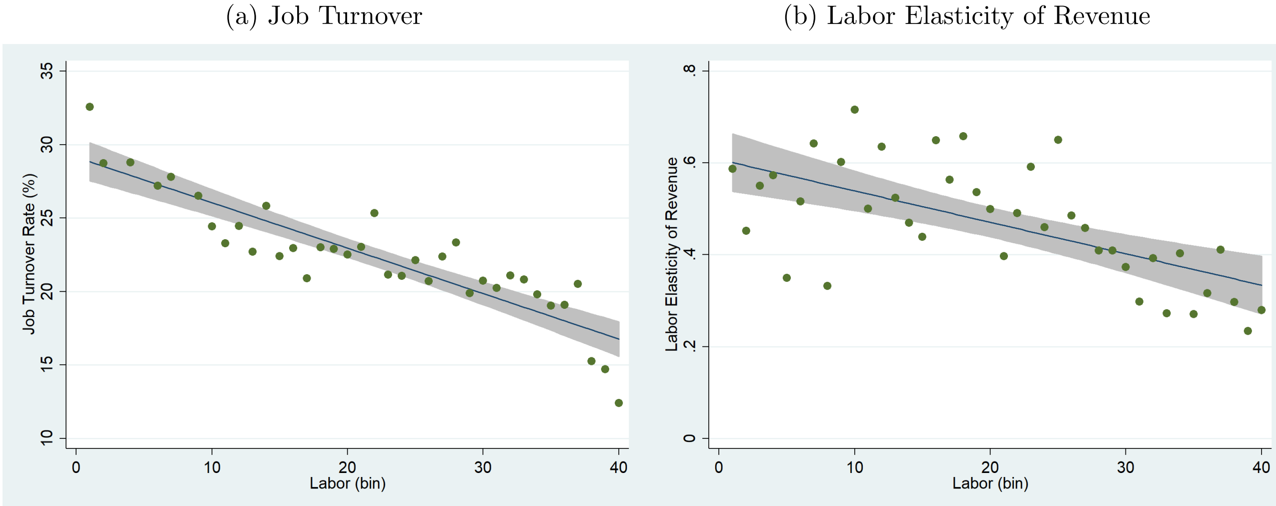
[19] Cooper and Haltiwanger (2006) use GMM to estimate the revenue function. Their estimation method is similar to the second stage of Levinsohn and Petrin (2003). Note that here I employ the control function approach to estimate the *revenue function* by writing the revenue shocks (which consists of both productivity and demand shocks) as a function of the proxy variable. The assumption here is monotonicity of the proxy variable in revenue shocks.

[20] As a robustness check, I use energy consumption as the proxy variable and show that the results hold.

[21] This is similar to the way that the capital adjustment literature, e.g., Cooper and Haltiwanger (2006), estimates capital elasticity of revenue: they assume all factors of production except capital are static.

[22] For the fixed-capital assumption to seem more appropriate, I use the relatively short sample period 1983-1991 to estimate revenue functions.

Figure 1: Job Turnover and Labor Elasticity of Revenue across the Firm Size Distribution



Notes: Plants are divided into 40 employment bins, displayed by the horizontal axes. The shaded areas reflect the linear fitted lines along with their 95% confidence bands.

continuing plants and exiting plants, respectively. I then take the average job turnover rate for each employment bin over the sample period.[23]

Figure 1 reports the results. The left panel shows that larger firms have lower job turnover. The right panel of this figure shows that labor elasticity of revenue falls with firm size.[24] This paper links firms' size and job stability through labor elasticity of revenue. Through the lens of the quantitative model in Section 3, larger firms face lower demand elasticities and therefore have smaller labor elasticities of revenue. This makes larger firms less responsive to their idiosyncratic shocks.

Suggestive Evidence 2 *The rise in job turnover is positively associated with the rise in labor elasticity of revenue. Moreover, plants with a larger rise in their labor elasticity of revenue experience a larger increase in their job turnover rates.*

This suggestive evidence exploits variations in labor elasticity of revenue and job turnover over

[23]Two points regarding the definition of job turnover rate are worth mentioning. First, to ensure the robustness of results, Appendix B measures job turnover rate *net of employment change* for each size bin by subtracting from the numerator the net employment change for each size bin. As Appendix B shows, all the results in this section are robust to that definition. Second, *aggregate* job turnover rate defined in the literature (and also in Section 4 of this paper) includes in the numerator the job creation by entrants. However, since entrants do not belong to any size bins in year $t-1$ (simply because they did not exist), they do not enter employment bins' job turnover rates.

[24]This is true even after controlling for industry. As a robustness check, I divide plants in each 3-digit ISIC industry into 5 employment bins based on their size, and show that within each industry, labor elasticity of revenue falls with size.

time. To this end, I follow the methodology outlined above to estimate the labor elasticity of revenue separately for each of the 40 employment bins, once for the pre-trade liberalization episode, i.e., from 1983-1991, and once using the post-liberalization data, i.e., from 1992-2012.[25,26] Moreover, for each employment bin, I take the average of within-bin job turnover in (6) over the pre- and post-liberalization episode.

Figure 2 plots the change in labor elasticity of revenue and job turnover rate for each employment bin from pre- to post-trade liberalization episode. It shows that both labor elasticity of revenue and job turnover rate rise after trade liberalization in Colombia. Moreover, firms that experience a larger rise in labor elasticity of revenue also experience a larger increase in their job turnover rates.[27] Through the lens of the quantitative model in Section 3, trade liberalization has a heterogeneous effect on the demand elasticity faced by firms with different size, which leads to a heterogeneous impact on job turnover across the firm size distribution. Firms with a larger increase in labor elasticity of revenue become more responsive to their idiosyncratic shocks which therefore implies a larger rise in job turnover.

Suggestive Evidence 3 *Plants with larger labor elasticities of revenue are more responsive (in terms of employment) to their revenue shocks.*

To measure revenue shocks, since plants in different industries potentially face different shocks, I first divide all plants within each 3-digit ISIC[28] industry into five employment bins. I then follow the methodology explained above to estimate a revenue function analogous to (5) separately for each employment bin j within industry k. This procedure estimates the labor elasticity of revenue $\hat{\zeta}_{jk}$, and the (transmitted part of) revenue shocks $\hat{A}_{ijkt}$ for firm i in employment bin j within industry k at time t.

Next, I estimate firms' employment responsiveness to their revenue shocks.[29] In the quantitative model developed in Section 3, in line with the firm dynamics literature, the employment policy function of a firm is a function of the revenue shock to the firm, last period employment

[25]For the pre-trade liberalization period, I divide plants into 40 employment bins based on their size in 1983. I use the same size quantiles to divide plants in the post-liberalization episode. As explained before, using the six categories of labor reported in the pre-1991 data, labor is measured in *effective units*. The data after 1992, however, do not report the detailed information about the types of workers employed at each plant. Hence, to make the post-92 labor units comparable to the pre-liberalization data, I proceed as follows. Using the pre-liberalization plant-level data, I fit effective labor to a polynomial function of total number of workers. Then, I use the coefficients from this regression to convert total number of workers observed in the post-liberalization data to effective labor units.

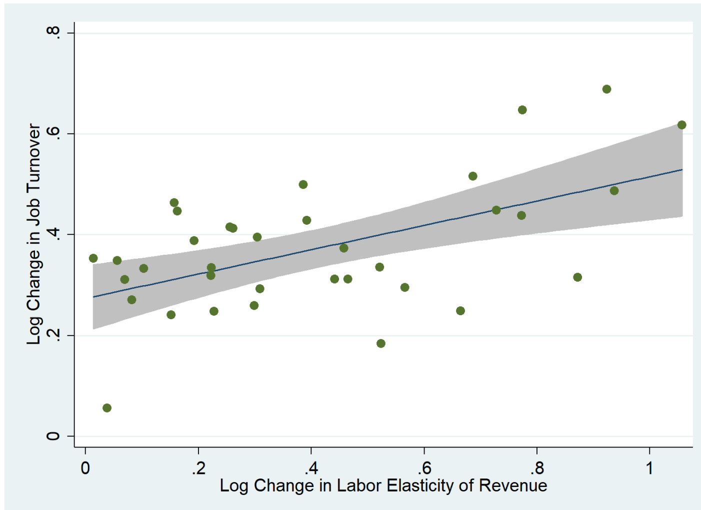
[26]There are different phases of trade liberalization in Colombia. The largest drop in tariffs and non-tariff barriers happened in 1991. For more details on trade liberalization in Colombia, look at Attanasio et al. (2004), Coşar et al. (2016), and Alessandria and Avila (2020) among others.

[27]As mentioned before, Appendix B shows that this result is robust to defining job turnover rate net of employment change for each size bin.

[28]International Standard of Industrial Classification.

[29]Recall that the employment responsiveness to revenue shock A for a firm with l workers is defined as $\frac{dl/l}{dA/A}$.

Figure 2: Changes in Job Turnover vs. Changes in Labor Elasticity of Revenue for Each Employment Bin



Notes: Plants are divided into 40 employment bins. The horizontal and vertical axes, respectively, measure the log change in labor elasticity of revenue and job turnover for each employment bin from pre- to post- trade liberalization episode. The shaded area reflects the linear fitted line along with its 95% confidence band.

of the firm (due to labor adjustment costs), and persistence of revenue shocks. I estimate responsiveness of firms by running the following regression separately for each employment bin j within industry k:[30]

$$\log(l_{ijkt}) = \alpha_{jk} + \beta_{jk}\ \log(\hat{A}_{ijkt}) + \theta_{jk}\ \log(l_{ijkt-1}) + D_t + \nu_{ijkt}\ , \tag{7}$$

where D_t are time dummies, and ν_{ijkt} is the error term.[31] The coefficients β_{jk} measure firms' employment responsiveness to revenue shocks in employment bin j within industry k.[32]

After estimating the employment responsiveness to revenue shocks for each size-industry pair jk, I examine whether the estimated responsiveness $\hat{\beta}_{jk}$ are positively correlated with estimated labor elasticities of revenue $\hat{\zeta}_{jk}$. To this end, I run the following regression:

$$\hat{\beta}_{jk} = \gamma_0 + \gamma_1\ \hat{\zeta}_{jk} + \gamma_2\ \rho_{jk} + D_k + \epsilon_{jk}\ , \tag{8}$$

[30]Since I measure persistence of revenue shocks at the size-sector level jk, I cannot include this in regression (7). I control for persistence of the shocks in what follows.

[31]Since I approximate a presumably highly non-linear employment policy function using a linear function, I assume the source of the error term ν_{ijkt} is the functional form assumption. Hence, I allow the error term to be heteroskedastic.

[32]In principle, what determines the firms' employment decisions is shocks to the revenue function rather than shocks to the production function. Measuring responsiveness using shocks to the revenue function is also done in the literature, e.g., Decker et al. (2020).

Table 1: Firms Responsiveness to Shocks vs. Labor Elasticity of Revenue

	Responsiveness
Labor Elasticity of Revenue	0.057*
	(0.029)
Shocks Persistence	0.090*
	(0.050)
Industry FE	✓
R^2	0.475
N	82

Notes: Plants within each 3-digit ISIC industry are divided into five employment bins. Responsiveness, labor elasticity of revenue, and persistence of shocks are estimated separately for each employment bin-industry pair. Standard errors in parentheses. * $p < 0.1$

where D_k are industry fixed effects, and ρ_{jk} is the persistence of revenue shocks at the size-industry level jk. Note that as suggested by the firm dynamics literature (e.g., Cooper and Haltiwanger, 2006; Cooper et al., 2007), in the presence of labor adjustment costs, firms' responsiveness to shocks rises with shocks' persistence. As a result, I also control for the persistence of shocks in the regression above. To estimate ρ_{jk}, I assume revenue shocks A_{ijkt} follow an AR(1) process, which I estimate separately for each size-industry pair jk.

Table 1 reports the results.[33] As expected, firms' employment responsiveness to shocks is positively associated with labor elasticity of revenue. Moreover, firms' responsiveness is also positively correlated with the persistence of shocks.

This section provided some suggestive evidence linking labor elasticity of revenue with firms' employment responsiveness to their shocks. The next section develops a dynamic general equilibrium trade model featuring endogenously variable markups to quantify how international competition, by affecting demand elasticities and therefore labor elasticities of revenue, can influence aggregate and distributional consequences of trade liberalization in frictional labor markets.

3 The Model

3.1 Environment

There are two countries in the world, Home (H) and Foreign (F)—the rest of the world. Product markets in H and F are segmented. There are three types of goods: intermediate goods (or

[33] I include only the size-sector pairs with a statistically significant estimate for the labor elasticity of revenue.

manufacturing sector), a final good, and home-production (or *services*, which is the model numeraire). Only intermediate goods are tradable. Final good producers bundle intermediate goods (both domestic and imported) to produce a homogeneous final good to sell to consumers as well as intermediate producers in a perfectly competitive market. Labor is not used in producing the final good. Intermediate producers are subject to idiosyncratic productivity shocks, and employ workers as well as the final good to produce a particular variety using a proprietary technology. Intermediate producers sell their goods to final good producers under an oligopoly market structure. Labor market is frictional. There is a unit measure of infinitely lived risk-neutral homogeneous workers who own the firms.

3.2 Consumers and Final Good Producers

Final good producers make a homogeneous composite good out of a continuum of intermediate goods ν, and sell it to consumers as well as intermediate producers in a perfectly competitive market. The final good in country $i \in \{H, F\}$ is produced according to the following commonly available Constant Elasticity of Substitution (CES) technology:[34]

$$M_i = \left[\int_0^{N_H} Q_i(\nu)^{\frac{\sigma-1}{\sigma}} d\nu \right]^{\frac{\sigma}{\sigma-1}} , \tag{9}$$

where σ is the elasticity of substitution, and N_H is the measure of intermediate goods available, which is an equilibrium object. Each good ν is a CES aggregate over one Home variety and K Foreign varieties:

$$Q_i(\nu) = \left[q_{Hi,1}(\nu)^{\frac{\alpha-1}{\alpha}} + \sum_{k=1}^{K} q_{Fi,k}(\nu)^{\frac{\alpha-1}{\alpha}} \right]^{\frac{\alpha}{\alpha-1}} , \tag{10}$$

where subscript ji, k refers to the goods produced by firm k in country j and sold in country i, K is a fixed number, and α is the elasticity of substitution between varieties within each good ν. Parameters σ and α govern the price elasticity of demand (i.e., demand elasticity) faced by intermediate producers, to be elaborated below.

Per-period utility of consumer n at time t equals

$$U_{nt} = M_{nt}^{\kappa} Y_{nt}^{1-\kappa} , \tag{11}$$

where M_{nt} and Y_{nt} are her consumption of the final composite good and home-production, respectively, and κ is the share of final good. Consumers maximize the expected present value

[34] The size of final good producers is indeterminate, since they use a constant returns to scale technology and sell their goods in a perfectly competitive market.

of their utility stream:

$$U_n = \sum_{t=1}^{\infty} \beta^{t-1} U_{nt} \ , \tag{12}$$

where β is the discount factor. Note that since workers are risk-neutral, they do not save. For ease of notation, I suppress the time subscript t in what follows.

The cost minimization problem for final good producers in country j implies the following demand for the variety produced by country i's firm k:

$$q_{ij,k}(\nu) = A_j P_j(\nu)^{\alpha-\sigma} p_{ij,k}(\nu)^{-\alpha} \ , \tag{13}$$

where A_j is the aggregate demand shifter in country j, $P_j(\nu)$ is the price index for good ν in country j, and $p_{ij,k}(\nu)$ is the price of this variety in country j. The price index for good ν in country j is defined as

$$P_j(\nu) = \left[p_{Hj,1}(\nu)^{1-\alpha} + \sum_{k=1}^{K} p_{Fj,k}(\nu)^{1-\alpha} \right]^{\frac{1}{1-\alpha}} \ . \tag{14}$$

3.3 Intermediate Good Producers

Each intermediate producer receives an idiosyncratic productivity shock (à la Melitz, 2003; Chaney, 2008) and employs labor and the final good to produce its particular variety using the following proprietary technology:

$$q(\phi, l) = \phi M(\phi, l)^{\eta} l^{1-\eta} \ , \tag{15}$$

where ϕ is productivity, l is the labor employed at the firm, $M(\phi, l)$ is the composite final good (call it material) demanded by firm (ϕ, l), and η is the elasticity of output with respect to material (given labor). Intermediate producers are subject to idiosyncratic productivity shocks which follow a stationary Markov process

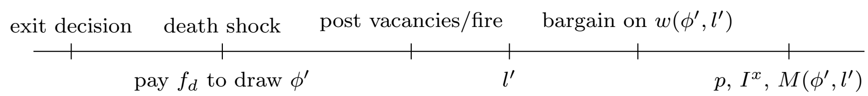
$$\ln \phi' = \gamma \ln \phi + \varepsilon \quad , \quad \varepsilon \sim N(0, \sigma_\phi^2) \ , \tag{16}$$

where γ is the persistence of the productivity process and σ_ϕ is the variance of shocks. In what follows, x' denotes the variable x in the next period.

3.4 Firms' Static Problem

Final good producers decide only about how much to buy each variety ν based on the demand equation (13). The rest of this section focuses on the decisions made by Home intermediate producers, which I call "firms" in what follows. Foreign firms' problem is discussed in the last part of this section.

Firms carry two state variables over time: productivity and labor. Productivity is a state variable since it follows a Markov process, and labor is the other state variable due to the presence of labor adjustment costs (see Section 3.5). Moreover, labor market features search and matching frictions à la Mortensen and Pissarides (1994). For an incumbent firm starting this period with the last period productivity and employment (ϕ, l) as its state variables, the timing of the events is as follows:



Before the new productivity realizes, the firm decides whether to exit the market. If it stays, the firm needs to pay a fixed operation cost f_d to draw the new productivity ϕ', and the firm may hit by an exogenous death shock which forces the firm to exit the market. Entrants then replace the firms that exited. Next, the firm decides whether to expand or contract. To expand, the firm posts vacancies and matches with an endogenous number of workers, determined in equilibrium. To contract, the firm simply fires workers. The state of the firm then updates to (ϕ', l'), after which the labor market closes. Since the labor market is frictional, there may exist rents generated at the firm. As a result, the firm and workers bargain over the surplus generated at the firm to determine the wage. As the last action within each period, the firm decides about whether to export, how much material to buy, and prices to charge at Home and, if exporting, in the Foreign market.

We solve for firms' decision variables backward. At the first stage, given the wage and number of workers, firms solve for prices, material usage, and exporting decision in a static problem. The second stage solves the wage bargaining problem given the number of workers. At the third stage, firms solve a dynamic vacancy posting/firing problem to determine the number of workers. For exposition purposes, I first describe the static pricing problem, then the dynamic vacancy posting problem, and at the end, the wage bargaining process.

Firms' pricing decision is a static problem. At this stage, given the number of workers and the negotiated wage (to be discussed in Sections 3.5 and 3.7 below), a Home firm producing good ν with productivity ϕ and l workers decides about prices to charge, whether to export, and the material usage by solving the following static optimization problem:

$$\Pi(\phi, l) = \max_{p_{HH,1}, p_{HF,1}, M, I^x} \Big[p_{HH,1}(\phi, l) q_{HH,1}(\phi, l) + p_{HF,1}(\phi, l) q_{HF,1}(\phi, l) I^x(\phi, l) - PM(\phi, l) - f_d - f_x I^x(\phi, l) \Big], \tag{17}$$

subject to

$$q_{HH,1}(\phi,l)+q_{HF,1}(\phi,l)I^{x}(\phi,l)d\leq\phi M^{\eta}(\phi,l)l^{1-\eta}\ , \tag{18}$$

$$q_{Hj,1}(\phi,l)=A_{j}P_{j}(\nu)^{\alpha-\sigma}p_{Hj,1}(\phi,l)^{-\alpha}\ , \tag{19}$$

where I^x is an exporting indicator function which takes 1 if the firm exports and zero otherwise, f_d is the fixed cost of operation, P is the price of the homogeneous final good (defined below), f_x is the fixed exporting cost, and d is the iceberg cost of exporting, i.e., in order to deliver one unit of the good in destination, the producer needs to ship d units. For future references, define the firm's revenue (R) as sum of the first two terms in (17).

Fixed costs are paid in terms of home-production (i.e., services). The first constraint above is the feasibility constraint, and the second constraint is the demand schedules derived in equation (13). Notice that since the firm and its matched workers l have already negotiated and agreed to a particular wage, the wage bill does not enter the optimization problem above. The price of the homogeneous final good at Home is the CES aggregate of the intermediate goods prices:

$$P=\left[\int P_{i}(\nu)^{1-\sigma}d\nu\right]^{\frac{1}{1-\sigma}}\ , \tag{20}$$

where the price index $P_i(\nu)$ is defined in equation (14) above.

The Foreign producer k of good ν solves the following maximization problem:

$$\Pi_{F,k}(\nu)=\max_{p_{FH,k},p_{FF,k}}\left[p_{FF,k}(\nu)q_{FF,k}(\nu)+\frac{p_{FH,k}(\nu)}{\tau}q_{FH,k}(\nu)-e\times q(\nu)\right]\ , \tag{21}$$

subject to

$$q_{FF,k}(\nu)+q_{FH,k}(\nu)d\leq q(\nu)\ , \tag{22}$$

$$q_{Fj,k}(\nu)=A_{j}P_{j}(\nu)^{\alpha-\sigma}p_{Fj,k}(\nu)^{-\alpha}\ , \tag{23}$$

where $(\tau-1)$ is the import tariff imposed by Home, and e is the marginal cost of production for all Foreign firms.[35] Note that since $p_{FH,k}$ is the price of the Foreign variety faced by Home consumers, $p_{FH,k}/\tau$ is the price that the Foreign producer receives.

I assume that Home and Foreign varieties within each good ν compete in prices.[36] Using demand equations (19) and (23) and following Atkeson and Burstein (2008) to solve the pricing game between Home and Foreign varieties, one shows that the (absolute value of) demand

[35] To solve the model, what matters is the productivity of Home producers relative to Foreign firms. Hence, I fix the marginal cost of Foreign producers, and calibrate the productivity process for Home producers.

[36] Assuming Cournot competition delivers similar results.

elasticity faced by country i's firm k in market j can be written as

$$\varepsilon_{ij,k}(\nu) = s_{ij,k}(\nu)\sigma + (1 - s_{ij,k}(\nu))\alpha \ , \tag{24}$$

where $s_{ij,k}(\nu)$ is the share of country i's firm k in total sales of good ν in market j, which can be written as

$$s_{ij,k}(\nu) = \left(\frac{p_{ij,k}(\nu)}{P_j(\nu)}\right)^{1-\alpha} \ , \tag{25}$$

and this producer charges the markup $\frac{\varepsilon_{ij,k}(\nu)}{\varepsilon_{ij,k}(\nu)-1}$ in market j. It is natural to think that the elasticity of substitution between varieties of a good is greater than that between different goods, i.e., $\alpha > \sigma$.[37] Equation (24) then implies that larger firms face lower demand elasticities and therefore charge higher markups, which is in line with a large body of the literature (e.g., De Loecker and Warzynski, 2012; Atkin et al., 2015; Edmond et al., 2015; De Loecker et al., 2016)

The pricing decision of firms does not have a closed form solution unless $\alpha = \sigma$, i.e., firms face a constant demand elasticity equal to σ (look at equation (24)). In the variable demand elasticity case, however, I solve the pricing game numerically. After solving for prices, the Home firm decides whether to export by comparing the profit from serving only Home with that from serving both Home and Foreign. Finally, total demand can be derived using the demand equations (19) and then, I solve for the material usage using the production function:

$$M(\phi, l) = (\phi l^{1-\eta})^{\frac{-1}{\eta}} (q_{HH,1}(\phi, l) + q_{HF,1}(\phi, l) I^x(\phi, l) d)^{\frac{1}{\eta}} \ . \tag{26}$$

The Demand structure above allows demand elasticities and markups to respond to trade liberalization. On the one hand, by making the domestic market more accessible to Foreign producers, trade liberalization reduces the share of domestic producers at Home, which puts a downward pressure on the markups that domestic producers charge at Home. On the other hand, trade liberalization raises the share of Home producers in the Foreign market which raises the markups that these producers charge in the Foreign market. The demand structure employed here therefore allows Foreign producers to charge higher markups in the Home market after trade liberalization, the importance of which emphasized by, for example, Helpman and Krugman (1989), Edmond et al. (2015), and Arkolakis et al. (2019).

As equation (24) implies, by imposing $\alpha = \sigma$ all firms would face the same demand elasticity and charge the same markup, which is invariant to trade liberalization. Hence, the demand structure employed here nests the commonly used workhorse model of International Trade and Macro, i.e., monopolistic competition with CES demand. By comparing my model to a nested

[37] Calibrating the model shows that this is indeed the case.

version with constant markups, I will quantify how variable markups influence labor market outcomes in a frictional labor market.

Discussion. The demand structure in this paper is slightly more general than the structure in Bernard et al. (2003), since that paper assumes an infinite elasticity of substitution between Home and Foreign varieties. Moreover, the demand structure here follows Atkeson and Burstein (2008) and Edmond et al. (2015) with one difference: They allow for multiple Home producers to compete at the lower tier, since their lower-tier aggregation in (10) is at the *sectoral* level. While in principle I could allow for multiple Home producers to compete within each good, it would be computationally very expensive. This is because this paper introduces labor market frictions with labor adjustment costs, and therefore allowing for more than one Home producer in (10) would require solving a dynamic vacancy posting game, on top of the static pricing game (see Section 3.5). To explore the robustness of results to the form of the demand structure, Appendix C employs an alternative demand structure similar to Simonovska (2015) which also features variable markups. Simulations of that alternative model deliver qualitatively similar results.[38]

3.5 Firms' Dynamic Problem

This is the third stage of the firms' problem. At this stage, given bargained wages (to be discussed in Section 3.7) and the optimal policies in the first stage, firms choose whether to stay in the market, and if so, decide about vacancy posting/firing. A firm entering the period with state variables (ϕ, l) first decides whether to stay active or exit the market:

$$V(\phi, l) = \max\{(1-\lambda)E_{\phi'|\phi}V^C(\phi', l), 0\} \ , \tag{27}$$

where $V(\phi, l)$ is the continuation value of the firm at state (ϕ, l), λ is the exogenous exit rate, and $V^C(\cdot)$ is the continuation value of staying active in the market, to be defined below. If the firm exits, its continuation value would be zero; If it stays active in the market, the firm would draw its new productivity and may hit by an exogenous death shock with probability λ. Solving the problem above delivers the policy function $I^c(\phi, l)$ which equals 1 if the firm stays in the market and 0 otherwise.

If the firm chooses to stay active, it decides whether to expand or contract. To expand, since the labor market features search and matching frictions, firms need to post vacancies to

[38] The model in the text and the one in Appendix C have the similar main property as the demand structure in Kimball (1995), i.e., larger firms face lower demand elasticities; see Klenow and Willis (2016) and Edmond et al. (2018) among others. The main reason that I used a structure similar to Atkeson and Burstein (2008) rather than Kimball (1995) is that it is numerically less expensive to solve for prices in the current structure.

match with workers. I assume the following matching function (Den Haan et al., 2000; Cosar, 2013; Coşar et al., 2016):

$$M(U,V) = \frac{UV}{(U^\rho + V^\rho)^{\frac{1}{\rho}}} \ , \tag{28}$$

where U is the number of job applicants, V is the number of vacancies, and ρ governs the degree of matching frictions. Higher values of ρ indicate less severe matching frictions since for a given number of vacancies and job applicants, the number of matches rises with ρ. Particularly, if ρ goes to infinity, there would be no matching frictions.[39] The job finding rate, which is the number of matches over the number of applicants, equals

$$m(\theta) = \frac{\theta}{(1+\theta^\rho)^{\frac{1}{\rho}}} \ , \tag{29}$$

where $\theta := \frac{V}{U}$ is the labor market tightness. The vacancy filling rate, which is the number of matches over the number of vacancies, equals therefore $\frac{m(\theta)}{\theta}$.

The firm decides about vacancy posting/firing by solving the following dynamic optimization problem:

$$V^C(\phi', l) = \max_{l'} \big[\Pi(\phi', l') - w(\phi', l')l' - C(l, l') + \beta V(\phi', l')\big] \ , \tag{30}$$

subject to

$$C(l,l') = \begin{cases} (l-l')c_f & l' \leq l \\ \frac{c_v}{l} v^2 & l' > l \end{cases} \tag{31}$$

$$v = (l'-l)\frac{\theta}{m(\theta)} \ , \tag{32}$$

where $\Pi(\cdot)$ is defined in equation (17), $w(\phi', l')$ is the wage that the firm with productivity ϕ' and l' workers pays to all its workers (to be discussed below), and firms discount the future at the same rate β as consumers. $C(l,l')$ is the cost of adjusting labor from l to l', which consists of a linear firing cost c_f and a convex vacancy posting cost. As equation (32) shows, to expand from l to l' the firm needs to post $(l'-l)\frac{\theta}{m(\theta)}$ vacancies since the vacancy filling rate equals $\frac{m(\theta)}{\theta}$. This is because I assume that the number of matches at each firm is proportional to the number of vacancies that the firm posts. For future references, note that the job finding rate and the vacancy filling rate are increasing and decreasing functions of labor market tightness, respectively. As a result, as labor market tightness rises, the same expansion in employment requires a higher vacancy posting cost.

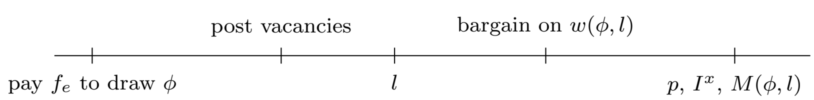
Solving the dynamic optimization problem in (30) delivers the employment policy function $l'(\phi', l)$, the vacancy posting policy function $v(\phi', l)$, and the hiring policy function $I^h(\phi', l)$

[39] To see this, note that we can write: $\lim_{\rho\to\infty} M(U,V) = \min\{U,V\}$. Hence, as $\rho \to \infty$, there would be no matching friction in the labor market.

which takes 1 if the firm expands and 0 otherwise. Note that in line with the firm dynamics literature, while I assume a linear firing cost, vacancy posting cost is convex. This formulation implies that while contracting firms adjust their workers at once, expanding firms hire new workers gradually (Coşar et al., 2016; Cooper and Willis, 2009; Cooper et al., 2007; Merz and Yashiv, 2007; Yashiv, 2006). Moreover, as will be discussed in detail in Section 3.7 below, without a convex hiring cost the model would imply no residual wage inequality among expanding firms (see, e.g., Felbermayr et al., 2011), which is not in line with either the literature or the data.

3.6 Entry

In equilibrium, an endogenous measure of entrants replace the firms that exit the market either endogenously or exogenously. The timing of the events for entrants is as follows:



Entrants pay the sunk entry cost f_e to start with l_e workers and draw their productivity.[40] Entrants draw their productivity from $J^0(\phi)$, which is the ergodic distribution implied by the productivity process (16), and are able to expand right away by posting vacancies. Entrants then bargain with workers, and decide about prices, exporting, and material usage. I assume that entrants are not hit by the exogenous death shock upon entry. The value of entry therefore can be expressed as

$$V^e := \int V^C(\phi, l_e) dJ^0(\phi) \ . \tag{33}$$

In equilibrium, the value of entry cannot exceed the sunk entry cost:

$$V^e \leq f_e \ , \tag{34}$$

which holds with equality if there is a positive mass of entrants.

3.7 Labor Market and Wage Bargaining

To model the labor market, I build on Coşar et al. (2016) with some modifications. As noted above, the labor market features search and matching frictions à la Mortensen and Pissarides

[40] Note that workers, who own firms, pay the entry costs. However, since there are no realized profits at the beginning of each period, one might question the financing source of these entry costs. One could assume that workers save a constant amount each period, just enough to finance the entry costs. Note that, as mentioned before, since workers are risk neutral, there are no other reasons for workers to save.

(1994). Timing of the events in the labor market is as follows. Incumbent firms decide whether to exit or stay active. If a firm exits, either endogenously or exogenously due to the death shock, its workers join the unemployment pool. Entrants replace the firms that exit the market, and draw their productivities from $J^0(\phi)$. Continuing incumbent firms also draw their new productivities based on the Markov process (16). Based on their realized productivities, firms decide whether to expand (by posting vacancies) or contract. If a firm contracts, fired workers join the unemployment pool. Unemployed individuals decide whether to search for a job or to home-produce. If a worker decides to home-produce, she can produce one unit of the home-production. This home-produced good is sold to consumers as well as intermediate producers in a perfectly competitive market.[41] Fixed costs of operation f_d, fixed exporting costs f_x, sunk entry costs f_e, and labor adjustment costs are paid in terms of this home-produced good.

Expanding intermediate producers post vacancies, and vacancies are filled at the vacancy filling rate noted above, which is an equilibrium object. If a worker decides to search for a job but does not match with a firm, she produces $b_u < 1$ units of the home-produced good this period and join the unemployment pool. After matching has taken place, the labor market closes. As a result, workers and firms cannot search for other alternatives at this point, and firms and matched workers therefore bargain on the wage to split the surplus generated at firms (to be discussed below). If the wage bargaining fails (which is not an equilibrium outcome), the match breaks down, the worker becomes unemployed and produces b_u units of the home-production and joins the unemployment pool.

To split the surplus, since marginal revenue product of labor varies by employment size, I employ the Stole and Zwiebel (1996) bargaining game, which I summarize here.[42] The firm bargains with its matched workers one by one. Within each bargaining session, the firm and the worker play the bargaining game of Binmore et al. (1986). Here is what happens at each bargaining session. First, the firm offers a wage to the worker. The worker either accepts, or rejects. If the worker accepts, the firm goes on to the next worker and starts bargaining. If the worker rejects, with some probability the match breaks down and the worker has to quit the firm. In this case, the firm starts over bargaining with all remaining workers. If breakdown does not happen, the worker offers a counteroffer to the firm. If the firm accepts the offer, this session closes and the firm goes on to bargain with the next worker. Otherwise, with some probability the match breaks down and the worker has to quit the firm. Again, in this case,

[41] Instead of calling it home-production, one could think of it as a homogeneous service in the economy, produced by perfectly competitive producers, with the production technology that produces one unit of this service using one worker.

[42] Basically, Stole and Zwiebel (1996) extend the Nash bargaining to the case in which marginal revenue product of labor varies across workers, e.g., because of a decreasing returns to scale production function as in Elsby and Michaels (2013). Here, although production technology features constant returns to scale and marginal product of labor is therefore constant, marginal *revenue* product of labor varies by employment. The reason is due to the fact that firms face a downward sloping demand curve.

the firm starts over bargaining with all remaining workers. In each bargaining session, as many offers and counteroffers are proposed as either an agreement or a breakdown emerges. Stole and Zwiebel (1996) show that the outcome of this game is such that the firm views each worker as the marginal one, and the firm and each worker therefore split the surplus generated by the *marginal* worker. As a result, all workers within the same firm are paid the same wage.

Discussion. It is worth elaborating more on the bargaining game that I employ in this paper. As Brügemann et al. (2019) emphasize, Stole and Zwiebel (1996)'s bargaining game can be viewed in two different ways. The first view is a perfect information game in which each worker is aware of the bargaining outcome between the firm and other workers. In this case, as Brügemann et al. (2019) show, the Stole and Zwiebel (1996)'s Theorem 2 is wrong and the unique Subgame Perfect Equilibrium of this game is not the one they report in the paper. Second, Stole and Zwiebel (1996) can be interpreted as an imperfect information game in which the outcome of each bargaining session is a private information of the worker. As shown by Fontenay and Gans (2014), if one adds the "passive belief" assumption for the off-equilibrium beliefs, Stole and Zwiebel (1996)'s solution to this modified game is correct. I assume that the underlying bargaining game between firms and matched workers in this paper is the private-information version of the Stole and Zwiebel (1996)'s game suggested by Fontenay and Gans (2014). Alternatively, one can assume that firms and matched workers play the Rolodex game, proposed by Brügemann et al. (2019). The Rolodex game results in the the same wage profile as the private-information version of Stole and Zwiebel (1996), which is widely used in the empirical macro-labor literature.[43]

I now characterize the bargaining game outcome to determine the wage schedule. At a firm with productivity ϕ and l workers, the firm's surplus from the marginal worker equals:

$$S^F(\phi, l) = \frac{\partial}{\partial l}[\Pi(\phi, l) - w(\phi, l)l + \beta V(\phi, l)] \ , \tag{35}$$

where $\Pi(\cdot)$ is defined in equation (17), $w(\phi, l)$ is the wage paid by firm (ϕ, l), and $V(\cdot)$ is the continuation value of the firm defined in (27). Note that there is no adjustment cost component in the firm's surplus function since adjustment costs assumed to be sunk at this stage and cannot be recovered. Moreover, since firms are not required to pay the firing cost for the workers who voluntarily quit (e.g., because of not reaching to an agreement with firms), there is no firing cost component in the firms' marginal surplus above.

The marginal worker's surplus from this match equals the wage plus continuation value of

[43]The Rolodex game is very similar to the Stole and Zwiebel (1996)'s game with one main difference: in each bargaining session, at most one offer and one counteroffer are involved. If neither agreement nor breakdown happens, the worker becomes the last person in the queue to renegotiate with the firm. In contrast, in Stole and Zwiebel (1996) as many offers and counteroffers are proposed as either an agreement or a breakdown emerges.

being at this firm minus her outside option:

$$S^W(\phi,l) = w(\phi,l) + \beta W^e(\phi,l) - W^u \ , \tag{36}$$

where $W^e(\phi,l)$ is the continuation value of being at firm (ϕ,l) at the beginning of next period, and the outside option of workers at this stage is joining the unemployment pool which delivers the value of unemployment W^u, both to be defined below.

As discussed above, the outcome of the Stole and Zwiebel (1996)'s bargaining protocol is Nash bargaining on the marginal surplus. As a result, the wage schedule satisfies the following:

$$\xi \max\{S^F(\phi,l),0\} = (1-\xi)S^W(\phi,l) \ , \tag{37}$$

where $\xi \in [0,1)$ is workers' bargaining power.[44]

To elaborate on the wage schedule, I use the solution to the firm's dynamic optimization problem in (30) to re-write the RHS of (35), which delivers

$$S^F(\phi,l) = \frac{\partial C(l_{-1},l)}{\partial l} \ , \tag{38}$$

where the labor adjustment cost $C(\cdot)$ is specified in (31), and l_{-1} is the last period employment at this firm. To explore the marginal surplus generated at firms, I divide firms into two categories: hiring versus non-hiring firms (including contracting firms). For a non-hiring firm, the RHS of the equation above is less than or equal to zero. Hence, the marginal worker in such a firm does not generate rents to be split between the firm and its workers. For a hiring firm, however, the RHS of the above equation is positive and also varies by the employment level l, due to the non-linearity of vacancy posting costs. Hence, the marginal worker in an expanding firm generates rents which vary with firm size. This creates a wage dispersion in the economy, even though workers are ex-ante identical. Intuitively, due to the convex hiring cost, it is not optimal for expanding firms to reach their long-run desired size right away. Therefore, there are rents to be split while expanding firms are transiting to their desired size.[45] With a large enough productivity persistence ρ, there are enough expanding large firms in the economy (see Bertola and Garibaldi, 2001) so that the model generates a positive size-wage correlation. As Section 4.3 will discuss in detail, this positive size-wage association has crucial implications for labor market consequences of trade liberalization in the presence of variable markups.

While Appendix E explains in details the procedure to solve for the wage schedule, it

[44]Note that workers' bargaining power has to be less than 1; otherwise, firms would not be able to finance vacancy posting costs, and therefore, the labor market breaks down.

[45]Unlike this paper that employs a random search framework, Felbermayr et al. (2018) show the importance of non-linear adjustment costs in generating residual wage inequality in a directed search environment.

proves useful to characterize the wage schedule at non-hiring firms. The non-hiring firm (ϕ, l) generates no surplus and therefore equations (36) and (37) imply that such a firm pays the workers' outside option:

$$w(\phi, l) + \beta W^e(\phi, l) = W^u \ . \tag{39}$$

A few points are worth mentioning here. First, the outside option for fired workers is joining the unemployment pool which delivers W^u. Hence, workers are indifferent between working in a non-hiring firm or being laid off from such firms. I assume that a firing firm randomly picks the workers to be laid off and therefore each worker is equally likely to be fired. Second, non-hiring firms pay different wages because the continuation value $W^e(\phi, l)$ varies across firms (to be discussed below). Finally, note that I assume that firms do not have to pay the firing cost for the workers who voluntarily quit. This assumption implies that workers are not able to threaten non-hiring firms to quit, and therefore these workers are paid no more than their outside option.

An unemployed worker decides whether to search for a job or to home-produce. If she decides to home-produce, she would produce one unit of the home-production. Hence, the value of home-producing equals

$$W^h = 1 + \beta \max\{W^h, W^a\} \ , \tag{40}$$

where W^a is the continuation value of applying for a job:

$$W^a = m(\theta) W^m + (1 - m(\theta)) W^u \ . \tag{41}$$

With the job finding probability $m(\theta)$ the worker gets randomly matched with a firm and enjoys the continuation value W^m, to be specified below. With probability $1-m(\theta)$, the worker would be unmatched and joins the unemployment pool. The value of unemployment W^u equals producing b_u units of home-production this period plus the discounted value of searching or home-producing:

$$W^u = b_u + \beta \max\{W^h, W^a\} \ . \tag{42}$$

In equilibrium, while some unemployed individuals search for a job, others decide to home-produce. Hence, in equilibrium, the value of home-producing is equal to the value of applying for a job, i.e., $W^h = W^a = \frac{1}{1-\beta}$, where the last equality uses equation (40).[46]

[46]Recall that the home-produced good is used by firms to pay fixed costs and also is consumed by consumers. Hence, the home-produced good must be produced in equilibrium. However, there might exist an equilibrium in which all individuals search for a job, and the unmatched workers are just enough to produce the required amount of the home-production. In such an equilibrium, the value of searching for a job does not have to be equal to the value of home-producing. However, by matching the model to the data in the next section, it turns out that a fraction of individuals decide to home-produce in equilibrium, which means that the continuation

It remains to specify the expected value of getting matched with a firm, W^m, and the continuation value of being at firm (ϕ, l) at the beginning of a period, $W^e(\phi, l)$. Given the continuation policy function $I^c(\phi, l)$, the hiring policy function $I^h(\phi, l)$, the employment policy function $l'(\phi, l)$, and the vacancy posting policy function $\upsilon(\phi, l)$, all of which were discussed in Section 3.5, the expected value of getting matched W^m can be written as

$$W^m = \int_\phi \int_l W^m(\phi, l) \underbrace{h(\phi, l)}_{\text{distribution of vacancies}} d\phi dl \ , \tag{43}$$

and the distribution of vacancies is

$$h(\phi, l) = \frac{\upsilon(\phi, l)G(\phi, l) + \frac{N_e}{N_H}\frac{l_e\theta}{m(\theta)}\mathbf{1}_{l=l_e}J^0(\phi)}{\int_\phi \int_l [\upsilon(\phi, l)G(\phi, l) + \frac{N_e}{N_H}\frac{l_e\theta}{m(\theta)}\mathbf{1}_{l=l_e}J^0(\phi)]d\phi dl} \ , \tag{44}$$

where $W^m(\phi, l)$ is the value of getting matched with firm (ϕ, l), $G(\phi, l)$ is the distribution of firms after realization of productivities but before firms decide about their employment, N_e and N_H are the measure of entrants and total measure of intermediate producers, respectively, l_e is entrants' initial size, and $\mathbf{1}_x$ is an indicator function equals to one if x holds and zero otherwise. Note that each entrant posts $\frac{l_e\theta}{m(\theta)}$ vacancies to start with l_e number of workers.[47]

The continuation value of getting matched with a firm at state (ϕ, l) consists of the wage $w(\phi, l')$ and the expected value of being at this firm at the beginning of next period:

$$W^m(\phi, l) = w(\phi, l') + \beta W^e(\phi, l') \ , \tag{45}$$

where l' is the outcome of the employment policy function $l'(\phi, l)$, defined in Section 3.5. Finally, the continuation value of starting the period at firm (ϕ, l) consists of three parts:

$$\begin{aligned} W^e(\phi, l) = [\underbrace{\lambda}_{\text{firm's exogenous exit}} &+ \underbrace{(1-\lambda)(1-I^c(\phi, l))}_{\text{firm's endogenous exit}}]W^u \\ &+ (1-\lambda)I^c(\phi, l)E_{\phi'|\phi}(1-I^h(\phi', l))W^u \\ &+ (1-\lambda)I^c(\phi, l)E_{\phi'|\phi}I^h(\phi', l)\max\{\underbrace{W^u}_{\text{worker's voluntary quit}}, W^m(\phi', l)\} \ . \end{aligned} \tag{46}$$

To elaborate, for an exogenous or endogenous reason, this firm may exit, in which case the worker becomes unemployed and joins the unemployment pool (the first line above). If the firm stays at the market but does not hire, all workers are paid their outside option W^u (the second line). This is because, as discussed above, no surplus is generated at such firms. If the

value of home-producing is equal to that of applying for a job in equilibrium.

[47] Entrants are also allowed to expand right after entry. See Section 3.6.

firm expands, workers may decide whether to stay or quit (the last line). Notice that there would be no voluntary quit in equilibrium since firms pay at least the workers' outside option, i.e., $W^m(\phi, l) \geq W^u$.

3.8 Stationary Equilibrium and Numerical Algorithm

I study the steady state equilibrium of the model, and assume Home country is a small open economy which takes the Foreign aggregate demand shifter A_F as given. I focus on a symmetric equilibrium in which all K Foreign producers within each good ν charge the same price. The aggregate equilibrium objects in the model are the Home aggregate demand shifter A_H, labor market tightness θ, measure of intermediate producers N_H, the stationary distribution of Home intermediate producers over productivity and labor, and Foreign firms' marginal cost of production e (which is relative to the model numeraire).[48] The steady state equilibrium is defined as follows. Given the aggregate equilibrium objects, firms solve problems (17) and (21) to optimally decide about prices to charge, buy the optimal material specified in (26), and decide whether to export; firms optimally decide about the number of vacancies to post by solving the dynamic problem (30); the markets for the final good, the intermediate goods, and the home-production clear; trade between Home and Foreign is balanced; free entry condition (34) holds with equality;[49] the flow of workers into and out of the unemployment pool are equal; workers are indifferent between applying for a job and home-producing; the distribution of domestic intermediate producers over (ϕ, l) evolves through the Markov productivity process, entrants' productivity draws, and hiring/firing decisions by firms, and reproduces itself. Appendix D provides a formal definition of the stationary equilibrium.

To solve for the stationary equilibrium, one needs to start with a guess on the aggregate equilibrium objects and iterate over those objects until they converge. The aggregate demand shifter A_H moves around to satisfy the free entry condition (34) with equality. The relative price e makes trade between Home and Foreign balanced. The measure of intermediate producers N_H makes the demand for home-production equal to its supply, given that the flow into and out of the unemployment pool are equal in equilibrium. Labor market tightness makes workers indifferent between applying for a job and home-production. Appendix E provides more details on the numerical algorithm to solve for the steady state of the model.

[48] Note that what matters in equilibrium is the price of home-production relative to the Foreign producers' marginal cost. For ease of notation in the model, I take home-production as the model numeraire, and define this relative price as the Foreign producers' marginal cost relative to the home-production, not the other way around.

[49] In general, the equilibrium in this class of models might take one of the following forms: with entry/exit or without. The equilibrium in this paper, however, is the one with entry/exit because of the exogenous exit shock. Therefore, the free entry condition (34) holds with equality.

4 Quantitative Analysis

As explained above, the main goal of this paper is to explore pro-competitive consequences of trade in frictional labor markets, i.e., to quantify the extent to which accounting for variable markups can affect labor market outcomes and consequently welfare implications of trade in frictional labor markets. To this end, I first fit the model developed in the previous section to the plant-level data from Colombia, and then use the calibrated model to perform counterfactual exercises. Colombia is a suitable case to investigate because, by reducing its average import tariffs from 40% to 7.5% (Attanasio et al., 2004; Alessandria and Avila, 2020), this country performed a large trade liberalization in late 1980s and early 1990s. We can therefore compare the counterfactual outcomes of the model to the data observed after trade liberalization in this country.

4.1 Calibration

I fit the model to the Colombia Annual Manufacturing Survey data in the pre-liberalization episode from 1983-1990. These annual data cover all manufacturing plants with at least ten employees. There are five parameters that are calibrated outside the model. The discount factor β is set to 0.85, consistent with the annual interest rate of 15% in Colombia (Bond et al., 2015; Coşar et al., 2016). The average GDP share of services in Colombia between 1983-1990 is around 0.49, so I set $\kappa = 0.51$. Iceberg trade cost d is set to 2.5, following Coşar et al. (2016) and Eaton and Kortum (2002).[50] The average import tariffs in manufacturing before trade liberalization in Colombia is 40% (Alessandria and Avila, 2020), so I set $\tau = 1.4$. Heckman and Pages (2000) document that the average cost of dismissing a worker in Colombia over this period was around 6 months of wages (look at their Graph 1). Given that the average annual wage in the equilibrium of model is around 1.8, I put $c_f = 0.9$.[51] Lastly, to solve the model I assume the number of Foreign firms within each variety is $K = 5$, but results are robust to alternative assumptions, for example $K = 10$.

This leaves us with 14 parameters to calibrate:

$$\Theta \equiv (\sigma, \alpha, c_v, \rho, A_F, \eta, f_d, f_x, f_e, \gamma, \sigma_\phi, b_u, \lambda, \xi) \ .$$

I calibrate these parameters using Simulated Method of Moments (SMM) by minimizing the

[50] Eaton and Kortum (2002)'s estimate for the tariff equivalent of iceberg trade cost for the Colombian economy is between 123 and 174 percent.

[51] Note that the average wage itself depends on c_f and other parameters of the model. Calibrating c_f therefore is based on try and error to find that given all calibrated parameters as well as $c_f = 0.9$, the average annual wage in the model equals 1.8.

Table 2: Data- versus Model-Based Statistics

Moments	Data	Model	Moments	Data	Model
$E(\log l_t)$	3.706	3.661	$\text{cov}(I_t^x, \log R_{t+1})$	0.211	0.215
$E(\log R_t)$	5.655	5.647	$\text{cov}(I_t^x, I_{t+1}^x)$	0.086	0.052
$E(I_t^x)$	0.117	0.066	*firms' employment distribution*		
$\text{var}(\log l_t)$	1.002	0.996	20^{th} percentile	17.505	16.149
$\text{var}(\log R_t)$	2.589	2.593	40^{th} percentile	25.874	23.443
$\text{cov}(\log l_t, \log R_t)$	1.324	1.333	60^{th} percentile	42.225	41.005
$\text{cov}(\log l_t, I_t^x)$	0.129	0.129	80^{th} percentile	88.187	88.749
$\text{cov}(\log R_t, I_t^x)$	0.208	0.222	material share of sale (median)	0.586	0.592
$\text{cov}(\log l_t, \log l_{t+1})$	0.979	0.972	coefficient of regressing		
$\text{cov}(\log l_t, \log R_{t+1})$	1.325	1.258	material share of sale on log(labor)	-0.006	-0.006
$\text{cov}(\log l_t, I_{t+1}^x)$	0.133	0.132	job turnover rate (%)	21.458	21.004
$\text{cov}(\log R_t, \log l_{t+1})$	1.322	1.361	continuing firms' job turnover (%)	9.371	8.502
$\text{cov}(\log R_t, \log R_{t+1})$	2.559	2.435	mean of exporters' export intensity	0.181	0.180
$\text{cov}(\log R_t, I_{t+1}^x)$	0.215	0.230	std. of log wages	0.515	0.518
$\text{cov}(I_t^x, \log l_{t+1})$	0.129	0.132	exit rate (%)	10.328	10.915

Notes: Data statistics are based on Colombia manufacturing plant-level dataset from 1983-1990.

distance between a set of data moments and their model counterparts:

$$\hat{\Theta} \equiv \text{argmin}(D - M(\Theta))'(D - M(\Theta)) \ ,$$

where D stands for data moments and $M(\Theta)$ denotes model-based simulated moments. I target 28 moments to calibrate the parameters, and Table 2 summarizes the data- and model-based statistics. Although all parameters of the model are jointly calibrated, a particular set of moments play a key role in calibrating each particular parameter, which I discuss below.

Demand parameters σ and α. Using the production function (15) as well as demand elasticities $\varepsilon_{Hi,1}$ faced by Home intermediate producers in (24), the profit maximization problem of these producers implies the following first order condition (see Appendix F for more details):

$$\frac{\varepsilon_{Hi,1}(\phi, l)}{\varepsilon_{Hi,1}(\phi, l) - 1} = \eta \ \frac{p_{Hi,1}(\phi, l) q_{Hi,1}(\phi, l)}{P M_{Hi,1}(\phi, l)} \ , \tag{47}$$

where $M_{Hi,1}(\phi, l)$ is the material needed to produce $q_{Hi,1}$ for market i. The intuition behind equation (47) follows the work by De Loecker and Warzynski (2012): Since material is a static (i.e., freely adjustable) input, the markup that firm (ϕ, l) charges in market i (i.e., the left-hand-side)[52] is equal to the gap between the elasticity of output with respect to material, η,

[52]Note that I define markup as price over marginal cost where marginal cost takes all costs into account, e.g., production costs, labor adjustment costs, etc.

and the material share of sale in market i.

To calibrate demand elasticity parameters σ and α, I employ a similar strategy as in Edmond et al. (2015). In particular, I exploit the relationship between material share of sale and firm size that is implied by equation (47). To elaborate, under $\alpha > \sigma$ ($\alpha < \sigma$), equation (24) implies that larger firms face lower (higher) demand elasticities and have therefore lower (higher) material share of sale, according to equation (47). The *gap* between σ and α therefore determines to what extent material share of sale varies with firm size. In the data, I regress material share of sale on log(labor) at the firm level, including industry fixed effects to control for cross-industry differences in material share of sale.[53] The resulting coefficient in the data is -0.006 and statistically significant; this coefficient implies that firms within the same industry that are 10% larger have on average 0.06 smaller material share of sale.[54] Since this coefficient is negative we expect that in the model the lower-tier elasticity α to be larger than the higher-tier elasticity σ, implying that larger firms face lower demand elasticities and charge higher markups. To learn about the *level* of σ and α, I also target the cross-firm median of material share of sale, guided by equation (47). Note that these two demand elasticity parameters influence several other moments as well, e.g., the mean of exporters' export intensity (i.e., share of exports in sales); as α or σ rises, product markets become more competitive and therefore export intensity among exporters fall.

Labor adjustment cost and matching friction. I use firms' employment distribution, covariance of employment and revenue $\mathrm{cov}(\log l_t, \log R_t)$, wage dispersion, job turnover rate, and job turnover rate among continuing firms to learn about labor adjustment cost parameter c_v and matching friction ρ. Firms' revenues are expressed in thousands of 1977 pesos. Job turnover rate is the cross-year average of annual job turnover rate over the sample period 1983-1990, and annual job turnover rate is defined as

$$\mathrm{JT}_t = \frac{\sum_{i\in c} |l_{it} - l_{it-1}| + \sum_{i\in exit} l_{it-1} + \sum_{i\in entry} l_{it} - |L_t - L_{t-1}|}{(L_{t-1} + L_t)/2} \times 100 \,, \tag{48}$$

where c is the set of continuing plants, l_{it} is plant i's employment in year t, and L_t is total employment at time t. Job turnover among continuing plants is defined in the same way, but it does not include entry and exit in the numerator. The difference between these two measures of job turnover is therefore due to job creation/destruction by entry/exit.

A fall in labor adjustment costs influence the size distribution by shifting employment toward larger plants. In particular, a fall in the hiring cost parameter c_v influences the firm size distribution by inducing firms to expand more when hitting by positive productivity shocks.

[53]Note that my model does not feature multiple industries.

[54]In Edmond et al. (2015), unlike this paper, labor is a freely adjustable input and they therefore use the labor share of sale to calibrate demand elasticity parameters.

Labor adjustment costs influence job turnover as well. On the one hand, since larger firms are less likely to exit, reducing labor adjustment costs tends to reduce job turnover by shifting employment toward larger firms. On the other hand, reducing labor adjustment costs creates more incentive for firms to adjust their workforce in response to transitory productivity shocks, which in turn raises job turnover (Ljungqvist, 2002; Mortensen and Pissarides, 1999). The matching friction parameter ρ affects firms' responsive to their idiosyncratic shocks. This is because, given the labor market tightness θ, a larger ρ implies a higher vacancy filling rate, and therefore firms would have more incentive to respond to their transitory shocks. Hence, the matching friction parameter ρ influences job turnover rate, size distribution, and $\mathrm{cov}(\log l_t, \log R_t)$.

Wage dispersion also rises with the hiring cost parameter c_v. As discussed below equation (38), as the (convex) hiring cost rises, the heterogeneity of firms' surplus across expanding firms rises, and due to wage bargaining, so does the wage dispersion in the economy.

Other parameters. The production function parameter η influences the employment distribution. In particular, as η rises, the size distribution shifts to the left. Moreover, the variance of employment and the covariance between employment and revenue are affected by η. Means, variances, and covariances of employment, revenue, and export indicator function I^x as well as firm size distribution help us learn about the productivity process parameters γ and σ_ϕ.

Job turnover rate increases with workers' outside option b_u. To elaborate, as b_u rises, firms become more restricted in reducing their wages, since payments to workers have to be above their outside option. As a result, firms will adjust their workforce more frequently which increases job turnover rate. Furthermore, wage dispersion helps us learn about workers' outside option as well as workers' bargaining power. The intuition is that the range of "feasible" wages falls as b_u rises, and therefore, the wage dispersion falls. Moreover, as workers' bargaining power rises, firms' heterogeneity translates into a larger wage heterogeneity.

Firms' exit rate as well as job turnover due to entry and exit helps us learn about the exogenous exit rate λ. The exit rate measures the fraction of plants that exit the market in each year, averaged over the sample period 1983-1990. Sunk entry cost f_e and fixed production cost f_d affect the overall size of the economy. The reason being the aggregate demand shifter A_H is such that the free entry condition (34) holds with equality in equilibrium. The mean of employment and the mean of revenue are therefore influenced by these costs. Moreover, the fixed production cost influences firms' exit rate. Finally, the fraction of plants that export, mean of export intensity among exporters, and the covariance of exporting indicator function I^x and revenue help us learn about fixed exporting cost f_x and the aggregate demand shifter in the Foreign economy A_F.

Table 3: Calibrated Parameters

Parameter	Description	Value
σ	demand elasticity parameter	8.594
α	demand elasticity parameter	13.002
c_v	hiring cost	24.157
ρ	matching friction	2.481
$\log(A_F)$	aggregate demand shifter in market F	24.604
η	material elasticity of output	0.652
f_d	fixed production cost	2.950
f_x	fixed exporting cost	39.094
f_e	sunk entry cost	485.363
γ	persistence of productivity shocks	0.936
σ_ϕ	std. of productivity shocks	0.182
b_u	workers' outside option	0.626
λ	death shock	0.099
ξ	workers' bargaining power	0.266

Notes: Calibrated parameters by minimizing the distance between the set of model moments and their data counterparts, summarized in Table 2.

4.2 Model Fit, Calibrated Parameters, and Validation

Now that I explained the intuition behind the set of targeted moments, this section discusses the calibrated parameters and the model fit. Tables 2 and 3 report targeted moments (and their model counterparts) and calibrated parameters, respectively. Overall, the model fits the data reasonably well. In particular, the model matches the negative coefficient of regressing material share of sale on firm size. As will be shown below, the standard constant-markup model would not be able to generate this relationship.

As explained in Section 2.2, in the data I measure labor in terms of effective units, which means that I control for worker heterogeneity to the extent allowed by the data.[55] Hence, the notion of wage in the data refers to the wage per effective labor. The wage dispersion reported in Table 2 therefore measures the *residual* wage dispersion, and the model matches it quite well. As discussed above, the fact that the model is able to match the observed residual wage dispersion is due to the convexity of hiring cost. In fact, in a model with linear vacancy posting cost, all expanding firms pay the same wage (see e.g., Felbermayr et al., 2011), which would substantially reduce the residual wage inequality in the model economy.

To put the calibrated parameters in the context, note that the unweighted and size-weighted average markup in the model are equal to 1.10 and 1.12, respectively. These values are broadly

[55]Within each category of workers, however, there might be some unobservable heterogeneity which the data do not allow me to control for.

in line with the literature (e.g., Edmond et al., 2015; De Loecker and Warzynski, 2012; Coşar et al., 2016; De Loecker et al., 2016; Eslava et al., 2004).[56] Furthermore, since $\sigma < \alpha$, larger firms in the model face lower demand elasticities and therefore charge higher markups, which is in line with the literature (De Loecker et al., 2016; Atkin et al., 2015; Edmond et al., 2015; De Loecker and Warzynski, 2012).

The estimated value for the persistence of productivity shocks shows that the productivity process is very persistent, which is in line with the literature (see e.g. Foster et al. (2008) for the U.S.; Eslava et al. (2010) and Coşar et al. (2016) for Colombia). Moreover, the average labor adjustment costs (both hiring and firing) paid by firms is 3.5% of average firms' sales in the stationary equilibrium of the model. Sunk entry cost f_e is 41% of average firms' annual sales, while fixed exporting cost is an order of magnitude smaller.

The Constant-Markup Model. To explore the pro-competitive consequences of trade (i.e., the effects resulting from the responses of markups to trade), I will compare the counterfactual results of my baseline model to those of a nested version that is a standard constant-markup model. In this nested version of the model, I impose constant markups, i.e., $\sigma = \alpha$, and re-calibrate all parameters by targeting the same set of moments in Table 2.[57] In what follows, I will refer to the baseline model as the variable-markup model, and to the nested version as the constant-markup model.[58]

Appendix Tables B.1 and B.2 report model-based moments and calibrated parameters, respectively, for the constant-markup model. Overall, the constant-markup model also matches the targeted moments reasonably well. As noted before, however, since all firms face the same demand elasticity in the constant-markup model, this model cannot explain the negative relationship between size and material share of sale.

Furthermore, imposing constant markups overestimates the importance of labor market frictions: Total labor adjustment costs paid by firms (as a fraction of total income) in the constant-markup model is 11% larger than that in the baseline model.[59] This is because without markup adjustments, limited hiring and firing responses to idiosyncratic shocks are likely to be attributed entirely to labor market frictions. In a world with variable markups,

[56] The model by Edmond et al. (2015) implies an average and a median markup of 1.15 and 1.11, respectively. De Loecker and Warzynski (2012) estimate the markups for the Slovanian firms ranging from 1.13 to 1.28.

[57] For the five parameters that I calibrated outside the variable-markup model ($\beta, \kappa, d, \tau, c_f$), I use the same values here. Note that after calibrating this constant markup model with $c_f = 0.9$, the average annual wage is still around 1.8, i.e., around 6 months of wages.

[58] As mentioned before, I define markup as price over marginal cost where marginal cost takes all costs into account, e.g., production costs, labor adjustment costs, etc. The constant-demand-elasticity assumption $\sigma = \alpha$ therefore implies that all firms charge the same markup $\sigma/\sigma - 1$, which is invariant to trade liberalization.

[59] In the constant-markup model, total labor adjustment costs paid by firms is 3.91% of total income, while that is 3.52% in the baseline model.

however, reducing (raising) markups and firing (hiring) workers are substitutes.

Model Validation and Non-Targeted Moments. Before employing models to run counterfactual experiments, this section explores how both models perform in generating some non-targeted moments. First, since larger firms in the baseline model face lower demand elasticities, the model generates a correlation of -0.47 between firms' size and labor elasticity of revenue, which is in line with the negative size-labor elasticity of revenue association documented in Figure 1b. In the constant-markup model, however, there is no correlation between size and labor elasticity of revenue (since all firms face the same demand elasticity).

Furthermore, as mentioned before, imposing $\sigma = \alpha$ implies that the demand elasticity that firms face would be the same both across firms and across markets. As Appendix G shows, only in such a world all exporting firms would have the same export intensity. For the case of $\sigma \neq \alpha$, however, as equation (24) shows, demand elasticities vary both across firms and across markets, and therefore there would be a dispersion in export intensity across exporters. In the data, export intensity has a standard deviation of 0.25, one-fifth of which is explained by the baseline model. In the constant-markup model, however, all firms face the same demand elasticity in both markets and the dispersion in export intensity is therefore equal to zero. In terms of total exports, the share of total exports in aggregate manufacturing revenue in Colombia was 9% over the sample period. This ratio equals 13% and 10% in the baseline and constant-markup models, respectively.

Finally, larger firms pay higher wages in the data, and both models replicate this pattern reasonably well: The correlation between wage and size in the data is 0.58, and is 0.49 and 0.45 in the baseline and constant-markup models, respectively. As explained below equation (38), this positive size-wage correlation in both models is due to the non-linear cost of posting vacancies, which implies that there are rents to be split while expanding firms are transiting to their desired size. Since productivity process is persistent, there are enough expanding firms in the economy, and therefore both models generate this positive size-wage correlation. In a model with linear vacancy posting cost, however, all expanding firms would pay the same wage, and the size-wage correlation would therefore be very limited.[60] The counterfactual analysis in next section shows that this positive size-wage association has important implications for pro-competitive consequences of trade in a frictional labor market.

[60] Notice that even if vacancy posting cost was linear, hiring firms would still pay higher wages than non-hiring firms do. This is because while the marginal surplus in non-hiring firms is zero, that is positive (but the same) for all hiring firms; see the discussion below equation (38). Hence, there would be a limited degree of size-wage correlation in a model with linear vacancy posting costs.

4.3 Counterfactual Analysis

This section employs the calibrated models to perform counterfactual analysis. The goal of this section is to explore the pro-competitive consequences of trade in a frictional labor market, by comparing the counterfactual outcomes of the baseline model to those of the constant-markup model. This section shows that accounting for variable markups in the presence of labor market frictions increases unemployment and wage inequality consequences of trade, and reduces the gains from trade, i.e., the pro-competitive "gains" from trade are negative.

To do the counterfactual experiments, I simulate in the model the effects of Colombia's trade liberalization in early 1990s. In Colombia, import tariffs averaged 40% in the 80s and reduced to 7.5% on average in early 1990s (Attanasio et al., 2004; Alessandria and Avila, 2020). In both variable- and constant-markup models, I simulate the effects of this trade liberalization by reducing import tariffs τ from 1.4 to 1.075. As a result of this trade liberalization, the share of total exports in revenue rises by 221% in both models (in the steady state), which shows that both models have a quite similar (ex-post) trade elasticity. In the data, this share rises by 250% from 1980s to 2000s (Coşar et al., 2016). The rise in export activities in the data is larger than that in both models, which is partly due to other sources of globalization during this period.

Colombia deregulated the labor market as well in early 1990s, by reducing the cost of dismissing workers by a half (see Graph 1 and Table 1 in Heckman and Pages, 2000). In a separate counterfactual exercise therefore I combine the trade liberalization experiment with this labor market deregulation by reducing c_f by 50%. This exercise would help us compare the counterfactual outcomes to what we observe in the data.

Table 4 reports the counterfactual results. The first (last) four columns correspond to the variable- (constant-) markup model. The "Base" columns report the initial steady state of models. The "Openness", "Labor", and "Openness & Labor" columns report the counterfactual results in the new steady state associated with reducing import tariffs τ, reducing the firing cost c_f, and reducing both, respectively, as explained above. To make the comparison easier, the "Base" values for aggregate statistics are normalized to one.

As columns "Labor" in Table 4 show, reducing the firing cost c_f has quite limited effects on the size distribution as well as on most aggregate statistics in both models. The variables changing the most in response to the reduction in c_f are job turnover rates, to be discussed below. In what follows I therefore mostly focus on the effects of trade liberalization.

Firm Size Distribution. Reducing import tariffs ("Openness" columns) increases import competition and raises the size of Foreign firms in the Home market, which in turn raises demand elasticities faced by Home producers in the baseline model (see equation (24)). Note that although Home exporters become larger in the Foreign market and therefore face lower

Table 4: Counterfactual Results

Model-based moments	Variable-Markup Model				Constant-Markup Model			
	Base	Openness	Labor	Openness & Labor	Base	Openness	Labor	Openness & Labor
firms' employment distribution								
20^{th} percentile	16.15	16.15	15.31	15.72	16.15	15.72	16.15	15.72
40^{th} percentile	23.44	23.44	22.83	22.23	24.08	23.44	23.44	22.83
60^{th} percentile	41.01	41.01	38.88	38.88	41.01	41.01	41.01	38.88
80^{th} percentile	88.75	96.13	88.75	88.75	91.14	93.60	91.14	91.14
90^{th} percentile	172.68	187.04	168.14	182.12	177.34	187.04	168.14	177.34
95^{th} percentile	286.37	318.56	278.85	318.56	286.37	302.04	286.37	294.10
aggregate statistics								
job turnover rate	1	1.013	1.013	1.020	1	1.002	1.021	1.025
job turnover (continuing firms)	1	1.018	1.078	1.099	1	0.998	1.101	1.113
unemployment rate	1	1.162	1.002	1.163	1	1.058	1.004	1.062
measure of domestic producers	1	0.865	1.011	0.892	1	0.957	1.010	0.968
exit rate	1	1.061	0.988	1.021	1	1.004	0.991	0.991
labor market tightness	1	0.823	1.001	0.823	1	0.929	1.001	0.931
unemployment inflow	1	0.956	1.003	0.957	1	0.984	1.005	0.989
exp. value from searching (W^m)	1	1.139	0.999	1.138	1	1.049	0.999	1.047
std. of log(wage) across workers	1	1.090	0.995	1.087	1	1.038	0.995	1.032
aggregate price index (P^κ)	1	0.979	1.000	0.977	1	0.966	1.000	0.966
real income	1	1.003	1.001	1.006	1	1.017	1.001	1.019

Notes: The first (last) four columns correspond to the variable (constant) markup model. The "Base" columns report the initial steady state of models. The "Openness", "Labor", and "Openness & Labor" columns report the counterfactual results associated with reducing import tariffs τ, reducing firing cost c_f, and reducing both, respectively, as explained in the text. To make the comparison easier, the "Base" values for aggregate statistics are normalized to one. Numbers are rounded to the nearest thousandth.

demand elasticities there, the rise in the Home demand elasticity is the dominating factor and Home producers face higher demand elasticities and charge lower markups overall.[61] This rise in demand elasticities raises firms' labor elasticities of revenue, even for large, exporting firms, which is in line with what section 2.2 documented in the data, i.e., labor elasticity of revenue rises after trade liberalization for all employment bins in the data.

The rise in labor elasticities of revenue, which is operative in the baseline model only, makes firms more responsive to their idiosyncratic shocks, and consequently shifts employment toward larger/expanding firms. To elaborate, due to the increase in firms' responsiveness, less efficient firms exit more frequently, and exit rate rises. Moreover, firms hitting by positive productivity shocks expand more, and therefore large firms become even larger.[62] Since this channel is not operative in the constant-markup model, the rightward shift in size distribution in this model is limited, which is discussed below.

Since the change in the firm size distribution has crucial implications for various labor market outcomes that will be discussed below, Table 5 explores whether the variable- and constant-markup models are able to capture what happened to the firm size distribution after reforms in Colombia. In the models, pre- and post-reform columns correspond to the initial steady state and the "Openness & Labor" counterfactual experiment, respectively. The pre- and post-reform data statistics are calculated as the average across 1983-1990 and 1992-2012, respectively.

The first two columns in Table 5 report that Colombia has a more dispersed firm size distribution after reforms, due to a drastic increase in the size of large firms. In particular, the right tail of the size distribution (e.g., the 95^{th} and 97^{th} percentiles) in the data shifts to the right by around 14-19%. While the post-reform size distribution is obviously not targeted in the calibration procedure, the baseline model explains the expansion of large firms quite well. In particular, the right tail of the size distribution in the baseline model rises by around 11%. In the constant-markup model, however, the size distribution does not respond much to the reforms and barely changes. Since the variable- and constant-markup models share the same channels except for the endogenous response in demand elasticities and markups, we conclude that the rise in labor elasticities of revenue plays a major role in explaining the changes in the firm size distribution. As will be discussed below, the same channel crucially influences various labor market outcomes as well.

Unemployment. Trade liberalization influences the unemployment rate in both models through two competing channels. On the one hand, as explained above, after trade liberalization

[61] In fact, the 5, 10, 90, and 95th percentile of markup distribution charged by Home producers fall from [1.085, 1.087, 1.128, 1.130] to [1.084, 1.085, 1.108, 1.111] after trade liberalization, respectively.

[62] In addition to this mechanism, Melitz-type forces are operative in both models: Openness in both variable- and constant-markup models reallocates resources toward larger, more-efficient firms, i.e., inducing a rightward shift in the size distribution.

Table 5: Firm Size Distribution: Data vs. Model

Size Distribution	Data		Variable-Markup Model		Constant-Markup Model	
	Pre	Post	Pre	Post	Pre	Post
20^{th} percentile	17.51	15.15	16.15	15.72	16.15	15.72
40^{th} percentile	25.87	26.65	23.44	22.23	24.08	22.83
60^{th} percentile	42.23	48.82	41.01	38.88	41.01	38.88
80^{th} percentile	88.19	113.59	88.75	88.75	91.14	91.14
90^{th} percentile	173.70	224.87	172.68	182.12	177.34	177.34
95^{th} percentile	317.68	379.71	286.37	318.56	286.37	294.10
97^{th} percentile	453.61	517.57	383.82	426.95	383.82	394.18

Notes: "Pre" and "Post" columns refer to the pre- and post-reform episodes, respectively. In the models, pre- and post-reform correspond to the initial steady state and the "Openness & Labor" counterfactual experiment, respectively. The pre- and post-reform data statistics are calculated as the average across 1983-1990 and 1992-2012, respectively.

jobs get concentrated at larger firms which pay higher wages. Moreover, the rents generated at larger (exporting) firms jump after trade liberalization because larger firms get easier access to the Foreign market, which increases wages at these firms. Therefore, the expected value from searching for jobs W^m rises, which in turn induces more individuals to search for a job and reduces the labor market tightness. This reduction in the labor market tightness reduces the job finding rate $m(\theta)$, which in turn raises the unemployment rate (see equations (73) and (75) in Appendix D).

On the other hand, however, the rightward shift in the size distribution makes jobs more concentrated in larger firms which are less likely to exit or downsize. As a result, the mass of individuals that flow into the unemployment pool falls which puts a downward pressure on the unemployment rate (see equations (69)-(71) in Appendix D). Overall, the first channel dominates and the unemployment rate rises in both models. Since the shift in the size distribution and therefore the fall in the labor market tightness are more pronounced in the variable-markup model, the rise in the unemployment rate is almost three times larger in the variable- compared to the constant-markup model.

This result highlights that pro-competitive forces of trade liberalization can have adverse unemployment consequences in frictional labor markets, which also has important welfare implications (to be discussed below). The surge in the unemployment rate in the variable-markup model is more in line with the rise in the unemployment rate in Colombia even 20 years after the reforms (see Figure B.4), although one cannot necessarily attribute the entire increase in the unemployment rate observed in the data to trade liberalization and labor market deregulations.[63]

[63] As discussed, the rise in unemployment in the model is mainly due to an increase in the number of

Wage Inequality. As Table 4 shows, trade liberalization also increases residual wage inequality in both models. To elaborate, the more dispersed firm size distribution after openness leads to higher wage inequality. This is because larger firms pay higher wages and also since generated rents at larger (exporting) firms jump after trade liberalization.[64] Since the response of size distribution to openness is much stronger in the variable- than in the constant-markup model, the rise in residual wage inequality is more than two times larger in the former model. This result shows that pro-competitive forces of trade liberalization worsen wage inequality in frictional labor markets. As the "Openness & Labor" columns show, while wage inequality rises by only around 3% in the constant-markup model, the 8.7% increase in wage dispersion in the variable-markup model is more consistent with what is observed in Colombia: Attanasio et al. (2004) document that the standard deviation of log wages within education categories rises by about 15% from 1990 to 1998.[65,66]

Job Turnover. By reducing the firing cost, labor market deregulation creates more incentive for firms to adjust their workforce in response to transitory productivity shocks. This channel, as "Labor" columns in Table 4 report, raises job turnover in both models (Ljungqvist, 2002; Mortensen and Pissarides, 1999).

We now focus on the "Openness" columns. Trade liberalization influences job turnover through two channels. The first channel is a general equilibrium effect that works through the size distribution. On the one hand, the rightward shift in the size distribution explained above makes jobs more concentrated in larger firms which are less likely to exit or downsize, and thereby reduces job turnover. On the other hand, however, the same rightward shift in the size distribution reduces the labor market tightness, as explained above, which tends to increase job turnover. To elaborate, in a less tight labor market it is more likely for firms to fill vacancies, which raises firms' responsiveness to idiosyncratic shocks. Overall, this general equilibrium effect tends to reduce job turnover, as can be seen from the reduction in the mass of individuals that flow into the unemployment pool.

Second, as noted above, import tariffs reduction raises firms' labor elasticity of revenue (in the variable-markup model only), and firms thereby become more responsive to their idiosyncratic shocks. This channel tends to increase job turnover. This channel is dampened by the

job seekers in response to higher wages. This presumably takes some time, which might partly explain why unemployment starts to rise a few years after trade liberalization in 1991. Again, I note that there were other shocks going on in Colombia in 1990s, e.g., the financial crisis in 1999.

[64] Note that in theory, openness does not necessarily raise wage inequality. As shown by Helpman et al. (2017), since more and more workers get hired by larger firms as openness rises, wage inequality may start to fall at some point.

[65] Note that since Attanasio et al. (2004) divide workers into education groups and look at the wage inequality within each group, their measure is comparable to my measure of residual wage inequality.

[66] Since my data set does not report workers' skill category in the post-92 data, I cannot measure post-reform residual wage inequality in my data.

first force, which results in a moderate increase in job turnover in the variable-markup model. Since the second channel does not exist in the constant-markup model, job turnover barely responds to openness in this model, which is also noted in the literature (e.g., Coşar et al., 2016).

Real Income. Finally, to evaluate the pro-competitive gains/losses from trade, we compare steady-state changes in real income between the variable- and constant-markup models in the "Openness" counterfactual exercise. As Table 4 shows, openness raises real income by only 0.3% in the variable-markup model, about 80% smaller than the rise in real income in the constant-markup model which is 1.7%. That is the pro-competitive gains from trade liberalization (in the steady state) are *negative*. Recall that both models have the same (ex-post) trade elasticity and exhibit the same increase in aggregate export share in the steady state in this "Openness" counterfactual exercise.

Real income in both models rises after trade liberalization due to a fall in the aggregate price index. Overall, the aggregate price index in both models tends to fall after openness due to cheaper Foreign varieties and also since resources get more concentrated at more efficient firms. As Table 4 shows, the main reason why real income rises by less in the variable-markup model is the fact that the price index in this model falls by less than that in the constant-markup model, due to the surge in unemployment under variable markups. To elaborate, since unemployed individuals are less productive than those who decide to home-produce, the supply of home-production demanded by firms (for fixed operation cost, fixed exporting cost, etc.) falls as unemployment rises, which in equilibrium reduces the mass of domestic firms/varieties N_H (see Appendix D for equilibrium conditions). Since unemployment rises by more under variable markups, the fall in the mass of domestic firms/varieties is more pronounced in this model (see Table 4), which puts a downward pressure on real income.

In addition to the unemployment effect, variable markups also affect the welfare consequences of trade through two other forces that are standard in the literature. On the one hand, Home producers' markups fall and become less dispersed.[67] Moreover, employment shifts toward larger, under-producing firms that charge higher markups. This effect, as in Edmond et al. (2015), tends to reduce misallocation arising from markups and to generate pro-competitive gains from trade liberalization, i.e., increasing welfare consequences of trade relative to the constant-markup model. On the other hand, however, as emphasized by Arkolakis et al. (2019), Foreign firms charge higher markups after trade liberalization, which tends to reduce the pro-competitive gains from trade. To emphasize the role of search frictions in driving the results, it is therefore important to show that the negative pro-competitive gains from trade liberalization that I report in this paper are indeed due to labor market frictions,

[67] Recall that the 5, 10, 90, and 95th percentile of markup distribution charged by Home producers fall from [1.085, 1.087, 1.128, 1.130] to [1.084, 1.085, 1.108, 1.111] after trade liberalization, respectively.

not due to Foreign firms charging higher markups.

To this end, I shut down search frictions in the labor market in both constant- and variable-markup models, and perform the "Openness" counterfactual exercise by reducing import tariffs from 40% to 7.5%, as before. Both models generate the same increase in export share of revenue in the steady state, around 220%, similar to the models with search frictions. This shows that these two models with no labor market frictions have the same (ex-post) trade elasticity, which is equal to that in the models with search frictions.[68] Interestingly, in this world without labor market frictions, the pro-competitive gains from trade liberalization are positive: While the steady-state real income rises by 2.5% in the variable-markup model, it rises by 2% in the constant-markup model. These positive pro-competitive gains from trade liberalization in a frictionless labor market are consistent with Edmond et al. (2015), as my model structure without search frictions is broadly in line with theirs.

To summarize, as discussed above, the variable- and constant-markup models in the presence of labor market frictions match the same set of moments, have the same (ex-post) trade elasticity, and exhibit the same increase in aggregate export (and import) share after trade openness. The welfare implications of trade liberalization in these two models are, however, quite different. Interestingly, while abstracting from labor market frictions in my framework implies positive pro-competitive gains from trade liberalization, taking labor market frictions into account implies that the pro-competitive gains from trade liberalization are *negative*. We can therefore conclude that accounting for variable markups in a frictional labor market reduces the gains from trade liberalization by around 80%. In the language of Arkolakis et al. (2019), my counterfactual exercises therefore show that the pro-competitive gains from trade can be even more "elusive" in the presence of labor market frictions.[69]

5 Conclusion

This paper develops and estimates a dynamic general equilibrium model of international trade featuring search frictions in the labor market and endogenously variable markups to show that trade-induced changes in markups have crucial impacts on labor market outcomes in a frictional labor market. The link between openness, markups, and labor market outcomes comes from that trade liberalization increases competition in product markets thereby raising demand elasticities and putting a downward pressure on markups. This in turn increases

[68] Note that to do this exercise I do not re-calibrate the models, i.e., I use the same parameters as in the models with search frictions. Re-calibrating the models would, however, deliver the same conclusion that the pro-competitive gains from trade are positive once we abstract from labor market frictions.

[69] Under Pareto productivity distribution, frictionless labor market, and some assumptions on preferences (which does not nest my demand structure), Arkolakis et al. (2019) show that the gains from trade liberalization under variable markups are up to 14% smaller than those under constant markups.

labor elasticities of revenue and makes firms' employment decisions more responsive to their idiosyncratic shocks, which in a frictional labor market increases unemployment and residual wage inequality. I show that once markups are allowed to respond to trade liberalization, unemployment and residual wage inequality rise almost three times more than in a model with constant markups (in the steady state). The presence of labor market frictions makes the pro-competitive gains from trade liberalization negative.

References

Ackerberg, Daniel A, Kevin Caves, and Garth Frazer (2015), "Identification properties of recent production function estimators." *Econometrica*, 83, 2411–2451.

Alessandria, George and Oscar Avila (2020), "Trade integration in colombia: a dynamic general equilibrium study with new exporter dynamics." *Journal of Economic Dynamics and Control*, 115, 103871.

Amiti, Mary and Donald R Davis (2011), "Trade, firms, and wages: Theory and evidence." *The Review of economic studies*, 79, 1–36.

Arkolakis, Costas (2016), "A unified theory of firm selection and growth." *The Quarterly Journal of Economics*, 131, 89–155.

Arkolakis, Costas, Arnaud Costinot, Dave Donaldson, and Andrés Rodríguez-Clare (2019), "The elusive pro-competitive effects of trade." *The Review of Economic Studies*, 86, 46–80.

Atkeson, Andrew and Ariel Burstein (2008), "Pricing-to-market, trade costs, and international relative prices." *American Economic Review*, 98, 1998–2031.

Atkin, David, Azam Chaudhry, Shamyla Chaudhry, Amit K Khandelwal, and Eric Verhoogen (2015), "Markup and cost dispersion across firms: Direct evidence from producer surveys in pakistan." *American Economic Review*, 105, 537–44.

Atrianfar, Hamed and Hamid Firooz (2019), "Competing on price and quality: Theory and evidence from trade data." *Available at SSRN 3401094*, URL https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3401094.

Attanasio, Orazio, Pinelopi K Goldberg, and Nina Pavcnik (2004), "Trade reforms and wage inequality in colombia." *Journal of development Economics*, 74, 331–366.

Badinger, Harald (2007), "Has the eu's single market programme fostered competition? testing for a decrease in mark-up ratios in eu industries." *oxford Bulletin of Economics and statistics*, 69, 497–519.

Bernard, Andrew B, Jonathan Eaton, J Bradford Jensen, and Samuel Kortum (2003), "Plants and productivity in international trade." *American economic review*, 93, 1268–1290.

Bertola, Giuseppe and Pietro Garibaldi (2001), "Wages and the size of firms in dynamic matching models." *Review of Economic Dynamics*, 4, 335–368.

Binmore, Ken, Ariel Rubinstein, and Asher Wolinsky (1986), "The nash bargaining solution in economic modelling." *The RAND Journal of Economics*, 176–188.

Bond, Eric W, James Tybout, and Hale Utar (2015), "Credit rationing, risk aversion, and industrial evolution in developing countries." *International Economic Review*, 56, 695–722.

Bottasso, Anna and Alessandro Sembenelli (2001), "Market power, productivity and the eu single market program: Evidence from a panel of italian firms." *European Economic Review*, 45, 167–186.

Brügemann, Björn, Pieter Gautier, and Guido Menzio (2019), "Intra firm bargaining and shapley values." *The Review of Economic Studies*, 86, 564–592.

Chaney, Thomas (2008), "Distorted gravity: the intensive and extensive margins of international trade." *American Economic Review*, 98, 1707–21.

Cooper, Russell, John Haltiwanger, and Jonathan L Willis (2007), "Search frictions: Matching aggregate and establishment observations." *Journal of Monetary Economics*, 54, 56–78.

Cooper, Russell and Jonathan L Willis (2009), "The cost of labor adjustment: Inferences from the gap." *Review of Economic dynamics*, 12, 632–647.

Cooper, Russell W and John C Haltiwanger (2006), "On the nature of capital adjustment costs." *The Review of Economic Studies*, 73, 611–633.

Cosar, A Kerem (2013), "Adjusting to trade liberalization: Reallocation and labor market policies." *University of Chicago Booth School of Business, unpublished manuscript.*

Coşar, A Kerem, Nezih Guner, and James Tybout (2016), "Firm dynamics, job turnover, and wage distributions in an open economy." *American Economic Review*, 106, 625–63.

David, Joel M and Venky Venkateswaran (2019), "The sources of capital misallocation." *American Economic Review*, 109, 2531–67.

Davidson, Carl, Lawrence Martin, and Steven Matusz (1999), "Trade and search generated unemployment." *Journal of International Economics*, 48, 271–299.

Davidson, Carl, Steven J Matusz, and Andrei Shevchenko (2008), "Globalization and firm level adjustment with imperfect labor markets." *Journal of international Economics*, 75, 295–309.

Davis, Donald R and James Harrigan (2011), "Good jobs, bad jobs, and trade liberalization." *Journal of international Economics*, 84, 26–36.

Davis, Steven J and John Haltiwanger (1992), "Gross job creation, gross job destruction, and employment reallocation." *The Quarterly Journal of Economics*, 107, 819–863.

de Desarrollo, Banco Interamericano (2004), "Good jobs wanted: Labor markets in latin america." *Economic and Social Progress Report, Washington*.

De Loecker, Jan, Jan Eeckhout, and Gabriel Unger (2020), "The rise of market power and the macroeconomic implications." *The Quarterly Journal of Economics*, 135, 561–644.

De Loecker, Jan, Pinelopi K Goldberg, Amit K Khandelwal, and Nina Pavcnik (2016), "Prices, markups, and trade reform." *Econometrica*, 84, 445–510.

De Loecker, Jan and Frederic Warzynski (2012), "Markups and firm-level export status." *American Economic Review*, 102, 2437–71.

De Melo, Jaime and Shujiro Urata (1986), "The influence of increased foreign competition on industrial concentration and profitability." *International Journal of Industrial Organization*, 4, 287–304.

Decker, Ryan A, John Haltiwanger, Ron S Jarmin, and Javier Miranda (2020), "Changing business dynamism and productivity: Shocks versus responsiveness." *American Economic Review*, 110, 3952–90.

Decker, Ryan A, John C Haltiwanger, Ron S Jarmin, and Javier Miranda (2018), "Changing business dynamism and productivity: Shocks vs. responsiveness." Technical report, National Bureau of Economic Research.

Den Haan, Wouter J, Garey Ramey, and Joel Watson (2000), "Job destruction and propagation of shocks." *American economic review*, 90, 482–498.

Dinopoulos, Elias, Constantinos Syropoulos, Bin Xu, and Yoto V Yotov (2011), "Intraindustry trade and the skill premium: Theory and evidence." *Journal of International Economics*, 84, 15–25.

Dix-Carneiro, Rafael, Pinelopi K Goldberg, Costas Meghir, and Gabriel Ulyssea (2021), "Trade and informality in the presence of labor market frictions and regulations." Working Paper 28391, National Bureau of Economic Research, URL http://www.nber.org/papers/w28391.

Eaton, Jonathan and Samuel Kortum (2002), "Technology, geography, and trade." *Econometrica*, 70, 1741–1779.

Edmond, Chris, Virgiliu Midrigan, and Daniel Yi Xu (2015), "Competition, markups, and the gains from international trade." *American Economic Review*, 105, 3183–3221.

Edmond, Chris, Virgiliu Midrigan, and Daniel Yi Xu (2018), "How costly are markups?" Technical report, National Bureau of Economic Research.

Egger, Hartmut and Udo Kreickemeier (2009), "Firm heterogeneity and the labor market effects of trade liberalization." *International Economic Review*, 50, 187–216.

Elsby, Michael WL and Ryan Michaels (2013), "Marginal jobs, heterogeneous firms, and unemployment flows." *American Economic Journal: Macroeconomics*, 5, 1–48.

Ericson, Richard and Ariel Pakes (1995), "Markov-perfect industry dynamics: A framework for empirical work." *The Review of economic studies*, 62, 53–82.

Eslava, Marcela, John Haltiwanger, Adriana Kugler, and Maurice Kugler (2004), "The effects of structural reforms on productivity and profitability enhancing reallocation: evidence from colombia." *Journal of development Economics*, 75, 333–371.

Eslava, Marcela, John Haltiwanger, Adriana Kugler, and Maurice Kugler (2010), "Factor adjustments after deregulation: panel evidence from colombian plants." *The Review of Economics and Statistics*, 92, 378–391.

Fajgelbaum, Pablo D (2013), "Labor market frictions, firm growth, and international trade." Technical report, National Bureau of Economic Research.

Felbermayr, Gabriel, Giammario Impullitti, and Julien Prat (2018), "Firm dynamics and residual inequality in open economies." *Journal of the European Economic Association*, 16, 1476–1539.

Felbermayr, Gabriel, Julien Prat, and Hans-Jörg Schmerer (2011), "Globalization and labor market outcomes: Wage bargaining, search frictions, and firm heterogeneity." *Journal of Economic theory*, 146, 39–73.

Fontenay, Catherine C and Joshua S Gans (2014), "Bilateral bargaining with externalities." *The Journal of Industrial Economics*, 62, 756–788.

Foster, Lucia, Cheryl Grim, John Haltiwanger, and Zoltan Wolf (2017), "Innovation, productivity growth and productivity dispersion." Technical report, Working Paper.

Foster, Lucia, John Haltiwanger, and Chad Syverson (2008), "Reallocation, firm turnover, and efficiency: Selection on productivity or profitability?" *American Economic Review*, 98, 394–425.

Gopinath, Gita, Şebnem Kalemli-Özcan, Loukas Karabarbounis, and Carolina Villegas-Sanchez (2017), "Capital allocation and productivity in south europe." *The Quarterly Journal of Economics*, 132, 1915–1967.

Hall, Robert E, Olivier Jean Blanchard, and R Glenn Hubbard (1986), "Market structure and macroeconomic fluctuations." *Brookings papers on economic activity*, 1986, 285–338.

Haltiwanger, John, Ron S Jarmin, and Javier Miranda (2013), "Who creates jobs? small versus large versus young." *Review of Economics and Statistics*, 95, 347–361.

Haltiwanger, John, Adriana Kugler, Maurice Kugler, Alejandro Micco, and Carmen Pages (2004), "Effects of tariffs and real exchange rates on job reallocation: evidence from latin america." *The Journal of Policy Reform*, 7, 191–208.

Haltiwanger, John C and Milan Vodopivec (2002), "Gross worker and job flows in a transition economy: an analysis of estonia." *Labour economics*, 9, 601–630.

Hamermesh, Daniel S (1996), *Labor demand*. princeton University press.

Harrison, Brian Howard (1994), *Drink and the Victorians: the temperance question in England, 1815-1872*. Keele University Press.

Heckman, James J and Carmen Pages (2000), "The cost of job security regulation: evidence from latin american labor markets." Technical report, National bureau of economic research.

Helpman, Elhanan and Oleg Itskhoki (2010), "Labour market rigidities, trade and unemployment." *The Review of Economic Studies*, 77, 1100–1137.

Helpman, Elhanan, Oleg Itskhoki, Marc-Andreas Muendler, and Stephen J Redding (2017), "Trade and inequality: From theory to estimation." *The Review of Economic Studies*, 84, 357–405.

Helpman, Elhanan, Oleg Itskhoki, and Stephen Redding (2010), "Inequality and unemployment in a global economy." *Econometrica*, 78, 1239–1283.

Helpman, Elhanan and Paul Krugman (1989), *Trade policy and market structure*. MIT press.

Hopenhayn, Hugo and Richard Rogerson (1993), "Job turnover and policy evaluation: A general equilibrium analysis." *Journal of political Economy*, 101, 915–938.

Hopenhayn, Hugo A (1992), "Entry, exit, and firm dynamics in long run equilibrium." *Econometrica: Journal of the Econometric Society*, 1127–1150.

Jovanovic, Boyan (1982), "Selection and the evolution of industry." *Econometrica: Journal of the Econometric Society*, 649–670.

Kim, Euysung (2000), "Trade liberalization and productivity growth in korean manufacturing industries: price protection, market power, and scale efficiency." *Journal of Development Economics*, 62, 55–83.

Kimball, Miles S (1995), "The quantitative analytics of the basic neomonetarist model." *Journal of Money, credit and Banking*, 27, 1241–1277.

Klenow, Peter J and Jonathan L Willis (2016), "Real rigidities and nominal price changes." *Economica*, 83, 443–472.

Klette, Tor Jakob and Samuel Kortum (2004), "Innovating firms and aggregate innovation." *Journal of political economy*, 112, 986–1018.

Konings, Jozef, Patrick Van Cayseele, and Frederic Warzynski (2005), "The effects of privatization and competitive pressure on firms' price-cost margins: Micro evidence from emerging economies." *Review of Economics and Statistics*, 87, 124–134.

Krishna, Pravin and Devashish Mitra (1998), "Trade liberalization, market discipline and productivity growth: new evidence from india." *Journal of development Economics*, 56, 447–462.

Levinsohn, James (1993), "Testing the imports-as-market-discipline hypothesis." *Journal of International Economics*, 35, 1–22.

Levinsohn, James and Amil Petrin (2003), "Estimating production functions using inputs to control for unobservables." *The Review of Economic Studies*, 70, 317–341.

Ljungqvist, Lars (2002), "How do lay-off costs affect employment?" *The Economic Journal*, 112, 829–853.

Luttmer, Erzo GJ (2007), "Selection, growth, and the size distribution of firms." *The Quarterly Journal of Economics*, 122, 1103–1144.

MacKenzie, Gaelan (2021), "Trade and market power in product and labor markets." Technical report, Bank of Canada Staff Working Paper.

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

Merz, Monika and Eran Yashiv (2007), "Labor and the market value of the firm." *American Economic Review*, 97, 1419–1431.

Mortensen, Dale T and Christopher A Pissarides (1994), "Job creation and job destruction in the theory of unemployment." *The review of economic studies*, 61, 397–415.

Mortensen, Dale T and Christopher A Pissarides (1999), "New developments in models of search in the labor market." *Handbook of labor economics*, 3, 2567–2627.

Pollak, Robert A. (1971), "Additive utility functions and linear engel curves." *Review of Economic Studies*, 38, 401–414.

Roberts, Mark J and James R Tybout (1996), "Industrial evolution in developing countries: a preview." *Industrial Evolution in Developing Countries*, 1–14.

Rodrik, Dani (1997), *Has Globalization Gone Too Far?* Columbia University Press.

Rossi-Hansberg, Esteban and Mark LJ Wright (2007), "Establishment size dynamics in the aggregate economy." *American Economic Review*, 97, 1639–1666.

Ruggieri, Alessandro (2018), "Trade and labor market institutions: A tale of two liberalizations." *Working Paper*.

Simonovska, Ina (2015), "Income differences and prices of tradables: Insights from an online retailer." *The Review of Economic Studies*, 82, 1612–1656.

Slaughter, Matthew J (2001), "International trade and labor–demand elasticities." *Journal of International Economics*, 54, 27–56.

Stole, Lars A and Jeffrey Zwiebel (1996), "Intra-firm bargaining under non-binding contracts." *The Review of Economic Studies*, 63, 375–410.

Tybout, James R (2003), "Plant-and firm-level evidence on the new trade theories." *In Handbook of international trade, ed. E. Kwan Choi and James Harrigan*.

Yashiv, Eran (2006), "Evaluating the performance of the search and matching model." *Contributions to Economic Analysis*, 275, 509–550.

Appendices

A Demand Elasticity and Firms' Responsiveness: Another Perspective

Section 2 of the paper provided a simple model to show firms with lower labor elasticities of revenue are more responsive to shocks. This section expresses the same idea through a different, but closely related, angle. Here, instead of arguing that labor elasticity of revenue is affected by changes in output demand elasticity, I take the perspective that labor demand elasticity responds to changes in output demand elasticity. These two perspectives are closely connected since labor elasticity of revenue and labor demand elasticity are two sides of the same coin. To elaborate, the fundamental law of factor demand, discussed in Hamermesh (1996), shows how derived labor demand elasticity and output demand elasticity are linked together:

$$\frac{\partial l/l}{\partial w/w} = -(1-s)\sigma_{l,all} - s\left|\frac{\partial q/q}{\partial p/p}\right| \,, \tag{49}$$

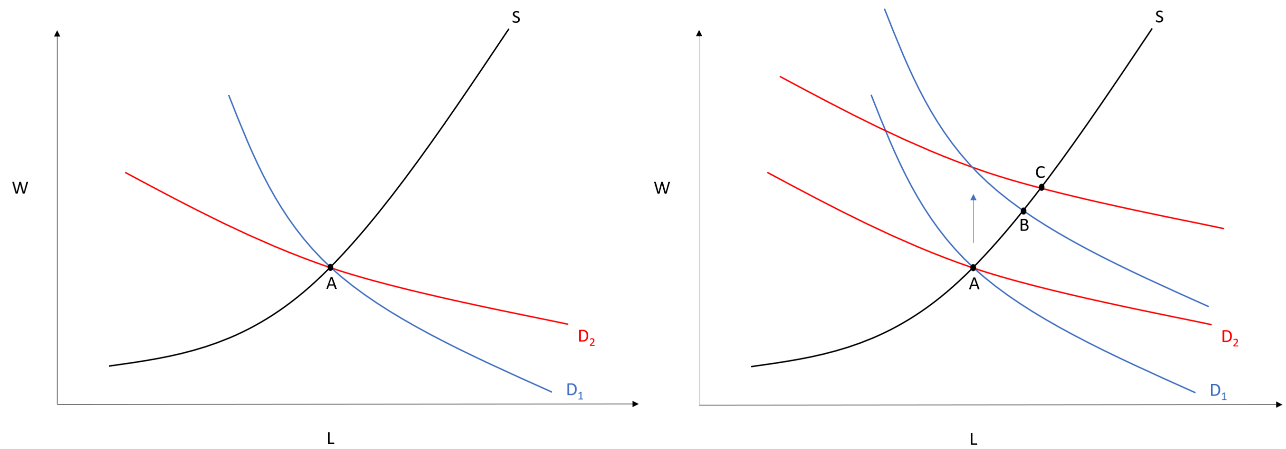
where the LHS is labor demand elasticity, s is share of labor in revenue, $\sigma_{l,all}$ is elasticity of substitution between labor and all other factors of production, and $\frac{\partial q/q}{\partial p/p}$ is output demand elasticity. This equation shows as output demand becomes more elastic, so does labor demand. This is intuitive because when output demand is more elastic, changes in wage (via affecting marginal cost of production and, in turn, output price) has a larger effect on the quantity demanded, and therefore on labor demand. Now, the claim is that firms are more responsive (in terms of employment) to their revenue shocks when they face a more elastic labor demand. Figure A.1 shows this idea graphically. Suppose we have two different labor demand curves D_1 and D_2, before and after trade liberalization, respectively. Suppose a firm faces the same labor supply S and, initially, the firm is at the equilibrium point A. Now, consider the same positive revenue shock that hits the firm. Since a revenue shock changes the marginal revenue product of labor, both labor demand curves shift upward with the same magnitude. The new equilibria are B and C for the less and more elastic labor demand, respectively. As seen in the figure, the same revenue shock changes employment by more when labor demand is more elastic.

B Additional Figures and Tables

As noted in the paper, Figure B.1 employs Ackerberg et al. (2015)'s methodology to estimate labor elasticities of revenue, which shows the estimated values are robust to the method, and

Figure A.1: Firms' responsiveness and labor demand elasticity

(a) Initial equilibrium (b) After the revenue shock hits



also to the inclusion of capital. In particular, the pattern and also the estimated values are quite similar to those reported in the paper.

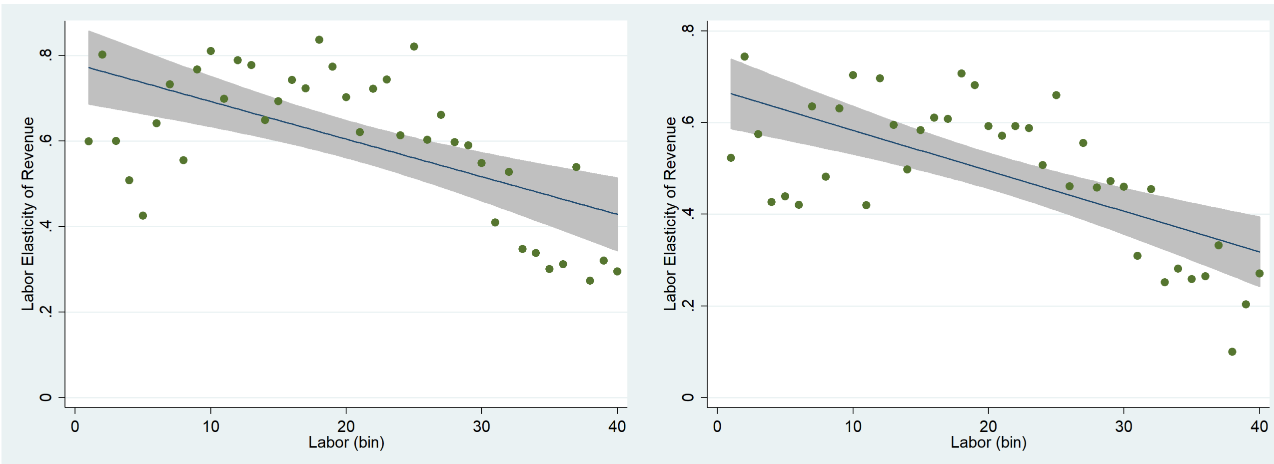
As a robustness check, here I calculate within-employment bin job turnover rate "net of employment change" in year t for each employment bin j as

$$\mathrm{JT}_{jt} = \frac{\sum_{i \in \mathrm{c}} |l_{ijt} - l_{ijt-1}| + \sum_{i \in exit} l_{ijt-1} - |L_{jt} - L_{jt-1}|}{(L_{jt-1} + L_{jt})/2} \times 100 \ , \tag{50}$$

where i denotes plants, c is the set of continuing plants, and L_{jt} is total employment for employment bin j at time t. The first two terms in the numerator measure job turnover by continuing and exiting plants, respectively. The last term in the numerator is the net change in total employment for employment bin j. I take the average job turnover rate for each employment bin over the sample period. Figures B.2 and B.3 confirm the patterns reported as suggestive evidence 1 and 2, respectively, in the paper.

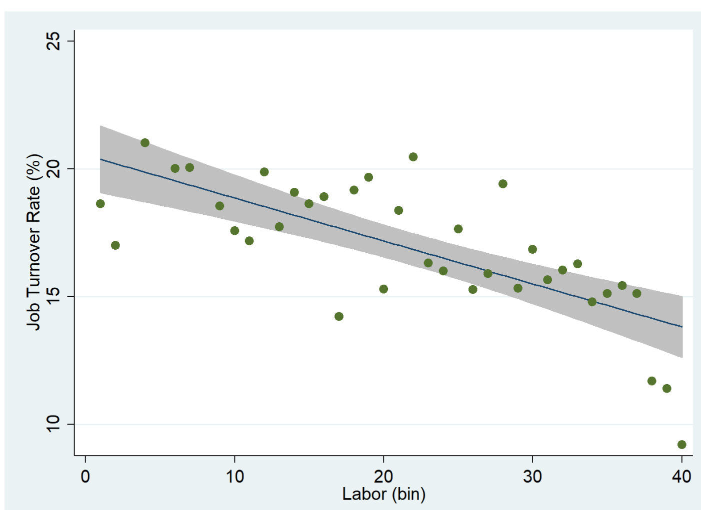
Figure B.1: Job Turnover and Labor Elasticity of Revenue for Each Employment Bin

(a) Labor Elasticity of Revenue- ACF No Capital (b) Labor Elasticity of Revenue- ACF with Capital



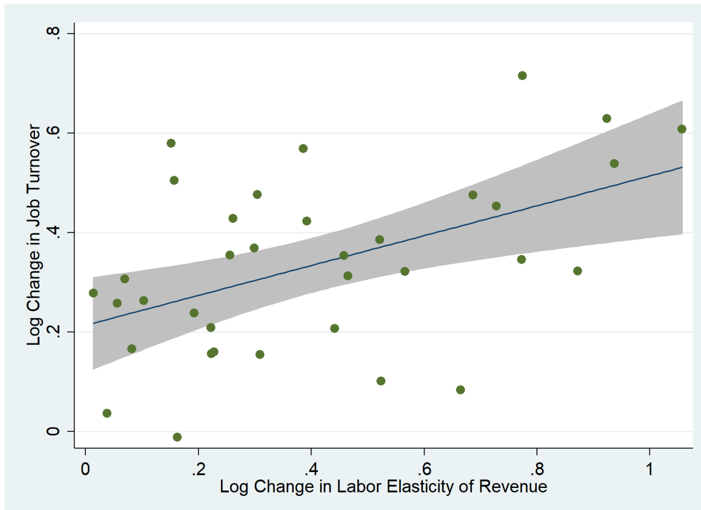
Notes: Plants are divided into 40 employment bins, displayed by the horizontal axes. The shaded areas reflect the linear fitted lines along with their 95% confidence bands.

Figure B.2: Job Turnover across the Firm Size Distribution



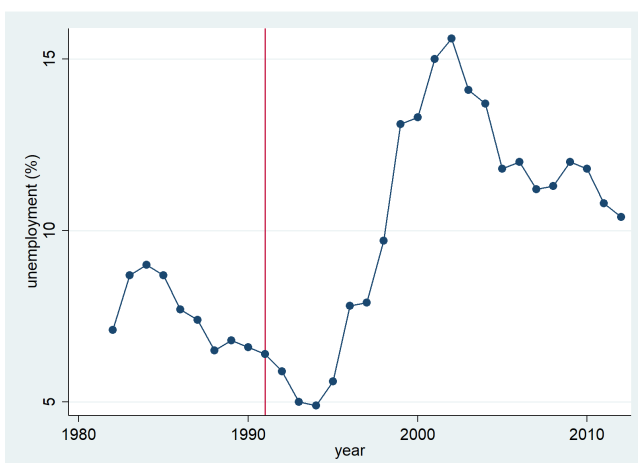
Notes: Plants are divided into 40 employment bins, displayed by the horizontal axis. The shaded area reflects the linear fitted line along with its 95% confidence band.

Figure B.3: Changes in Job Turnover vs. Changes in Labor Elasticity of Revenue for Each Employment Bin



Notes: Plants are divided into 40 employment bins. The horizontal and vertical axes, respectively, measure the log change in labor elasticity of revenue and job turnover for each employment bin from pre- to post- trade liberalization episode. The shaded area reflects the linear fitted line along with its 95% confidence band.

Figure B.4: Unemployment rate in Colombia



Notes: Data for unemployment rates are from International Monetary Fund. The red line shows year 1991 in which Colombia experienced a large reduction in trade barriers.

Table B.1: Data- versus Model-Based Statistics (Constant-Markup Model)

Moments	Data	Model	Moments	Data	Model
$E(\log l_t)$	3.706	3.677	$\text{cov}(I_t^x, \log R_{t+1})$	0.211	0.216
$E(\log R_t)$	5.655	5.611	$\text{cov}(I_t^x, I_{t+1}^x)$	0.086	0.049
$E(I_t^x)$	0.117	0.066	*firms' employment distribution*		
$\text{var}(\log l_t)$	1.002	0.995	20^{th} percentile	17.505	16.149
$\text{var}(\log R_t)$	2.589	2.612	40^{th} percentile	25.874	24.076
$\text{cov}(\log l_t, \log R_t)$	1.324	1.282	60^{th} percentile	42.225	41.005
$\text{cov}(\log l_t, I_t^x)$	0.129	0.124	80^{th} percentile	88.187	91.144
$\text{cov}(\log R_t, I_t^x)$	0.208	0.227	material share of sale (median)	0.586	0.596
$\text{cov}(\log l_t, \log l_{t+1})$	0.979	0.969	coefficient of regressing		
$\text{cov}(\log l_t, \log R_{t+1})$	1.325	1.198	material share of sale on log(labor)	-0.006	0
$\text{cov}(\log l_t, I_{t+1}^x)$	0.133	0.123	job turnover rate (%)	21.458	19.299
$\text{cov}(\log R_t, \log l_{t+1})$	1.322	1.312	continuing firms' job turnover (%)	9.371	8.074
$\text{cov}(\log R_t, \log R_{t+1})$	2.559	2.412	mean of exporters' export intensity	0.181	0.167
$\text{cov}(\log R_t, I_{t+1}^x)$	0.215	0.229	std. of log wages	0.515	0.514
$\text{cov}(I_t^x, \log l_{t+1})$	0.129	0.127	exit rate (%)	10.328	9.891

Notes: Data statistics are based on Colombia manufacturing plant-level dataset from 1983-1990.

Table B.2: Calibrated Parameters (Constant-Markup Model)

Parameter	Description	Value
$\sigma = \alpha$	demand elasticity	8.940
c_v	hiring cost	28.400
ρ	matching friction	2.509
$\log(A_F)$	aggregate demand shifter in market F	17.109
η	material elasticity of output	0.671
f_d	fixed production cost	8.279
f_x	fixed exporting cost	76.643
f_e	sunk entry cost	497.725
γ	persistence of productivity shocks	0.913
σ_ϕ	std. of productivity shocks	0.220
b_u	workers' outside option	0.331
λ	death shock	0.088
ξ	workers' bargaining power	0.225

Notes: Calibrated parameters by minimizing the distance between the set of model moments and their data counterparts, summarized in Table B.1.

C An Alternative Model to Generate Variable Markups

C.1 Environment

The environment is exactly the same as in the model presented in the text, except that intermediate producers sell their goods to the final producers in a monopolistically competitive market.

C.2 Consumers and Final Good Producers

The final good producers make a composite good out of the domestic and Foreign intermediate varieties and sell it to (domestic[1]) consumers as well as intermediate good producers. The final good is produced according to the following commonly available technology:

$$M = [\int_0^{1+1} (q(\nu) + \alpha)^{\frac{\sigma-1}{\sigma}} \ d\nu]^{\frac{\sigma}{\sigma-1}} \ , \tag{51}$$

where the intermediate goods are denoted by ν. I assume the measure of Foreign intermediate producers is one. Moreover, while the measure of *potential* domestic intermediate producers is one, the measure of *active* domestic intermediate producers is N_H, an endogenous object determined in equilibrium.[2] Parameters σ and α govern the price elasticity of demand (i.e. demand elasticity) faced by intermediate goods ν. This will be elaborated below. I assume that the final good is produced by a unit measure of producers and is sold at the market-clearing price P.[3] As for consumers, I assume the same utility function as the one in the main text.

Since the main focus of this paper is to show the role that variable demand elasticity plays in labor market outcomes of an economy, it is worth elaborating more on the demand elasticity implied by equation (51). As I show below, solving the cost minimization problem of country i's final good producers implies that these producers demand the following amount of the Home intermediate good ν (which is produced by a Home firm with productivity ϕ and l workers):

$$q_i(\phi, l) = A_i p_i(\phi, l)^{-\sigma} - \alpha \ , \tag{52}$$

where I label the intermediate producer by its productivity ϕ and number of workers l. $p_i(\phi, l)$ and $q_i(\phi, l)$ are the price of and demand for the Home intermediate producer (ϕ, l) in market i, respectively, and A_i is aggregate demand shifter. Note that while the aggregate demand shifter

[1]Recall that the final good is non-tradable.

[2]Notice that the final good production is not zero even if no intermediate inputs are used; I interpret the parameter α as managerial ability that could (to some extent) replace the intermediate inputs.

[3]I study the unique symmetric equilibrium in which all producers produce the same amount.

in the Home market (A_H) is an endogenous equilibrium object, the aggregate demand shifter in the Foreign market is a model parameter that I estimate.[4] Moreover, under the assumption that $\alpha > 0$, there is a choke price in the demand curve (52) above which the demand for an intermediate good in market i is zero:

$$p_i^{\text{choke}} = (\frac{A_i}{\alpha})^{\frac{1}{\sigma}} \ . \tag{53}$$

As I show below, the (absolute value of) demand elasticity which the intermediate producer (ϕ, l) faces in market i is

$$\varepsilon_i(\phi, l) = \sigma(1 + \frac{\alpha}{q_i(\phi, l)}) \ . \tag{54}$$

Few points are in order. First, as σ or α rises, intermediate good producers face more elastic demand curves. Second, more productive intermediate producers are larger, and therefore, face lower demand elasticities and charge higher markups. Furthermore, any policy that affects the firm size distribution, changes the demand elasticity faced by firms. Finally, in the special case where α is set to zero, we are back in the constant demand elasticity world in which all intermediate producers face the same demand elasticity σ.

Discussion. While not employing a similar formulation, using a demand curve featuring choke price to generate variable demand elasticity is used also in the literature (Pollak, 1971; Dinopoulos et al., 2011; Simonovska, 2015; Arkolakis et al., 2019). With no income heterogeneity, instead of using a displaced CES production function in (51), one could define consumers' utility as

$$U = [\int_0^{1+1} (q(\nu) + \alpha)^{\frac{\sigma-1}{\sigma}} d\nu]^{\frac{\sigma}{\sigma-1}} \ , \tag{55}$$

and then aggregate the demand for each variety across all workers (as in Simonovska (2015) who uses the above utility function and imposes $\sigma = 1$). However, if individuals earn different incomes, each individual would have her own choke price for each variety ν.[5] As a result, summing each good's demand across all individuals is not feasible since this model features wage heterogeneity across a continuum of workers. To solve this aggregation problem, I assume consumers demand a final good which is produced using the displaced CES production function (51). This way, these final good producers collect income from all workers and intermediate firms, and demand intermediate goods ν.

[4]Home is a small economy.

[5]This is because, in that case, the demand shifter A would depend on the consumer's income. To see this, note that utility maximization problem would result in the F.O.C.s that are exactly the same as those stated below for the case of cost minimization problem, except that one needs to replace M with the utility of the consumer and also the Lagrange multiplier would be the inverse of Ψ. Hence, one can see that the demand shifter in that case would be a function of consumer's income.

C.3 Final Good Producers' Problem

The cost minimization problem of the final good producers in the Home economy is as follows:

$$\min_{q(\nu)\geq 0} p(\nu)q(\nu) \quad \text{s.t.} \quad M = [\int_0^{1+1} (q(\nu)+\alpha)^{\frac{\sigma-1}{\sigma}} \; d\nu]^{\frac{\sigma}{\sigma-1}} \; . \tag{56}$$

The F.O.C.s yield ($\forall\ q(\nu) > 0$)

$$(q(\nu)+\alpha)^{\frac{-1}{\sigma}}[\int_0^{1+1} (q(\nu)+\alpha)^{\frac{\sigma-1}{\sigma}} \; d\nu]^{\frac{1}{\sigma-1}} = \frac{p(\nu)}{\Psi} \; , \tag{57}$$

where Ψ is the Lagrange multiplier. Multiplying both sides by $(q(\nu)+\alpha)$ and use the definition of M yields

$$(q(\nu)+\alpha)^{\frac{\sigma-1}{\sigma}} M^{\frac{1}{\sigma}} = \frac{p(\nu)(q(\nu)+\alpha)}{\Psi} \; . \tag{58}$$

Summing over all varieties with $q(\nu) > 0$ yields

$$M^{\frac{1}{\sigma}} \int_0^{1+1} (q(\nu)+\alpha)^{\frac{\sigma-1}{\sigma}} \mathbf{1}_{q(\nu)>0} \, d\nu = \frac{\displaystyle\int_0^{1+1} p(\nu)(q(\nu)+\alpha)\mathbf{1}_{q(\nu)>0} \, d\nu}{\Psi} \; . \tag{59}$$

Moreover, as in the text, assume that while all the Foreign varieties are imported, only a subset of the domestic varieties with measure N_H are produced. Hence, using the definition of M, one can write

$$M^{\frac{\sigma-1}{\sigma}} = \int_0^{1+1} (q(\nu)+\alpha)^{\frac{\sigma-1}{\sigma}} \mathbf{1}_{q(\nu)>0} \, d\nu + (1-N_H)\alpha^{\frac{\sigma-1}{\sigma}} \; . \tag{60}$$

Combining the last two equations delivers the Lagrange multiplier

$$\Psi = \frac{\displaystyle\int_0^{1+1} p(\nu)(q(\nu)+\alpha)\mathbf{1}_{q(\nu)>0} \, d\nu}{M(1 - M^{\frac{1-\sigma}{\sigma}}(1-N_H)\alpha^{\frac{\sigma-1}{\sigma}})} \tag{61}$$

To find the demand for each variety ν, rearrange the terms in equation (57) and use the definition of M to get

$$(q(\nu)+\alpha)^{\frac{-1}{\sigma}} = \frac{M^{\frac{-1}{\sigma}}}{\Psi} p(\nu) \; . \tag{62}$$

Rearranging the terms yields

$$q(\nu) = M\Psi^{\sigma} p(\nu)^{-\sigma} - \alpha \; . \tag{63}$$

Defining the aggregate demand shifter $A := M\Psi^{\sigma}$ delivers the demand for variety ν as expressed above

$$q(\nu) = Ap(\nu)^{-\sigma} - \alpha \; . \tag{64}$$

Note that the aggregate demand shifter A is an equilibrium object. The (absolute value of) demand elasticity which the variety ν producer faces is

$$\varepsilon(\nu) = -\frac{\partial q(\nu)}{\partial p(\nu)}\frac{p(\nu)}{q(\nu)} = \frac{\sigma A p(\nu)^{-\sigma}}{q(\nu)} = \frac{\sigma A p(\nu)^{-\sigma} - \sigma\alpha + \sigma\alpha}{q(\nu)} = \frac{\sigma q(\nu) + \sigma\alpha}{q(\nu)} = \sigma(1 + \frac{\alpha}{q(\nu)}) \ .$$

The rest of this model is the same as the model presented in the paper. The main implication that markups are variable and rise with firms' size hold under this structure as well. Simulations of this alternative model show similar implications as those reported in the text.

D Stationary Equilibrium

The equilibrium notion in this paper is steady state equilibrium. Here I define the steady state equilibrium of the model. The steady state equilibrium consists of steady state distributions $J(\phi, l)$ and $G(\phi, l)$, total production of the composite final good M and its price P, measure of intermediate producers N_H, measure of entrants N_e, aggregate income I, measure of employees L_T working for intermediate producers, measure of unemployed individuals L_U, measure of individuals working at home L_h, the labor market tightness θ, the job finding rate $m(\theta)$, the relative price e, the employment policy function $l'(\phi, l)$, continuation policy function $I^c(\phi, l)$, hiring policy function $I^h(\phi, l)$, firing policy function $I^f(\phi, l)$, wage schedule $w(\phi, l)$, export policy function $I^x(\phi, l)$, Home intermediate producers' prices and quantities $p_{HH,1}(\phi, l)$, $p_{HF,1}(\phi, l)$, $q_{HH,1}(\phi, l)$, $q_{HF,1}(\phi, l)$ as well as material usage $M(\phi, l)$, Foreign intermediate producers' prices and quantities in the Home market $p_{FH,k}(\phi, l)$ and $q_{FH,k}(\phi, l)$[6], value functions $V(\phi, l)$, $V^C(\phi, l)$, W^u, W^a, and W^h, satisfying the following conditions:

I) In equilibrium, the distributions $J(\phi, l)$ and $G(\phi, l)$ reproduces themselves through the Markov productivity process, employment policy function $l'(\phi, l)$, and continuation policy function $I^c(\phi, l)$. Recall that while $J(\phi, l)$ is the end-of-period firms distribution, $G(\phi, l)$ is the mid-period distribution, i.e., firms distribution after realization of productivities (and so after entry and exit) but before firms decide about their employment. Hence, we can write the mid-period distribution $G(\phi, l)$ as a function of the end-of-period distribution $J(\phi, l)$ as follows:

$$G(\phi', l) = \begin{cases} \frac{N_e}{N_H} J^0(\phi') + (1-\lambda)\displaystyle\int I^c(\phi, l) J(\phi, l) T(\phi'|\phi) d\phi & l = l_e \\ (1-\lambda)\displaystyle\int I^c(\phi, l) J(\phi, l) T(\phi'|\phi) d\phi & l \neq l_e \end{cases} \tag{65}$$

where $T(\phi'|\phi)$ is the transition density of the productivity Markov process, $J^0(\cdot)$ is the ergodic distribution implied by the productivity Markov process, l_e is the number of workers that

[6]The label (ϕ, l) for the Foreign producer corresponds to the productivity and labor of its Home rival.

entrants start with upon entry, and λ is the exogenous death rate. The first term of the first equation in (65) corresponds to the entrants, who start with l_e number of workers. In equilibrium, an endogenous measure of firms replace exiters (due to endogenous or exogenous reasons) every period so that the total mass of firms remains constant:

$$N_e = N_H[\underbrace{\lambda}_{\text{exogenous exit}} + \underbrace{(1-\lambda)\int_\phi \int_l (1 - I^c(\phi, l))J(\phi, l)dld\phi]}_{\text{endogenous exit}} \ . \tag{66}$$

The end-of-period distribution $J(\phi, l)$, on the other hand, can be written as a function of the mid-period distribution $G(\phi, l)$:

$$J(\phi, L) = \frac{\int_l G(\phi, l)\mathbf{1}_{l'(\phi,l)=L}dl}{\int_\phi \int_l G(\phi, l)\mathbf{1}_{l'(\phi,l)=L}dld\phi} \ , \tag{67}$$

where $\mathbf{1}_x$ is an indicator function equals to one if x holds, and zero otherwise.

II) In equilibrium, a measure L_T of workers are employed by the intermediate producers:[7]

$$L_T = N_H \int_\phi \int_l lJ(\phi, l)dld\phi \ . \tag{68}$$

At the beginning of each period, some jobs may be destroyed due to firms' endogenous exit or exogenous death. Total inflow to the unemployment pool at the beginning of each period equals:

$$U^{\text{inflow}}_{\text{begin}} = \lambda L_T + (1-\lambda)N_H \int_\phi \int_l (1 - I^c(\phi, l))lJ(\phi, l)dld\phi \ . \tag{69}$$

Moreover, after realization of the productivity shocks, some firms decide to contract, and the laid off workers enter the unemployment pool:

$$U^{\text{inflow}}_{\text{mid}} = N_H \int_\phi \int_l I^f(\phi, l)(l - l'(\phi, l))G(\phi, l)dld\phi \ . \tag{70}$$

Total inflow to the unemployment pool in each period equals the sum of these two:

$$U^{\text{inflow}} = U^{\text{inflow}}_{\text{begin}} + U^{\text{inflow}}_{\text{mid}} \ . \tag{71}$$

An endogenous fraction (which is the job finding rate) of unemployed individuals L_U find a

[7]Recall that final good producers do not hire labor.

job.[8] Hence, outflow from the unemployment pool can be written as

$$U^{\text{outflow}} = m(\theta) L_U \ . \tag{72}$$

In equilibrium, flow into and out of the unemployment pool are equal so that the measure of unemployed individuals is constant. Therefore, rearranging equation (72) yields

$$L_U = \frac{U^{\text{inflow}}}{m(\theta)} \ . \tag{73}$$

Now that we have L_T and L_U from equations (68) and (73), respectively, the measure of individuals who decide to home-produce equals

$$L_h = 1 - L_T - L_U \ . \tag{74}$$

Then, unemployment rate equals the fraction of job seekers who cannot find a job:

$$\text{unemployment rate} = \frac{L_U}{L_U + L_T} \ . \tag{75}$$

Notice that a rise in labor market tightness, or a reduction in the inflow to the unemployment pool, or an increase in the size of the intermediate sector workforce reduces unemployment rate.

III) Prices $p_{HH,1}(\phi, l)$ and $p_{HF,1}(\phi, l)$, quantities $q_{HH,1}(\phi, l)$ and $q_{HF,1}(\phi, l)$, material usage $M(\phi, l)$, and export decision $I^x(\phi, l)$ solve the domestic intermediate producers' problem in (17). Moreover, Foreign producers' price $p_{FH,k}(\phi, l)$ and quantity $q_{FH,k}(\phi, l)$ in the Home market solve Foreign firms' problem in (21).

IV) In equilibrium, international trade balances. Total export (EX) and total import (IM) can, respectively, be expressed as

$$EX = N_H \int_\phi \int_l p_{HF,1}(\phi, l) q_{HF,1}(\phi, l) I^x(\phi, l) J(\phi, l) dl d\phi \ , \tag{76}$$

$$IM = N_H \sum_{k=1}^{K} \int_\phi \int_l p_{FH,k}(\phi, l) q_{FH,k}(\phi, l) J(\phi, l) dl d\phi \ , \tag{77}$$

where N_H is the measure of intermediate producers.

V) In equilibrium, the market for the non-tradable final good clears. Total supply of the final

[8] Note that in equilibrium, workers are indifferent between searching for a job and producing at home. Hence, no individual who is home-producing decides to search for a job.

good in the economy is

$$M^s = \left[N_H \int_\phi \int_l Q(\phi,l)^{\frac{\sigma-1}{\sigma}} J(\phi,l) dl d\phi \right]^{\frac{\sigma}{\sigma-1}} , \tag{78}$$

where

$$Q(\phi,l) = \left[q_{HH,1}(\phi,l)^{\frac{\alpha-1}{\alpha}} + \sum_{k=1}^{K} q_{FH,k}(\phi,l)^{\frac{\alpha-1}{\alpha}} \right]^{\frac{\alpha}{\alpha-1}} . \tag{79}$$

As for the demand, recall that the final good is demanded by both consumers and intermediate producers. Hence, total demand of the final good can be expressed as

$$M^d = \kappa \frac{I}{P} + N_H \int_\phi \int_l M(\phi,l) J(\phi,l) dl d\phi , \tag{80}$$

where the first term is the consumers' demand and the second term is the demand by intermediate producers. The aggregate income I can be written as

$$I = N_H \int_\phi \int_l \Pi(\phi,l) J(\phi,l) dl d\phi - N_H \int_\phi \int_l C(l,l'(\phi,l)) G(\phi,l) dl d\phi - N_e f_e + IM(\tau-1) + b_u L_U + L_h , \tag{81}$$

where $\Pi(\phi,l)$ is defined in (17). The first term is intermediate producers' gross profit (i.e., including wage bill and labor adjustment costs). The second term is the labor adjustment costs paid by intermediate producers. The third and fourth terms are sunk entry cost and tariff revenue rebated to consumers, respectively. The last two terms are total revenue by unemployed individuals as well as home-producers.

VI) The home-production good (i.e., the numeraire) is supplied by those who decide to work at home as well as unemployed individuals. This good is demanded by consumers, and by intermediate producers to pay sunk entry cost, labor adjustment costs, fixed cost of production, and fixed exporting cost. In equilibrium, market for the home-production good clears:

$$\underbrace{L_h + b_u L_U}_{\text{supply}} = \underbrace{(1-\kappa)\frac{I}{P}}_{\text{consumers' demand}} + \underbrace{N_e f_e}_{\text{entry cost}} + \underbrace{N_H \int_\phi \int_l C(l,l'(\phi,l)) G(\phi,l) dl d\phi}_{\text{labor adjustment cost}} + \underbrace{N_H f_d}_{\text{fixed prod. cost}} + \underbrace{N_H f_x \int_\phi \int_l I^x(\phi,l) J(\phi,l) dl d\phi}_{\text{fixed exporting cost}} . \tag{82}$$

VII) In equilibrium, there is a positive mass of entrants and therefore, free entry condition holds with equality:

$$V^e := \int V^C(\phi, l_e) dJ^0(\phi) = f_e \ . \tag{83}$$

VIII) In equilibrium, individuals are indifferent between searching for a job or working at home:

$$W^a = W^h \ . \tag{84}$$

E Numerical Algorithm to Solve for Stationary Equilibrium

To solve the model, I discretize the state space on a log scale using 20 grid points for productivity and 200 points for labor. The numerical algorithm used to compute the stationary equilibrium consists of the following steps:

Step 1: Guess the equilibrium objects A_H, $w(\phi, l)$, θ, e, and N_H.

Step 2: Given all the aggregate equilibrium objects, compute the value function $V(\phi, l)$ in (27). Then, compute the value of entry V^e in (33). Reduce (raise) A_H if value of entry exceeds (falls behind) the sunk entry cost f_e. Iterate until $V^e = f_e$.

Step 3: Compute the value of unemployment W^u by using in equation (42) the fact that in equilibrium $W^h = W^a = \frac{1}{1-\beta}$. Then, use (45)-(46) to compute the value function $W^e(\phi, l)$ and $W^m(\phi, l)$. To do so, start with a guess on $W^e(\phi, l)$ and solve for $W^m(\phi, l)$ using equation (45). Then compute $W^e(\phi, l)$ using equation (46). Iterate until $W^e(\phi, l)$ converges. Then use equation (43) to solve for W^m.

Step 4: First, use equation (35) to calculate firms' surplus. To do so, since I have dicretized the state space, compute the marginal surplus generated by the marginal worker as

$$S^F(\phi, l) = [\Pi(\phi, l) - w(\phi, l)l + \beta V(\phi, l)] - [\Pi(\phi, l-\Delta) - w(\phi, l-\Delta)(l-\Delta) + \beta V(\phi, l-\Delta)] \ , \tag{85}$$

where Δ is size of the employment grid. To solve this recursive formulation, we start from the marginal surplus generated at a firm with the minimum employment l_e is

$$S^F(\phi, l_e) = [\Pi(\phi, l_e) - w(\phi, l_e)l_e + \beta V(\phi, l_e)] - [-f_d] \ . \tag{86}$$

Notice that, if the marginal worker quits the firm with l_e workers, the firm has to quit the market; however, the firm has already paid the fixed cost f_d to draw its productivity. Now that I have computed the firms' surplus, use the above two equations as well as equations (36)-(37) to compute the wage schedule $w(\phi, l)$. If the wage schedule does not match the initial guess, go back to step 1 with the new wage schedule. Repeat steps 1-4 until $w(\phi, l)$ converges.

Step 5: Given the value of unemployment computed in step 3 above, compute the value of searching for a job W^a using equation (41). If W^a exceeds (falls behind) $W^h = 1/1-\beta$, reduce (raise) labor market tightness and go back to step 1. Iterate steps 1-5 until W^a equals W^h.

Step 6: Compute total exports and total imports using (76)-(77). If total exports exceed (fall behind) total imports, reduce (raise) the relative price e and go back to step 1. Iterate steps 1-6 until total exports equal total imports.

Step 7: Use equation (82) to compute the supply of and the demand for the home-production good. If the supply exceeds (falls behind) the demand, raise (reduce) the measure of intermediate producers N_H and go back to step 1. Iterate steps 1-7 until the supply equals the demand.

F Markups

To estimate the parameters governing demand elasticities in the model, i.e., σ and α, I use the distribution of material share of sale. The idea is that, as this section shows, given the material elasticity of output η, markup is inversely related to material share of sale. The overview of this methodology is as follows (see Hall et al. (1986) and De Loecker and Warzynski (2012)).

Assume plants produce output Q using the following production function:

$$Q = Q(s^1, ..., s^n, d^1, ..., d^m, \phi) \ , \tag{87}$$

where s^i is a static (freely adjustable) input, d^i a dynamic (costly to adjust) input, and ϕ is productivity. A plant producing output Q decides about its inputs by minimizing the associated cost function. The Lagrangian for cost minimization problem is as follows:

$$L = \sum_{i=1}^{n} p^{s^i} s^i + \sum_{i=1}^{m} p^{d^i} d^i + \lambda(Q - Q(.)) \ , \tag{88}$$

where p^x is price of input x which the plant takes as given. First order condition implies the following demand for static input s^i:

$$p^{s^i} = \lambda \frac{\partial Q(.)}{\partial s^i} \ , \tag{89}$$

where λ is Lagrange multiplier. Rearranging terms yields:

$$\frac{P}{\lambda} = (\frac{\partial Q(.)}{\partial s^i} \frac{s^i}{Q}) \frac{PQ}{p^{s^i} s^i} \ , \tag{90}$$

where P is output price. Recalling that Lagrange multiplier is marginal cost of production, LHS is price over marginal cost, i.e. markup. Therefore, markup is equal to elasticity of output with respect to a static input over the share of that static input in revenue.[9]

G Relation between Export Intensity and Demand Elasticity

Consider a model with two countries, Home and Foreign. Firms are heterogeneous in their productivities. Suppose that a Home exporter i faces demand elasticities σ_{iH} and σ_{iF} in the Home and Foreign markets, respectively:

$$q_{iJ} = A_J p_{iJ}^{-\sigma_{iJ}} \ , \tag{91}$$

where $J = H, F$ denotes the market and A_J is the aggregate demand shifter in market J. The Home exporter i decides about the prices to charge in each market by solving the following maximization problem:

$$\max_{p_{iH}, p_{iF}} \left[p_{iH} q_{iH} + p_{iF} q_{iF} \right] \ , \tag{92}$$

s.t.

$$\lambda(q_{iH} + q_{iF} d \leq Q) \ , \tag{93}$$

where d is the iceberg trade cost, Q is the firm's total production, and λ is the Lagrange multiplier. Substituting the demand equations (91) into (92) yields the following F.O.C.s:

$$p_{iH} = \frac{\sigma_{iH}}{\sigma_{iH} - 1} \lambda \ , \tag{94}$$

$$p_{iF} = \frac{\sigma_{iF}}{\sigma_{iF} - 1} \lambda d \ . \tag{95}$$

Using the first F.O.C.s to remove λ yields

$$p_{iF} = \psi_i p_{iH} d \ , \tag{96}$$

where

$$\psi_i = \frac{\sigma_{iF}}{\sigma_{iF} - 1} \frac{\sigma_{iH} - 1}{\sigma_{iH}} \ . \tag{97}$$

[9] This approach doesn't allow for dynamic pricing, which is consistent with the model presented in the paper.

Now, I use demand equations (91) to derive Export Intensity (EI) for the Home exporter i:

$$\mathrm{EI}_i = \frac{p_{iF}q_{iF}}{p_{iH}q_{iH} + p_{iF}q_{iF}} = \frac{A_F p_{iF}^{1-\sigma_{iF}}}{A_H p_{iH}^{1-\sigma_{iH}} + A_F p_{iF}^{1-\sigma_{iF}}} \ . \tag{98}$$

Using equation (96) in (98) yields

$$\mathrm{EI}_i = \frac{A_F p_{iH}^{1-\sigma_{iF}}(\psi_i d)^{1-\sigma_{iF}}}{A_H p_{iH}^{1-\sigma_{iH}} + A_F p_{iH}^{1-\sigma_{iF}}(\psi_i d)^{1-\sigma_{iF}}} = \frac{A_F p_{iH}^{1-\sigma_{iF}}(\psi_i d)^{1-\sigma_{iF}}}{A_F p_{iH}^{1-\sigma_{iF}}(\psi_i d)^{1-\sigma_{iF}}(\frac{A_H}{A_F} p_{iH}^{\sigma_{iF}-\sigma_{iH}}(\psi_i d)^{\sigma_{iF}-1} + 1)} \ , \tag{99}$$

which simplifies to

$$\mathrm{EI}_i = \frac{1}{\frac{A_H}{A_F} p_{iH}^{\sigma_{iF}-\sigma_{iH}}(\psi_i d)^{\sigma_{iF}-1} + 1} \ . \tag{100}$$

Notice that, in general, export intensity varies by i. Moreover, it is easy to verify that if demand elasticities are the same both across markets and across firms, i.e., $\forall i : \sigma_{iF} = \sigma_{iH} = \sigma$, all exporters would have the same export intensity:

$$\forall i : \quad \mathrm{EI}_i = \frac{1}{\frac{A_H}{A_F} d^{\sigma-1} + 1} \ . \tag{101}$$

However, it can be shown that export share of sale would vary across firms if demand elasticities vary across markets but not across firms, i.e., $\forall i : \sigma_{iH} = \sigma_H$ and $\forall i : \sigma_{iF} = \sigma_F$. In this case, we have $\forall i : \psi_i = \psi$ and so rewriting equation (100) shows that the export intensity varies across firms:

$$\mathrm{EI}_i = \frac{1}{\frac{A_H}{A_F} p_{iH}^{\sigma_F-\sigma_H}(\psi d)^{\sigma_F-1} + 1} \ , \tag{102}$$

where the price p_{iH} varies across firms because firms are heterogeneous. Furthermore, even if demand elasticities are the same across markets but different across firms, i.e., $\sigma_{iH} = \sigma_{iF} = \sigma_i$, the export intensity would still vary across firms:

$$\mathrm{EI}_i = \frac{1}{\frac{A_H}{A_F} d^{\sigma_i-1} + 1} \ . \tag{103}$$

Hence, we have proved that exporters would have the same export intensity if and only if demand elasticities are the same, both across markets and across firms.