Trade-Induced Job Turnover and Unemployment: The Role of Variable Demand Elasticity*

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Abstract

This paper develops and estimates an open economy dynamic general equilibrium model to introduce and quantify a new mechanism through which openness influences welfare. The model features matching frictions in the labor market and endogenous variable demand elasticities in product markets. Because openness affects demand elasticities, it influences welfare through several channels. First, higher demand elasticities make firms’ employment decisions more responsive to their idiosyncratic productivity shocks. This causes aggregate job turnover to rise, and thereby tends to raise unemployment. Second, this same increase in job turnover means that workers are moved more frequently from less to more efficient firms. Finally, to the extent that openness reduces the cross-firm dispersion in markups, it likewise tends to reduce the distortionary wedges between firms’ marginal revenue products.

Counterfactual analysis quantifies these trade-induced impacts on job turnover, unemployment, and welfare. I show that a 10 percentage point reduction in import tariffs combined with a 12 percent reduction in the iceberg trade cost raises job turnover and unemployment (in steady state) by roughly 8 and 17 percent, respectively. These effects would be almost four times smaller if demand elasticities were not allowed to respond to openness. Moreover, gains from trade are almost 20 percent larger if one allows demand elasticities to respond to openness.

JEL Codes: E24, F12, F16, J64, L11

Keywords: Variable Demand Elasticity, Job Turnover, Unemployment, Firm Size Distribution, International Trade

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1 Introduction

In the past few decades, many Latin American countries have adopted outward-oriented trade policies. At the same time, these countries have experienced higher job turnover rates\(^1\) (Haltiwanger et al. (2004)) and the associated negative consequences for affected workers, including more frequent unemployment spells (de Desarrollo (2004)).\(^2\) While earlier studies have provided possible explanations for the openness-turnover linkage, they are not able to generate the observed drastic increase in job turnover following trade liberalization in several countries (see Section 2). This paper develops a dynamic general equilibrium model that quantifies a new mechanism which magnifies the openness-turnover linkage: when openness increases demand elasticities in product markets, it also causes labor demand elasticities to rise. This, in turn, makes firms’ employment decisions more responsive to their idiosyncratic shocks and can cause aggregate job turnover to rise.

The link between openness, demand elasticities, and job turnover comes from the fact that openness influences the firm size distribution, and demand elasticities fall with firms’ size. More precisely, openness causes small firms to get even smaller, face higher demand elasticities, and, as a result, become more responsive to their idiosyncratic shocks. But it also tends to reduce job turnover by shifting employment toward larger firms, which are more stable since they face lower demand elasticities. Counterfactual analysis in Section 5 shows that the former, in combination with heightened exit rates, dominates the latter.

Other features of my model are more standard. An endogenous measure of firms operate in a small open economy, each subject to idiosyncratic productivity shocks. Firms 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.

Fit to Colombian data, my baseline model explains the changes in turnover and unemployment that accompanied Colombia’s trade liberalization. But a restricted version of the model that imposes constant demand elasticities predicts roughly four times smaller effects on job turnover and unemployment. Therefore, accounting for variable demand elasticity

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\(^1\)Job turnover is defined as the sum of job creation (total number of jobs created this period) and job destruction (total number of jobs destroyed this period). For a precise definition of job turnover, see Section 3.

\(^2\)Haltiwanger et al. (2004) show that after trade liberalization, job reallocation within industries rises in the Latin American countries. Moreover, I show within sector job turnover rises after trade liberalization in Colombia. As for unemployment, de Desarrollo (2004) documents that unemployment rises in Latin American countries, following trade liberalization.
plays a crucial role in deriving the results. One implication is that constant demand elasticity
models may deliver misleading policy implications in contexts where elasticities are likely to
respond. Further, models that presume constant demand elasticities will tend to overtstate
the importance of labor market frictions: without mark-up adjustments, limited hiring and
firing responses are likely to be attributed entirely to these frictions.

In this paper, job turnover affects welfare through several channels. First, there is an
allocative efficiency gain associated with higher job turnover (Hopenhayn and Rogerson
(1993)): higher job turnover results in jobs more frequently reallocating from less to more
efficient firms. Second, however, due to the wage bargaining process, higher job turnover
may induce firms to overhire workers, which tends to reduce efficiency. Third, higher job
turnover shifts employment toward larger firms that pay higher wages, which in turn reduces
the labor market tightness and raises the unemployment rate. This higher unemployment
might also be a source of inefficiency.3

My focus on the response of demand elasticities to openness is supported by various stud-
ies in the empirical trade literature (see Section 2). To further motivate my specification,
I report a variety of reduced-form empirical exercises. Section 3 demonstrates a positive
cross-industry and cross-firm size correlation between estimated labor elasticities of revenue
and rates of job turnover. In line with the literature (Haltiwanger et al. (2013) for US; Coşar
et al. (2016) for Colombia; Dix-Carneiro et al. (2018) for Brazil), I also show that larger
firms provide more stable jobs, i.e., they have lower job turnover rates. Moreover, Section 3
shows that larger firms have lower labor elasticities of revenue. Hence, this paper provides
a new explanation for the size-stability relationship.

Although this paper studies the consequences of a trade liberalization policy, the mecha-
nism introduced here is not confined to international economics. Any policy enhancing
competition in an economy would potentially influence the demand elasticities faced by

3Job turnover is an important variable to study as there are many other channels through which job
turnover influences welfare, which are outside the scope of this paper. First, if workers are risk averse and
they do not have access to perfect insurance markets, higher job turnover can hurt workers’ welfare. Second,
as reported by Farber (1996), the risks of earnings losses are disproportionately borne by less-educated
workers in the U.S. economy. Farber (1996) shows that less-educated workers in the U.S. economy after
displacement, will be less likely to find a job than highly educated workers. Furthermore, the latter group
experience a lower wage cut after re-employment compared to the former group. Hence, higher turnover in
the labor market may have important distributional implications, which pertains to ongoing political issue
in the United States. This paper abstracts away from ex-ante worker heterogeneity. This is, however, an
avenue for my future research. Finally, each job requires some firm-specific training and skills which can not
be carried over by workers to a new job. As a result, when a job is destroyed, these firm-specific skills would
no longer be useful. Therefore, higher job turnover may result in welfare loss, depending on the importance
of firm-specific skills.
firms, and, in turn, can influence job turnover. Moreover, the insight provided in this paper is not limited to studies of the labor market. Changes in demand elasticities would influence not only the employment decisions of firms, but also their other decision variables. For instance, the model developed in this paper can be extended to study how investment volatility is affected by a policy, e.g., trade liberalization, that intensifies competition in the market.

The paper is organized as follows. Section 2 reviews the related literature to which this paper contributes. Section 3 presents a simple theory to show how changes in demand elasticities influence job turnover. Moreover, some reduced-form empirical evidence from the Colombian economy is provided to support the essential mechanism of the paper. Section 4 describes the environment, lays out the structural model, and defines the stationary equilibrium of the model. Section 5 discusses the estimation procedure, provides the intuition behind the moments targeted to learn about each parameter of the model, and performs counterfactual analysis. Section 6 concludes.

2 Related Literature

There are several strands of literature to which this paper is related. First, this work contributes to the literature on the effects of trade openness in the presence of frictional labor markets (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 Itskholi (2010), Helpman et al. (2010), Felbermayr et al. (2011), Cosar et al. (2016), Helpman et al. (2017), Dix-Carneiro et al. (2018), and Ruggieri (2018). Cosar et al. (2016), Dix-Carneiro et al. (2018), and Ruggieri (2018) provide possible explanations for the observed rise in job turnover following trade liberalization in Colombia, Brazil, and Mexico, respectively. However, their models do not generate the observed increase in job turnover. This paper contributes to this literature by allowing for endogenous demand elasticities in the product market, and thereby, establishes a link between demand elasticities and job stability. As will be shown in Section 5, this proposed link magnifies the job turnover and unemployment consequences of trade liberalization.

Decker et al. (2018) studies what causes the downward trend in job reallocation in the United States. They ask whether it is due to lower dispersion of shocks or lower responsiveness of firms to the shocks. They find the reason is the latter. Although identifying the exact source of lower responsiveness is outside the scope of Decker et al. (2018), they say lower responsiveness can be rationalized by higher adjustment costs. Their responsiveness channel, however, doesn’t consider the mechanism introduced in this paper: lower responsiveness may be due to a fall in the labor elasticity of revenue. Moreover, Decker et al. (2018) suggest that lower firms’ responsiveness might be due to globalization: firms may respond to shocks partly via adjusting labor working in their production lines outside the United States. As they don’t observe firms’ workforce who work abroad, they say one might conclude firms are less responsive to shocks. They examine the link between import penetration and responsiveness. They find a mixed result suggesting that, as they note, this is an important line of future research. Two points are worth mentioning. First, their story regarding the link between trade liberalization and responsiveness is different from the one this paper focuses on: in the current paper, globalization via affecting demand elasticities may affect firms’ responsiveness. Second, as discussed in detail in this paper, firms’ responsiveness (in terms of employment) to the shocks crucially depend on the labor elasticity of revenue, not import penetration per se.

Third, De Loecker and Eeckhout (2017) claim that the fall in workers flow in the U.S. economy over the past few decades is consistent with the rise in average markups. Rodrik (1997) argues that globalization, through offshoring, makes labor demand more elastic and this, in turn, can make wages more volatile. Slaughter (2001) documents that demand elasticity for production labor in most of the U.S. manufacturing industries has risen over the period 1961 through 1991, and this is partly due to international trade. None of these works explicitly document an association between demand elasticity and labor market outcomes, nor did they examine the quantitative importance of such mechanism. Contribution of the current paper to this literature is twofold. First, this paper documents a new fact which directly speaks to the link between demand elasticity and job turnover: this paper shows there is a positive association between labor elasticity of revenue, one component of which is demand elasticity, and firms’ responsiveness (in terms of employment) to revenue shocks. Then, as the second contribution to this literature, the quantitative importance of changes in demand elasticity for labor market outcomes is examined, through the lens of a structural model in a general equilibrium setting.
Fourth, the literature documents that larger firms charge higher markups (Atkin et al. (2015) for Pakistan; De Loecker and Warzynski (2012) for Slovenia; De Loecker et al. (2016) for India; Edmond et al. (2015) for Taiwan). Moreover, larger firms provide more stable jobs (Haltiwanger et al. (2013) for US; Coşar et al. (2016) for Colombia; Dix-Carneiro et al. (2018) for Brazil). As Section 3 shows, this paper provides a novel link between size, demand elasticity, and job stability: larger firms provide more stable jobs, possibly because they have lower labor elasticity of revenue. This is because firms with higher labor elasticity of revenue (mostly, smaller firms) are more responsive to the shocks (see Section 3.1 for a simple model). This paper is one of the first attempts to link demand elasticity to labor market outcomes in a general equilibrium framework, seemingly absent in the literature.

Fifth, studies on various countries suggest that import competition tends to lower the markups charged by firms (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. (2015), and Atrianfar (2019)). Tybout (2003) reviews this literature and concludes that price-cost margin falls by trade exposure. Lower markups charged by firms means perceived demand elasticity they face is higher. Eslava et al. (2004) estimate output demand elasticities for the Colombian manufacturing plants and show that demand elasticities fall by trade openness. Welfare implications of the change in markup distribution induced by international trade is also studied in literature (Feenstra and Weinstein (2017), Edmond et al. (2015), Arkolakis et al. (2015)). This paper estimates labor elasticity of revenue and shows that within industries, labor elasticity of revenue rises by trade liberalization in Colombia. Moreover, as documented in Section 3, this rise in labor elasticity of revenue is positively associated with the rise in within-industry job turnover. As discussed above, higher job turnover may affect welfare via various channels.

Sixth, this paper contributes to the literature studying patterns and underlying forces of job turnover (e.g., Davis and Haltiwanger (1992), Haltiwanger and Vodopivec (2002), Coşar et al. (2016)) by introducing a novel channel: one of the main forces which influences job turnover is the change in labor elasticity of revenue. There is a distinction between worker

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4 Markup in some studies is defined as price over marginal cost; In others, it is defined as total revenue over total variable cost. The former definition is used in this paper.

5 De Loecker et al. (2016) study the trade liberalization in India. Trade liberalization affects Indian firms’ markup through two competing forces: higher competition as well as lower input cost. They show that while firms charge higher markups after trade liberalization, markups fall conditional on input cost.
reallocate as opposed to job reallocation. Both in my model and my data, I measure job reallocation, instead of 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. Even a larger fraction is documented by Haltiwanger and Vodopivec (2002) for Estonia (about two-thirds). In this study, 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.

Finally, another block of related literature to which this paper contributes is measuring labor or capital misallocation and adjustment costs (Cooper and Haltiwanger (2006), Cooper et al. (2007), Coşar et al. (2016), and David and Venkateswaran (2017)). As pointed out, for example, by David and Venkateswaran (2017), one overestimates the adjustment cost if “other” sources of frictions or distortions are ignored. David and Venkateswaran (2017) 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 severely react to productivity shocks as they face large capital tax. In my model, however, this wedge is endogenous coming from endogenous demand elasticities. Moreover, this wedge reacts to any shock (in this paper a trade shock) that changes the product market competition. Using a structural model, this paper shows that one overestimates the importance of labor adjustment costs by (wrongly) assuming constant demand elasticities.

3 The Essential Mechanism

In this section, the main mechanism of the model is supported. First, Section 3.1 develops a simple model to show that firms’ responsiveness (in terms of employment) to shocks is a function of labor elasticity of revenue. Then, using the Colombian manufacturing plant-level data in Section 3.2, I show there is a negative association between labor elasticity of revenue and job stability, both across industries and across the firm size distribution.

3.1 A Simple Model

Although the full model developed in this paper is a dynamic general equilibrium model with labor market frictions, to fix the idea and show the main mechanism of this paper, here I...
employ a static model with frictionless labor market. Consider an economy with price-setter firms which face the demand elasticity $\sigma$:

$$q = Bp^{-\sigma} \quad (1)$$

where $q$ is the quantity demanded, $p$ is the price charged by the firm, and $B$ is the aggregate demand shifter. Assume labor is the only factor of production in the following production function:

$$q = \phi l^\eta \quad (2)$$

where $\phi$ is the firm’s productivity, $l$ is the number of workers, and $\eta$ governs the returns to scale. Based on (1)-(2), one can write the firm’s revenue function as

$$R = Al^\zeta \quad (3)$$

where $A \equiv B^{\frac{1}{\sigma}} \phi^{\frac{\eta-1}{\sigma}}$ is the revenue productivity residual, or the firm’s revenue shock, and $\zeta \equiv \eta(\frac{\sigma-1}{\sigma})$ is the labor elasticity of revenue. The labor elasticity of revenue consists of the labor elasticity of output as well as demand elasticity. As demand elasticity rises, so does the labor elasticity of revenue. The intuition is that higher demand elasticity in the product market means that prices respond less to the productivity shocks. As a result, changes in labor, and therefore quantity, result in more changes in revenue. Writing the first order condition of this firm which employs workers in a competitive labor market, one easily shows:

$$\frac{dl}{l} \frac{dA}{A} = \frac{1}{1 - \zeta} \quad (4)$$

where the left-hand-side is defined as the firm’s responsiveness (in terms of employment) to the revenue shock $A$. As seen from equation (4), the firms’ responsiveness (in terms of employment)\(^7\) to their shocks is positively correlated with the firms’ labor elasticity of revenue\(^8\). In other words, fixing the productivity shock, a firm responds more (in terms of employment) to its shock when the firm has higher labor elasticity of revenue. This is because as labor elasticity of revenue rises, the marginal revenue product of labor changes more slowly on the labor margin, and, therefore, firms respond more (in terms of employment) to the shocks. Section 3.2 empirically shows there is a positive association between labor elasticity of revenue and firms’ responsiveness to shocks: firms with higher labor elasticity of revenue responds more to their revenue shocks. Any policy affecting the degree of competition in a market (e.g., trade exposure, removing financial/informational friction, etc.), affects the

\(^7\)In this paper, the word “responsiveness” refers to “responsiveness in terms of employment.”

\(^8\)I assume $\zeta < 1$. Section 3.2 estimates labor elasticity of revenue for 3-digit SIC codes and shows this is indeed the case for all sectors.
labor elasticity of revenue and, in turn, may change job turnover in the labor market.

In short, labor elasticity of revenue is governed by two components: labor elasticity of output and demand elasticity. Although assuming these two factors are constant simplifies economic modeling by much, one should be cautious about assuming so as it might have important implications for the research question at hand. Any policy affecting either of these two underlying components will affect the labor elasticity of revenue, and in turn, job turnover in the economy. By focusing on the second component, this paper quantitatively investigates how international competition, through changes in demand elasticities, influences job turnover, unemployment, and misallocation. Then, the results are compared to a restricted version of the model in which demand elasticity is imposed to be constant.

Appendix A uses the labor demand function to relate output demand elasticity to firms’ responsiveness to the shocks. In other words, 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 as labor elasticity of revenue and labor demand elasticity are two sides of the same coin.

### 3.2 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 job turnover. This data cover all the manufacturing plants with at least 10 employees. This section presents three suggestive evidence. First, in line with the firm dynamics literature (Coșar et al. (2016) and Dix-Carneiro et al. (2018)), I show that larger firms are more stable (i.e. they have lower job turnover rates). Moreover, I show that larger firms have lower labor elasticity of revenue. Hence, there is a positive association between job turnover and labor elasticity of revenue across the firm size distribution. This paper is the first attempt to link firms’ size and job stability through labor elasticity of revenue. In this paper, larger firms face lower demand elasticity, and therefore, they have lower labor elasticity of revenue. This makes larger firms more stable. The second suggestive evidence shows that the industry-level revenue elasticities of labor rise by trade liberalization in Colombia and this increase is positively associated with the rise in within-industry job turnover. Moreover, I show the industries that experience a larger rise in labor elasticity of revenue, also experience a larger increase in their within-industry job turnover. The third evidence suggests that firms in the industries which have higher labor elasticity of revenue are more responsive to their revenue shocks.

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9This is a plant-level data set. In what follows, I use the words “firm” and “plant” interchangeably.
To present these three suggestive evidence, first I estimate the labor elasticity of revenue. To do so, following Levinsohn and Petrin (2003) and Olley and Pakes (1996), I use the control function approach to solve the simultaneity problem. Let $i$ and $t$ denote firm and time, respectively. Also let $R$ and $l$ denote the firms’ sale and employment, respectively. Note that as in the full structural model of Section 4, labor is a dynamic input, meaning that adjusting labor is subject to adjustment costs. I use energy consumption as my proxy variable to estimate the following revenue function:

$$\log(R_{it}) = \zeta \log(l_{it}) + \log(A_{it})$$ (5)

where $A_{ijt}$ is the revenue shock to firm $i$ at time $t$. In the revenue function estimation (5), I assumed all factors of production except labor are “static” (i.e. freely adjustable) and are optimized out. As an alternative, labor elasticity of revenue is also estimated under the assumption that capital is fixed and all other factors of production except labor are “static” and optimized out. Notice that estimating labor elasticity of revenue needs at least one of the aforementioned assumptions about capital (and other inputs of the firms). 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, labor elasticity of revenue $\zeta$ is estimated.

Before turning to the first suggestive evidence, note that there are six categories of workers employed at the plants: unskilled workers, apprentices, foreign technicians, local

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10 Cooper and Haltiwanger (2006) use GMM to estimate capital elasticity of revenue. Their estimation method is similar to the second stage of Levinsohn and Petrin (2003).

11 The advantage of energy consumption is that plants report the quantity of their consumed energy.

12 The key variables of the revenue function estimation (i.e. revenue, employment, and the proxy variable) are winsorized at the 1 percent level.

13 The revenue shock $A$ is also called revenue productivity residual and estimated also in the literature, e.g., Gopinath et al. (2017), Decker et al. (2018), and Foster et al. (2017).

14 I call this “revenue shock” since it may contain productivity as well as demand-side shocks.

15 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. However, one may not like the assumption of this paper that capital is static but labor is not. To such readers, the alternative way of estimating labor elasticity of revenue, which assumes capital is fixed, may seem more compelling.

16 Note that given my relatively short sample period, assuming that capital is fixed seems a reasonable assumption.

17 The text of the paper presents the results under the first assumption. The appendix shows that the results also hold under the alternative assumption that capital is assumed to be fixed over the sample period. To do so, I estimate labor elasticity of revenue including capital in (5). In interpreting the results, I treat capital as a fixed input during the period of analysis, which is eight years. This means that the coefficient of labor in the estimated equation still measures labor elasticity of revenue. As shown in the appendix, these three suggestive evidence still hold under this alternative assumption.
technicians, skilled workers, and management staff. Hence, in what follows, I use
“effective labor” to measure the employment at the plant-level. To measure effective labor, the average
wage of each type of worker across all plants and all time periods is calculated. Then, each
type of worker is weighted by its average wage relative to the average wage of the unskilled
workers. The sum of these weighted workers is called effective labor.

**Suggestive Evidence 1:** Larger firms have lower labor elasticity of revenue, and, larger
firms are more stable (i.e. they have lower job turnover rates). Hence, there is a positive as-
sociation between labor elasticity of revenue and job turnover across the firm size distribution.

To provide the first suggestive evidence, I divide the plants into 40 employment bins based
on the plant size distribution in year 1983. I estimate the revenue function (5) for each
employment bin separately, using the data from 1983-1990. Moreover, I calculate the
job turnover (net of employment growth) for each employment bin. Job turnover for each
employment bin in year $t$ is defined as the following:

$$
\text{turnover}_t = \frac{\sum_{i\in c} |l_{it} - l_{it-1}| + \sum_{i\in \text{exit}} l_{it-1} + \sum_{i\in \text{entry}} l_{it} - |L_t - L_{t-1}|}{L_{t-1}}
$$

(6)

where I include only the firms $i$ which belong to the associated employment bin, and $c$ is the
set of continuing plants. The first, second, third, and fourth term in the numerator measures
the job turnover by continuing plants, job turnover by exiting plants, job turnover by en-
trants, and net employment growth of the associated employment bin in year $t$, respectively.
Then, I take the average over the years 1983-1990 to calculate the average job turnover for
each employment bin.

The left panel of Figure 1 shows that larger firms have lower job turnover, i.e., they
are more stable. Moreover, the right panel of this figure shows that larger firms have lower
labor elasticity of revenue. To Combine these two patterns, I regress job turnover on labor
elasticity of revenue. Table 1 shows that firms with lower labor elasticity of revenue are
more stable, i.e. they have lower job turnover. This paper is the first attempt to link firms’
size and job stability through labor elasticity of revenue. As the simple model of Section 3.1
suggests, firms with lower labor elasticity of revenue are less responsive to their idiosyncratic
shocks, and therefore, are more stable.

**Suggestive Evidence 2:** The rise in industries’ job turnover is positively associated with
the rise in industries’ labor elasticity of revenue. Moreover, the industries that experience

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18Trade liberalization episode started in 1991 in Colombia. Therefore, the years 1983-1990 is the pre-
liberalization episode.
a larger rise in labor elasticity of revenue, also experience a larger increase in their within-industry job turnover.

This suggestive evidence exploits variation in industry-level labor elasticity of revenue and job turnover over time. I estimate labor elasticity of revenue separately for each 3-digit SIC industry, using the revenue function (5). I do this estimation once using the pre-liberalization data, i.e. from 1983-1990, and once for the post-liberalization episode, i.e. from 1995-1999. Let the subscript $t$ denote time, which is 1 for the pre-liberalization and 2 for the post-liberalization episode. Moreover, let $j$ denote each 3-digit SIC industry. Hence, I estimate labor elasticity of revenue $\zeta_{jt}$ for each industry $j$ for the pre- and post-liberalization. Moreover, I calculate the intra-industry job turnover in each year using the job turnover definition in (6). Then, I take the average of job turnover over the pre- and post-liberalization episode for each industry. In short, I estimate labor elasticity of revenue $\zeta_{jt}$ and calculate “job turnover$_{jt}$” for each 3-digit SIC industry $j$ and episode $t$, where $t = 1, 2$ denote the pre- and post-liberalization episodes, respectively.
I regress the logarithm of job turnover on the logarithm of labor elasticity of revenue. Table 2 shows that within-industry rise in job turnover is positively associated with the rise in labor elasticity of revenue. The appendix provides the estimates of labor elasticity of revenue for each industry. It shows that, for most industries, labor elasticity of revenue rises by trade liberalization in Colombia. Moreover, we expect to see the industries that experience a larger rise in labor elasticity of revenue after trade liberalization, also experience a larger increase in their within-industry job turnover. To see this, I calculate percentage changes in industry-level labor elasticity of revenue as well as percentage changes in within-industry job turnover rate after trade liberalization in Colombia. Figure 2 shows this is indeed the case: industries with a larger rise in labor elasticity of revenue, are those that, on average, experience a larger increase in job turnover rates.

**Suggestive Evidence 3:** Plants in the industries with higher labor elasticity of revenue are more responsive to the shocks.

The last suggestive evidence exploits the pre-liberalization cross-industry variation in labor elasticity of revenue. First, using the data from 1983-1990, I estimate the revenue function (5) separately for each 3-digit SIC industry to back out the labor elasticity of revenue \( \zeta_j \) for each industry \( j \), and the revenue shock \( A_{ijt} \) for firm \( i \) in industry \( j \) at time \( t \). Then, to measure the firms’ (employment) responsiveness to revenue shocks, I do the following.\(^{19}\)

In the structural model developed in this paper, the employment decision of a firm is a policy function depending on the revenue shock to the firm, persistence of the shock, and last period employment of the firm (because of labor adjustment costs). So the employment policy function of the firm \( i \) in industry \( j \) at time \( t \) can be written as

\[^{19}\text{Recall that the (employment) responsiveness to the revenue shock } A \text{ for a firm with } l \text{ workers is defined as } \frac{dl/l}{dA/A}.\]
Figure 2: Change in Job Turnover vs Change in Labor Elasticity of Revenue for Each Industry

\[ l_{ijt} = f(A_{ijt}, \rho_j, l_{ijt-1}) \]  

(7)

where \( \rho_j \) is the persistence of the shock in industry \( j \). Therefore, to find the employment responsiveness of a firm with respect to its revenue shock, one needs to control for persistence of the shock as well as last period employment of the firm. To measure the employment responsiveness of firms to the revenue shocks, I run the following regression separately for each industry \( j \):

\[ \log(l_{ijt}) = \alpha_j + \beta_j \log(A_{ijt}) + \theta_j \ l_{ijt-1} + D_t + \varepsilon_{it} \]  

(8)

where \( D_t \) are time dummies and standard errors are clustered at the plant-level. The parameter \( \beta_j \) measures firms’ employment responsiveness to the revenue shocks in industry \( j \).\(^{20}\) The source of the error term \( \varepsilon_{it} \) is worth discussing. Here I assume it comes from the functional form assumption in equation (8). The employment policy function in (7) is highly non-linear on the revenue shock \( A \) and last period employment. Hence, imposing the function form

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\(^{20}\) In principle, what determines the firms’ employment decisions is the shocks to the revenue function rather than the shocks to the production function. Measuring responsiveness using the shocks to the revenue function is also done in the literature, e.g., Decker et al. (2018). To see the difference between these two, consider the following simple model. Suppose a firm faces product demand \( p = q^{\sigma-1} \), where demand elasticity rises by \( \sigma \). Moreover, suppose production function is given by \( q = A l^n \), where \( A \) is total factor productivity (TFP) and \( l \) is labor, the only factor of production. Then, revenue function would be \( R = A^\sigma l^n \sigma \). So one can see shocks to production function are not equal to shocks to revenue function. In particular, if shocks to TFP changes demand elasticity, which is the case in the general equilibrium model presented in Section 4, the magnitude of shocks to TFP would be different from shocks to revenue function.
in (8) introduces some error to the estimated employment policy function. As the source of the error term is functional form assumptions, I allow the error term to be heteroscedastic.

After estimating the employment responsiveness to the shocks for each industry, I examine whether this responsiveness is positively correlated with labor elasticity of revenue. To this end, I run the following regression:

$$\text{responsiveness}_j = \gamma_0 + \gamma_1 \zeta_j + \gamma_2 \rho_j + \varepsilon_j$$ (9)

where $\zeta_j$ and $\rho_j$ are labor elasticity of revenue and persistence of revenue shocks at the industry $j$, respectively. The parameter of interest is $\gamma_1$ and is expected to be positive: as explained before, we expect to see that the firms are more responsive to the shocks if they have higher labor elasticity of revenue. Note that as suggested by the firm dynamics literature (e.g., Cooper and Haltiwanger (2006) and Cooper et al. (2007)), in the presence of labor adjustment costs, firms’ responsiveness to the shocks is also a function of the persistence of the shocks. The literature suggests that firms responsiveness to the shocks rises as does the persistent of the shocks. As a result, one needs to control for the persistence of the shocks as well. To do so, I assume revenue shocks $A$ follow an AR(1) process. This process is estimated separately for each industry to back out the persistence $\rho_j$.

Table 3 summarizes the results. As expected, firms’ employment responsiveness to the shocks is positively associated with labor elasticity of revenue. Moreover, firms’ responsiveness is also positively correlated with the persistence of the shocks.

![Table 3: Firms Responsiveness to the Shocks vs Labor Elasticity of Revenue](image)

<table>
<thead>
<tr>
<th></th>
<th>responsiveness</th>
</tr>
</thead>
<tbody>
<tr>
<td>labor elasticity of revenue</td>
<td>0.280***</td>
</tr>
<tr>
<td></td>
<td>(135.16)</td>
</tr>
<tr>
<td>persistence</td>
<td>0.162***</td>
</tr>
<tr>
<td></td>
<td>(21.29)</td>
</tr>
<tr>
<td>$N$</td>
<td>53449</td>
</tr>
</tbody>
</table>

$t$ statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$
4 The Model

4.1 Environment

There are two countries in the world, Home (or H) and rest of the world \(^{(21)}\) (or F). Home is a small open economy. \(^{(22)}\) There are two types of goods: intermediate goods, which are tradable, and the final good, which is non-tradable. The final good producers bundle the intermediate goods (both domestic and imported) and make the final good to be sold to consumers as well as intermediate good producers (both domestic and Foreign) in a perfectly competitive market. Labor is not used in producing the final good. Each intermediate good producer employs workers as well as the final good to produce a particular variety with proprietary technology. These firms are subject to idiosyncratic productivity shocks. Intermediate producers sell their goods to the final good producers in a monopolistically competitive market. Firms hire workers in a frictional labor market. There is a unit measure of infinitely lived risk-neutral homogeneous individuals who own the firms.

4.2 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\(^{(23)}\)) consumers as well as intermediate good producers. The final good is produced according to the following commonly available technology:

\[
M = \left[ \int_0^{1+1} (q(\nu) + \alpha)^{2-1} \, d\nu \right]^{\sigma-1/\sigma}
\]

where the intermediate goods are denoted by \(\nu\). 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. \(^{(24)}\) Parameters \(\sigma\) and \(\alpha\) govern the price elasticity of demand (i.e. demand elasticity) faced by intermediate goods \(\nu\). This will be elaborated on below. I assume that the final good is produced by a unit measure of producers and sold in a perfectly competitive market at the market-clearing price \(P\). \(^{(25)}\) As for consumers, I assume per-period

---

\(^{(21)}\)I also call it “Foreign” in what follows.

\(^{(22)}\)In this paper, following Demidova and Rodriguez-Clare (2009), Demidova and Rodriguez-Clare (2013), and Melitz (2017), being a “small open economy” means that the Home economy takes as given the cost of production in the Foreign economy as well as the demand schedule for its exporters.

\(^{(23)}\)Recall that the final good is non-tradable.

\(^{(24)}\)Notice that the final good production is not zero even if no intermediate inputs are used; I interpret the parameter \(\alpha\) as managerial ability that could (to some extent) replace the intermediate inputs.

\(^{(25)}\)I study the unique symmetric equilibrium in which all producers produce the same amount.
utility of consumer $j$ at time $t$ is equal to her consumption of this final good:

$$U_{jt} = M(I_{jt}) \quad (11)$$

where consumer $j$’s demand for final good depends on her income $I_{jt}$. Consumers maximize the expected present value of their utility stream:

$$U_j = \sum_{t=1}^{\infty} \beta^{t-1} U_{jt} \quad (12)$$

where $\beta$ is the discount factor.\(^{26}\) For ease of notation, I suppress the time subscript $t$ in what follows.

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 (10). 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 $\nu$ (which is produced by a Home firm with productivity $\phi$ and $l$ workers):

$$q_i(\phi, l) = A_i p_i(\phi, l)^{-\sigma} - \alpha \quad (13)$$

where I label the intermediate producer by its productivity $\phi$ 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 $(\phi, l)$ in market $i$, respectively, and $A_i$ is aggregate demand shifter.\(^{27}\) Note that while the aggregate demand shifter in the Home market ($A_H$) is an endogenous equilibrium object, the aggregate demand shifter in the Foreign market is a model parameter to be estimated.\(^{28}\) Moreover, under the assumption that $\alpha > 0$, there is a choke price in the demand curve (13) above which the demand for an intermediate good in market $i$ is zero:

$$p_i^{\text{choke}} = \left( \frac{A_i}{\alpha} \right)^{\frac{1}{\sigma}} \quad (14)$$

Moreover, it can be shown that the (absolute value of) demand elasticity which the intermediate producer $(\phi, l)$ faces in market $i$ is\(^{29}\)

$$\varepsilon_i(\phi, l) = \sigma \left( 1 + \frac{\alpha}{q_i(\phi, l)} \right) \quad (15)$$

Few points are in order. First, as $\sigma$ or $\alpha$ rises, intermediate good producers face more elastic

\(^{26}\)Note that since workers are risk-neutral, they do not save.

\(^{27}\)See Appendix B for derivation of this demand equation.

\(^{28}\)This is because I assume that Home is a small economy.

\(^{29}\)See Appendix B.
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. As will be shown in Section 5, trade liberalization shifts employment toward larger firms, and also makes the small firms even smaller. Finally, in the special case where $\alpha$ is equal to zero, we are back in the constant demand elasticity world in which all intermediate producers charge the same Dixit-Stiglitz markup $\frac{\sigma}{\sigma - 1}$.

4.2.1 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), and Arkolakis et al. (2015)). With no income heterogeneity, instead of using a displaced CES production function in (10), one could define consumers’ utility as

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

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 income, each individual would have her own choke price for each variety $\nu$.\(^{30}\) As a result, summing each good’s demand across all individuals is not feasible if there is a continuum of individuals. The current model features wage heterogeneity across a continuum of homogeneous workers because labor market is frictional (look at Section 4.7). To solve this aggregation problem, I assume consumers demand a final good which is produced using the displaced CES production function (10). This way, these final good producers collect income from all workers and the intermediate firms, and demand the intermediate goods $\nu$. To show that the implications of the model is robust to how one generates variable demand elasticity, Appendix C employs an oligopoly market structure (à la Atkeson and Burstein (2008)). Then, as explained in Appendix C, I re-estimate the new model and show that the results in the text of the paper also hold in the new model.

\(^{30}\)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 in Appendix B 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 $\Psi$. Hence, one can see that the demand shifter in that case would be a function of consumer’s income.
4.3 Intermediate Good Producers

Each intermediate producer receives an idiosyncratic productivity shock, and employs labor and the final good to produce its particular variety using the following proprietary technology:

\[ q(\phi, l) = \phi M(\phi, l)^{\eta} l^{1-\eta} \]  

where \( \phi \) is productivity, \( l \) is the number of workers employed at the firm, \( M(\phi, l) \) is the composite final good (call it material) defined in equation (10) demanded by the firm \((\phi, l)\), and \( \eta \) is the elasticity of output with respect to material. Intermediate producers are subject to idiosyncratic productivity shocks which follow a stationary Markov process

\[ \ln \phi' = \gamma \ln \phi + \varepsilon , \quad \varepsilon \sim N(0, \sigma^{2}_\phi) \]  

where \( \gamma \) is the persistence of the productivity process and \( \sigma^{2}_\phi \) is the variance of the shock.

4.4 Firms’ Static Problem

Final good producers decide only about how much to demand for each variety \( \nu \) based on the demand equation (13). The rest of this section focuses on the decisions made by the domestic intermediate good producers. The Foreign firms’ problem is discussed in the last part of this section. Hence, the word “firms” in what follows refers to the domestic intermediate producers.

Firms carry two state variables over time: productivity and the number of workers. Productivity is a state variable as it follows a Markov process. Labor is the other state variable since the hiring cost is non-linear (see Section 4.5). Moreover, labor market features search and matching friction, à la Mortensen and Pissarides (1994). For an incumbent firm starting this period with the last period productivity and employment \((\phi, l)\) as its state variables, the timing of the events is as follows:

- exit decision
- death shock
- post vacancies/fire
- bargain on \( w(\phi', l') \)
- pay \( f_d \) to draw \( \phi' \)
- \( l' \)
- \( p, I^z, M(\phi', l') \)

First, this period productivity shock \( \phi' \) realizes. Then, some firms either decide to exit or exogenously hit by a death shock and exit the market. After entrants replaced the exiters, all existing firms decide whether to expand or contract. To expand, they post some vacancies and match with an endogenous number of workers, determined in equilibrium. After hiring/firing, state of the firm updates to \((\phi', l')\). Then the labor market closes. Since labor
market is frictional, there exists rent produced at the firms. As a result, firms and workers
bargain on the wage. As the last action within each period, firms decide about whether
to export, how much material to buy, and prices to charge in the Home and, if exporting,
in the Foreign market. In sum, firms decide whether to exit, whether to hire or fire and
by how much, composite material to buy, exporting, and prices to charge in each market.
Firms solve for these decision variables backward: at the first stage, given the wage and
number of workers, firms decide about prices, composite material and export decision. The
second stage solves for the wage bargaining given the number of workers. At the third stage,
firm solves a dynamic vacancy posting problem to determine the number of workers. For
exposition purposes, I first explain the static pricing problem, then the dynamic vacancy
posting problem and at the end, the wage bargaining process.

Before turning to the first stage, let’s rewrite the demand curve that each domestic
intermediate producer faces in the Home as well as the Foreign market. Express the domestic
demand for the variety produced by the firm $(\phi, l)$ by rewriting the demand equation (13)
as

$$q_{HH}(\phi, l) = A_H p_{HH}(\phi, l)^{-\sigma} - \alpha \quad (19)$$

and similarly, the Foreign demand for this variety can be expressed as

$$q_{HF}(\phi, l) = A_F^* p_{HF}^*(\phi, l)^{-\sigma} - \alpha \quad (20)$$

where an asterisk indicates that a variable is expressed in terms of the Foreign numeraire
(to be explained below), $A_i$ is the aggregate demand shifter in the country $i$, and $q_{Hi}(\phi, l)$
and $p_{Hi}(\phi, l)$ are the demand for and the price of the domestic variety produced by the firm
$(\phi, l)$ sold in country $i$, respectively.

The first stage is a static problem. At this stage, given the number of workers and
the negotiated wage (to be discussed in Sections 4.5 and 4.7, respectively), the firm with
productivity $\phi$ and $l$ workers decides about exporting, prices and the material usage by
solving the following static optimization problem:\(^31\)

$$\Pi(\phi, l) = \max_{p_{HH}, p_{HF}, M, I^x} \left[ p_{HH} q_{HH} + p_{HF} q_{HF} I^x - PM - f_d - f_x I^x \right] \quad (21)$$

subject to:

$$q_{HH} + I^x q_{HF} d \leq \phi M^{\eta} l^{1-\eta} \quad (22)$$

\(^31\)For ease of nation, I suppress the dependence of all decision variables on $(\phi, l)$. 

20
where $p_{Hi}$ is the price that this Home producer receives from serving market $i$, $I^x$ is an indicator function which takes 1 if the firm exports and zero otherwise, $P$ is the price of the homogeneous final good, $f_d$ is fixed cost of production, $f_x$ is fixed cost of serving the Foreign market, $d$ is iceberg trade cost for shipping goods from one country to the other, $(\tau - 1)$ is import tariff imposed by both Home and Foreign, and an asterisk indicates that a variable is expressed in terms of the Foreign numeraire. I assume there are two numeraires in this model, one in the Home and one in the Foreign market, and $e$ is the relative price of the former to the latter (I call it “exchange rate” in what follows). For future reference, define firm’s revenue ($R$) as sum of the first two terms in (21). Fixed costs are paid in terms of a homogeneous home-produced good. Note that international trade is subject to fixed cost, iceberg cost, and tariff. The first constraint is the feasibility constraint. The second and third constraints are the demand for this good in the Home and Foreign countries, respectively. The last constraint relates the price that the firm receives from exporting ($p_{HF}$) to the price that the Foreign consumers face in the market ($p_{HF}^*$). Notice that since the firm and its matched workers $l$ have already negotiated and agreed to a particular wage (to be discussed in Section 4.7), the wage bill does not enter the problem above.

The pricing decision of firms does not have a closed form solution unless the parameter $\alpha$ is equal to zero, i.e., demand elasticities are the same both across firms and across markets. In the variable demand elasticity case, however, prices, material usage, and exporting decision are solved for numerically. For a firm serving the domestic market only, the price ($p_{HH}$) satisfies the following first order condition:

$$A_H(1 - \sigma)p^{-\sigma} - \alpha + \sigma_{\eta} \left( \phi \frac{l^{1-\eta}}{(\phi l^{1-\eta})^{1-\eta}} \right)^{1-\eta} \left[ A_H p^{-\sigma} - \alpha \right] \frac{1-\eta}{\eta} A_H p^{-\sigma - 1} = 0$$

If the firm serves both the domestic and Foreign markets, the prices satisfy the following two first order conditions (define $p_1 := p_{HH}$ and $p_2 := p_{HF}$ to simplify the notation):

$$A_H(1 - \sigma)p_1^{-\sigma} - \alpha + \sigma_{\eta} \left( \phi \frac{l^{1-\eta}}{(\phi l^{1-\eta})^{1-\eta}} \right)^{1-\eta} \left[ A_H p_1^{-\sigma} - \alpha + A_F p_2^{-\sigma} (\tau)^{-\sigma} d - \alpha d \right] \frac{1-\eta}{\eta} A_H p_1^{-\sigma - 1} = 0$$
\[ A_F^* (1 - \sigma) p_2^{-\sigma} (\frac{\tau}{e})^{-\sigma} - \alpha + \sigma \frac{P_1}{\eta} (\phi^{1-\eta})^{-1} \left[ A_H p_1^{-\sigma} - \alpha + A_F p_2^{-\sigma} (\frac{\tau}{e})^{-\sigma} d - \alpha d \right]^{-1} \left[ A_F^* p_2^{-1-\sigma} (\frac{\tau}{e})^{-\sigma} d = 0 \right. \ (28) \]

When prices are solved for, total demand can be derived using the demand equations (23) and (24) and then, the material usage can be computed simply using the production function:

\[ M(\phi, l) = (\phi^{1-\eta})^{-\frac{1}{\eta}} (q_{HH} + I^x q_{HF} d)^{\frac{1}{\eta}} \]  

(29)

By comparing the profit of serving only the domestic market and the profit of serving both Home and Foreign markets, firms decide whether to export.\(^{32}\)

Foreign firms’ problem is similarly formulated as follows:

\[ \Pi^F = \max_{p_{FH}} [p_{FH}^* q_{FH} - MC \times q_{FH} d] \]  

s.t.

\[ q_{FH} = A_H p_{FH}^{-\sigma} - \alpha \]  

(31)

\[ p_{FH} = p_{FH}^* \tau e \]  

(32)

where \(MC\) is the marginal cost of production for all Foreign firms, normalized to one. The relative price of the numeraires \(e\) moves around so that the normalizations in Home and Foreign are consistent. The first order condition of the Foreign firms’ problem implies that the price satisfies the following equation (define \(p^* := p_{FH}^*\) to simplify notation):

\[ (1 - \sigma)(p^*)^{-\sigma} + \sigma d(p^*)^{-\sigma} - 1 = \alpha A_H (\tau e)^{\sigma} \]  

(33)

Having solved the price of the imported intermediate goods, we can write the total import of the domestic economy:

\[ \text{total import} = A_H e (p_{FH}^*)^{1-\sigma} (\tau e)^{-\sigma} - \alpha ep_{FH}^* \]  

(34)

where the measure of imported intermediates \((N_F)\) is normalized to one. Now we turn to the firms’ dynamic vacancy posting problem.

\(^{32}\)Note that if a firm decides to serve only the Foreign market, it has to pay both fixed cost of production \(f_d\) and fixed exporting cost \(f_e\). Hence, no firm decides to serve only the Foreign market in equilibrium.
### 4.5 Firms’ Dynamic Problem

This is the third stage of the firm’s problem. At this stage, given the wage bargaining to be discussed in Section 4.7 and the optimal policy in the first stage, firms decide about the number of vacancies to post and whether to exit. The firm with the state variables \((\phi, l)\) decides whether to exit or stay:

\[
V(\phi, l) = \max\{(1 - \lambda)E_{\phi\mid l}V^C(\phi', l), 0\}
\]  

where \(V(\phi, l)\) is the value of the firm at state \((\phi, l)\) and \(\lambda\) is the exogenous exit rate. Solving this problem delivers the continuation policy function \(I^c(\phi, l)\) which is 1 if the firm stays in the market and 0 otherwise. If the firm stays, it decides about employment (or equivalently, the number of vacancies to post) by solving the following dynamic problem:

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

subject to

\[
l' = l + \frac{m(\theta)}{\theta}v
\]

where firms discount the future at the same rate \(\beta\) as consumers, and \(V^C(\phi, l)\) is the value of staying active in the market. \(C(l, \ell')\) is the labor adjustment cost for adjusting labor from \(l\) to \(\ell'\), to be specified below. Equation (37) is the evolution of employment at the firm. The function \(m(.\) (specified below) is the job finding rate which is a function of the labor market tightness \(\theta\), and \(\frac{m(\theta)}{\theta}\) is the vacancy filling rate. The labor market tightness is defined as total number of vacancies \((V)\) over total applicants applying for a job \((U)\). The matching function is assumed to have the following functional form (Den Haan et al. (2000), Cosar (2013), and Coşar et al. (2016)):

\[
M(U, V) = \frac{UV}{(U^\rho + V^\rho)^{\frac{1}{\rho}}}
\]  

where the parameter \(\rho\) governs the degree of matching friction; for a given number of vacancies and job applicants, the number of matches rises as does \(\rho\). Hence, higher values of \(\rho\) mean labor market features less sever matching friction. Particularly, if \(\rho\) goes to infinity, there would be no matching friction.

33 The job finding rate is then the number of matches over the number of applicants:

\[
M(U, V) = \lim_{\rho \to \infty} \frac{UV}{(U^\rho + V^\rho)^{\frac{1}{\rho}}} = U.
\]

Hence, in this case, as \(\rho \to \infty\) the number of matches goes to the number of applicants, which means there is no matching friction in the labor market.

---

33To see this, suppose we have \(U < V\). Then we can write: \(\lim_{\rho \to \infty} M(U, V) = \lim_{\rho \to \infty} \frac{UV}{(U^\rho + V^\rho)^{\frac{1}{\rho}}} = U\). Hence, in this case, as \(\rho \to \infty\) the number of matches goes to the number of applicants, which means there is no matching friction in the labor market.
Adjusting labor is subject to two types of adjustment costs:

\[ C(l, l') = \begin{cases} 
(l - l')c_f & l' \leq l \\
\frac{c_f}{T}v^2 & l' > l 
\end{cases} \]  (40)

\[ v = (l' - l)\frac{\theta}{m(\theta)} \]  (41)

where \( c_f \) is the firing cost and \( v \) is the number of vacancies that an expanding firm posts. Note that in line with the firm dynamics literature, while firing cost is assumed to be linear, hiring cost features a convex cost of posting vacancies. 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)). Moreover, as will be discussed in detail in Section 4.7, without having a non-linear hiring cost, the model would imply no residual wage inequality among expanding firms (see, e.g., Felbermayr et al. (2011)). Equation (41) says that to expand the employment by \( l' - l \), the firm has to post \( v\frac{m(\theta)}{\theta} \) vacancies. The ratio of the job finding rate \( m(\theta) \) over the labor market tightness \( \theta \) is the vacancy filling rate, which is the total number of matches over the total number of vacancies. 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. The solution to the vacancy posting problem in (36) delivers the employment policy function \( l'(\phi', l) \), the vacancy posting policy function \( v(\phi', l) \), and the firing policy function \( I^f(\phi', l) \) which is equal to 1 if the firm contracts and 0 otherwise.

4.6 Entry

In equilibrium, an endogenous measure of entrants replace the firms who exit the market either endogenously or exogenously. The timing of the events for the entrants is as follows:
Entrants pay the sunk entry cost $f_e$ to start with $l_e$ number of workers and draw their productivity.\textsuperscript{34} Entrants draw their productivity from $J^0(\phi)$, which is the ergodic distribution implied by the productivity process (18). Moreover, entrants are able to expand right away by posting vacancies. Entrants are not hit by the exogenous death shock upon entry. Therefore, the value of entry can be expressed as

$$V^e := \int V^C(\phi, l_e) dJ^0(\phi)$$ (42)

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

$$V^e \leq f_e$$ (43)

and this holds with equality if the mass of entrants is positive.

4.7 Labor Market and Wage Bargaining

The labor market features search and matching frictions, à la Mortensen and Pissarides (1994). Timing of the events in the labor market is as follows. The incumbent firms decide whether to exit or continue. If a firm exits, either endogenously or exogenously due to the death shock, its workers join the unemployed 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 (18). Based on their productivities, firms decide whether to expand (by posting vacancies) or contract.\textsuperscript{35} If a firm contracts, the fired workers join the unemployed pool. Unemployed individuals decide whether to search for a job in the intermediate (tradable) sector 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 intermediate producers in a perfectly competitive market.\textsuperscript{36} Fixed costs $f_d$ and $f_x$, sunk entry cost $f_e$, and labor adjustment costs are paid using this home-produced good, which is the model numeraire. The expanding intermediate producers post vacancies, and each vacancy is filled with a given probability determined in equilibrium. If a worker does not get matched, she produces $b_u < 1$ unit of the home-produced good. After matching has taken place, the labor market closes. As a result, workers and firms can not search for other

\textsuperscript{34}Note that workers, who own the 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 earlier, since workers are risk neutral, there is no other reason for workers to save.

\textsuperscript{35}Note that entrants are only allowed to expand, not contract.

\textsuperscript{36}Instead of home-production, one could assume there is a homogeneous service in the economy, produced by perfectly competitive producers, and the production technology is such that each worker can produce one unit of this service. Please note that this model is exactly identical to the model presented in the text.
alternatives at this point, and therefore, there are some rents at the non-contracting firms to be split between firms and workers.\footnote{See the discussion below equation (46).} Hence, firms and matched workers bargain on the wage. If the wage bargaining fails (which is not an equilibrium outcome), the match breaks down, and the worker becomes unemployed and produces $b_u$ units of the home-production.

As the labor market is frictional, it is costly for firms/workers to end a relationship and match with a new worker/firm. As a result, firms and workers bargain over the rents resulted from an employment relationship at the firm. As marginal revenue of each employee varies by employment size, I employ the Stole and Zwiebel (1996) bargaining game, which I summarize here. 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 the next worker and starts bargaining. Otherwise, with some probability the match breaks down and the worker has to quit the firm. Again, in this case, 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.

Basically, Stole and Zwiebel (1996) extend the Nash bargaining to the case in which marginal product of labor varies across workers (e.g., because of decreasing returns to scale in Elsby and Michaels (2013)). Here, although we have constant returns to scale technology, and therefore, marginal product of labor is constant, marginal revenue product of labor varies by employment. The reason is due to the market structure: adding each worker has a different effect on firm’s revenue through the prices that the firm charges in the domestic and Foreign markets.\footnote{Notice that the marginal revenue product of labor is scale-variant even if, unlike in this paper, demand elasticity is constant. To see why, consider a CES demand with elasticity $\sigma$, i.e., $q \propto p^{-\sigma}$. The revenue of a firm with productivity $\phi$ and labor $l$ would be $pq \propto q^{-1/\sigma} q = q^{\sigma-1} = (\phi l)^{\sigma-1}$, which is scale-variant.} Hence, I employ the Stole and Zwiebel (1996) bargaining game so that each worker is viewed as the marginal worker by the firm, and the firm and workers solve the Nash bargaining over the surplus produced by the marginal worker. As a result of this bargaining game, all workers within the same firm are paid the same wage.
It is worth elaborating more on the bargaining game employed in this paper. As Brügemann et al. (2017) argue, Stole and Zwiebel (1996)'s bargaining game can be interpreted in two different ways. First, a perfect information game: each worker is aware of the outcome of the bargaining between the firm and other workers. If so, the Stole and Zwiebel’s Theorem 2 is wrong and the unique Subgame Perfect Equilibrium of this game is not equal to the Shapley values they report in the paper. Second, Stole and Zwiebel (1996) can be interpreted as an imperfect information game: the outcome of each bargaining session is a private information of the worker. As argued 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. Here, in this paper, I assume that the underlying bargaining game between firms and matched workers is the private information version of the Stole and Zwiebel (1996) game. One can also assume that the firms and workers play the Rolodex game, proposed by Brügemann et al. (2017), and still get the same desired wage profile widely used in the empirical macro-labor literature.39

Now I turn to characterize the wage schedule. At a firm with productivity $\phi$ and $l$ workers, the marginal worker generates the following surplus:

$$S_F(\phi, l) = \frac{\partial}{\partial l} [\Pi(\phi, l) - w(\phi, l)l + \beta V(\phi, l)]$$

(44)

where $\Pi(.)$ defined in (21), $w(\phi, l)$ is the wage paid by the firm $(\phi, l)$, and $V(.)$ is the continuation value of the firm defined in (35)-(36).40 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 can not be recovered. Using the firm’s dynamic optimization problem in (36), one can write the RHS of (44) as

$$\frac{\partial}{\partial l} [\Pi(\phi, l) - w(\phi, l)l + \beta V(\phi, l)] = \frac{\partial C(l_{-1}, l)}{\partial l}$$

(45)

where $l_{-1}$ is the last period employment at this firm. Combining (44) and (45) yields

$$S_F(\phi, l) = \frac{\partial C(l_{-1}, l)}{\partial l}$$

(46)

where $C(.)$ is the labor adjustment cost defined in (40).

39The Rolodex game is very similar to the Stole and Zwiebel (1996) 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 be renegotiated with by the firm. In contrast, in Stole and Zwiebel (1996), as many offers and counteroffers are proposed as either an agreement or a breakdown emerges.

40Recall that the outcome of this bargaining process is such that all workers within the same firm earn the same wage.
To explore the marginal surplus generated at different firms, I divide firms into three categories: contracting firms, expanding firms, and firms not changing their employment. For a contracting firm, the RHS of the above equation is negative. Hence, the marginal worker in such a firm does not generate rents. For an expanding firm, however, the RHS of the above equation is positive and also varies by the employment level \( l \). Hence, the marginal worker in an expanding firm generates rents which, due to the non-linearity of vacancy posting cost, vary by firm size \( l \). 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.\(^{41}\) With a large enough productivity persistence \( \rho \), 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 5 will discuss in detail, this positive size-wage association has crucial implications for job turnover, unemployment, and wage inequality consequences of trade liberalization.

The last category includes firms that do not change their workforce. In a world in which employment is a continuous variable, there are no rents generated at these firms, because the RHS of the above equation is zero for such firms. However, if employment is a discrete variable, there might be some positive rents generated at a firm that remains at the same employment level. This is because the generated rent might be positive, but less than the cost of jumping to the next employment level, and therefore, the firm decides not to change its employment. To solve the current model, as discussed in Appendix E, I will discretize the state space. Therefore, there might be positive rents generated at firms that do not change their employment. Hence, in what follows, I divide firms into two categories, and separately solve for wages paid by contracting and non-contracting firms.

I start with a contracting firm to characterize the firing wage schedule \( w_f(\phi, l) \). Each period, when new productivity shocks realize, some firms decide to downsize. I assume that a contracting firm randomly picks the workers to be laid off, and therefore, each worker is equally likely to be fired. Since contracting firms generate no surplus, these firms pay workers’ outside option:

\[
w_f(\phi, l) + \beta W^e(\phi, l) = W^u
\]

where \( W^e(\phi, l) \) is the continuation value of being at firm \((\phi, l)\) at the beginning of next

\(^{41}\)Unlike this paper that employs a random search framework, Felbermayr et al. (2018) show the importance of non-linear vacancy posting cost in generating residual wage inequality in a competitive search environment.
period, and $W^u$ is the value of unemployment, both to be defined below. Few points are worth mentioning here. First, note that the fired workers are able to search for a new job in the current period, and therefore, their outside option is joining the unemployment pool which delivers $W^u$. Hence, workers are indifferent between working in a contracting firm or being laid off from these firms. Second, however, contracting firms pay different wages because the continuation value $W^e(\phi, l)$ varies across firms (discussed below). Finally, note that I assume 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 contracting firms to quit, and therefore, these workers are paid no more than their outside option.

Now I turn to characterize the non-firing wage schedule $w_{nf}(\phi, l)$. The marginal worker generates the following surplus at the non-contracting firm $(\phi, l)$:

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

(48)

Note that 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. Worker’s surplus from this match is

$$S^W(\phi, l) = w_{nf}(\phi, l) + \beta W^e(\phi, l) - [b_u + \beta W^u]$$

(49)

Note that the outside option of workers at this stage is producing $b_u$ units of home-production and joining the unemployment pool next period. The outcome of the Stole and Zwiebel (1996)’s bargaining protocol is Nash bargaining on the marginal surplus. As a result, the non-firing wage schedule satisfies the following equation:

$$\xi S^F(\phi, l) = (1 - \xi) S^W(\phi, l)$$

(50)

where $\xi \in [0, 1)$ is the worker’s bargaining power.\footnote{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.} Appendix E explains the procedure to solve for the firing and non-firing wage schedules.

An unemployed worker decides whether to search for a job in the tradable sector of the economy (i.e., in one of the intermediate good producers) or to produce at home. If she decides to produce at home, she produces one unit of the home-production, which is the numeraire of the model. Hence, the value of working at home is

$$W^h = 1 + \beta W^u$$

(51)
If the worker decides to apply for a job, she enjoys the following

\[ W^a = m(\theta)W^m + (1 - m(\theta))[b_u + \beta W^u] \]  

(52)

where \( m(\theta) \) is the job finding rate specified in (39). With probability \( m(\theta) \) the worker is matched with a firm and enjoys the continuation value \( W^m \), to be specified below. With probability \( 1 - m(\theta) \), the worker is unmatched and produces \( b_u \) units of the home-production. The value of unemployment \( W^u \) is the maximum over these two options:

\[ W^u = \max\{W^h, W^a\} \]  

(53)

In equilibrium, while some unemployed individuals search for a job in the intermediate sector, others decide to home-produce.\(^{43}\) Hence, in equilibrium, the value of producing at home is equal to the value of applying for a job, i.e., \( W^h = W^a = W^u \).

It remains to specify the value of being matched with a firm \( (W^m) \) and the value of being employed at a firm with a particular productivity and employment \( (W^e(\phi, l)) \). Given the continuation policy function \( I^c(\phi, l) \), the firing policy function \( I^f(\phi, l) \), the employment policy function \( I'(\phi, l) \), and the vacancy posting policy function \( v(\phi, l) \), all of which were decided about at Section 4.5, the value of getting matched \( W^m \) can be written as

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

(54)

\[ v(\phi, l)G(\phi, l) + \frac{N_e}{N_H} \frac{L_\theta}{m(\theta)} \mathbf{1}_{l = l_e} J^0(\phi) \]

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

(55)

where \( W^m(\phi, l) \) is the value of getting matched with a firm at the state \( (\phi, l) \), \( v(\phi, l) \) is the number of vacancies posted by firms at state \( (\phi, l) \) (look at Section 4.5), \( G(\phi, l) \) is the distribution of firms after realization of productivities (and so after entry and exit) but before the firms decide about their workforce, \( N_e \) and \( N_H \) are the measures of entrants and the total measure of domestic 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. Recall that \( J^0(\phi) \) is

\(^{43}\)Recall that the home-produced good is used to pay the fixed costs in the model. Hence, the home-produced good must be produced in equilibrium so that operating intermediate producers could pay fixed costs of production. However, one could imagine an equilibrium in which all individuals search for a job in the intermediate sector, and the unmatched workers are just enough to produce the required amount of the home-production good. In such an equilibrium, the value of searching for a job might exceed the value of home-production. However, in this paper, it turns out that a fraction of individuals decide to home-produce in equilibrium.
the productivity distribution that entrants draw from. Note that each entrant posts $\frac{L_0}{m(\theta)}$ vacancies to start with $L_0$ number of workers.\footnote{Entrants are also allowed to expand right after entry. See Section 4.6.} Value of getting matched with a firm at the state $(\phi, l)$ consists of the non-firing wage schedule $w_nf(\phi, l')$ and the expected value of being at this firm at the beginning of next period:

$$W^m(\phi, l) = w_nf(\phi, l') + \beta W^e(\phi, l')$$  \hspace{1cm} (56)

where $l'(\phi, l)$ is the employment policy function, defined in Section 4.5, and $E$ is the expectation operator. Finally, the continuation value of a worker starting the period at the firm $(\phi, l)$ consists of three parts:

$$W^e(\phi, l) = \left[ \lambda \left( \frac{1}{\text{firm’s exogenous exit}} \right) + (1 - \lambda)(1 - I^c(\phi, l)) \right] W_u$$

$$+ (1 - \lambda)I^c(\phi, l) E_{\phi|\phi} I^f(\phi', l) W_u$$

$$+ (1 - \lambda)I^c(\phi, l) E_{\phi|\phi} (1 - I^f(\phi', l)) \max\{ W_u, W^m(\phi', l) \}$$  \hspace{1cm} (57)

For some exogenous or endogenous reasons, this firm may exit, in which case the worker becomes unemployed and join the unemployed pool. Note that these workers can search for a job in this period. If the firm stays at the market but contracts, all workers are paid their outside option $W_u$. This is because no surplus is generated at this firm. If the firm neither exits nor contracts, the workers may decide whether to stay or quit. If the workers decide to quit, I assume the firm has to exit the market and can not post vacancies to match with new workers. As a result, firms pay at least workers’ outside option $W_u$ in equilibrium. This means, for a firm to be active in the market, the outcome of the wage bargaining (50) has to satisfy the following inequality:

$$W^m(\phi, l) \geq W_u$$  \hspace{1cm} (58)

As a result, there would be no voluntary quit in equilibrium. Note that the continuation value of being at any firm is greater than (or equal to) the value of unemployment $W_u$. Now that all the components of the model are specified, we turn to define the stationary equilibrium of the model.
4.8 Stationary Equilibrium and Numerical Algorithm

This paper studies the steady state equilibrium of the model presented in Section 4. The steady state equilibrium is defined as follows. Given the equilibrium objects aggregate demand shifter $A_H$, price of the final good $P$, exchange rate $e$, labor market tightness $\theta$, measure of domestic intermediate producers $N_H$, and stationary distribution of the domestic intermediate producers over productivity and labor: firms solve the first order conditions (26)-(28) to optimally decide about prices to charge, buy the optimal material specified in (99), and optimally decide whether to export; firms optimally decide about the number of vacancies to post by solving the dynamic problem (36); the markets for the final good, the intermediate goods, and the home-production good clear; trade between Home and Foreign is balanced; free entry condition (43) holds with equality; the flow or workers into and out of the unemployment pool are equal; workers are indifferent between applying for a job and producing at home; the distribution of domestic intermediate producers over $(\phi, l)$ 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 equilibrium.

To solve for the stationary equilibrium, one needs to start with a guess on the equilibrium objects and iterate over those objects until they converge. The aggregate demand shifter $A_H$ moves to satisfy the free entry condition (43) with equality. Exchange rate $e$ has to make trade between Home and Foreign balanced. Measure of intermediate producers $N_H$ moves to make the demand for home-production (used for the adjustment costs, the sunk entry costs, and the fixed costs) equal to its supply, given the fact that the inflow to and outflow from the unemployment pool are equal in equilibrium. Labor market tightness moves to make the workers indifferent between applying to the tradable sector and producing at home. Price of the final good $P$ clears the final good market. Appendix E provides the details of the numerical algorithm.

5 Quantitative Analysis

5.1 Colombian Economy

This section explores the quantitative implications of the model developed in the previous section. To this end, I fit the model to the Colombia manufacturing plant-level data set, and then, use the estimated model to perform counterfactual analysis. One main goal of

\[\text{In general, the equilibrium in this class of firm dynamics models might take one of the following forms: with entry/exit or without. The equilibrium in this paper, however, is the one with entry/exit because of the exogenous exit shock. Therefore, the free entry condition (43) holds with equality.}\]
this paper is to explore the labor market volatility and unemployment consequences of trade openness. This makes Colombia a suitable case to investigate. This is because, first, by reducing its average tariff rate from 21 to 11 percent (Attanasio et al. (2004)), Colombia underwent a trade liberalization in the early 1990s. Moreover, the fraction of exporting firms as well as the revenue share of exports increased by almost 150 percent from the 1980s to 2000s (Coşar et al. (2016)). Second, like many other Latin American countries (Haltiwanger et al. (2004) and de Desarrollo (2004)), trade liberalization in Colombia accompanied by a more volatile labor market as well as higher unemployment rates. Figure 3 shows job turnover and unemployment rise after 1991, when these new policies were in effect. Job turnover is defined as changes in the plant-level number of employment opportunities due to expansion, contraction, entry, and exit, over total employment in the previous period. More precisely, the annual job turnover is defined as

$$\text{turnover}_t = \frac{\sum_{i \in c} |l_{it} - l_{it-1}| + \sum_{i \in \text{exit}} l_{it-1} + \sum_{i \in \text{entry}} l_{it} - |L_t - L_{t-1}|}{L_{t-1}} \times 100 \tag{59}$$

where $c$ is the set of continuing plants and $L_t$ is total employment at time $t$. The last term in the nominator is the change in total employment in the economy. Note that including the last term in the nominator guarantees that aggregate shocks (either domestic or foreign), which tend to reduce or raise employment at all firms, do not influence this measure of job turnover.

During the same period, Colombia started to deregulate the labor market by reducing firing cost by almost 50 percent (Heckman and Pages (2000)). Using the quantitative general equilibrium model developed in this paper, I disentangle the effects of labor market deregulation from the effects of trade liberalization. Moreover, this section explores to what extent this rise in job turnover and unemployment is due to the endogenous responses of demand elasticities.

The rise in job turnover observed in Figure 3 might be due to either of the following reasons. First, due to trade liberalization, the economy is restructuring to a new steady state. Hence, part of this rise in job turnover is due to the transition to a new equilibrium. Second, the reduction in firing cost may influence job turnover. On the one hand, firms adjust their labor force more frequently as the labor adjustment cost falls. On the other hand, reducing the firing cost tends to shift employment towards the larger and more stable plant, which tends to reduce job turnover. Third, which is the main focus of this paper, trade liberalization tends to raise labor elasticity of revenue by enhancing the competition in the product market. As argued in this paper, as labor elasticity of revenue rises, firms
Figure 3: Job Turnover and Unemployment rate in Colombia

(a) Job turnover in Colombia  
(b) Unemployment rate in Colombia

Notes: Job turnover is defined in (6). Job turnover rates for all years except 1993-1995 are author’s calculation using the Colombia plant-level data set. Job turnover rates for 1993-1995 are based on de Desarrollo (2004) which uses the same definition. Unemployment rates are from International Monetary Fund.

become more responsive to their idiosyncratic shocks and, as a result, adjust their labor force more frequently. This channel tends to raise job turnover even in the new steady state of the economy.\footnote{One might argue that some part of this observed rise in job turnover after trade liberalization, is due to the fact that Colombian economy is more exposed to aggregate foreign shocks after trade liberalization, or due to the financial crisis at the end of 1990s. However, as discussed below the job turnover definition (59), aggregate shocks that tend to reduce or raise employment at all firms, do not influence the measure of job turnover used in this paper.}

The first goal of this section is to isolate the third channel described above. In other words, I aim to quantify to what extent trade liberalization, via affecting demand elasticities, raises job turnover in the new steady state.

5.2 Estimation

The model is estimated using Simulated Method of Moments (Gourieroux et al. (1996)). I fit the model to the annual pre-liberalization data in Colombia from 1983-1990, assuming that Colombia was in a steady state before implementing the reforms.\footnote{Although I also have the data for 1980-1982, I restrict the analysis to 1983-1990. This is because of a change in the survey at 1983: the data before 1983 cover all the manufacturing plants, but plants with less than ten workers were not surveyed after 1983.} The basic idea is to minimize the distance between a set of data moments and model moments. More precisely, let $\Theta$ denote the set of all parameters of the model:

$$\Theta \equiv (\sigma, \alpha, \beta, c_v, c_f, \rho, A^*_e, d, \tau, \eta, f_d, f_x, f_e, \gamma, \sigma_\phi, b_u, \lambda, \xi)$$ (60)
Then, the Simulated Method of Moments (hereafter, SMM) estimator \( \hat{\Theta} \) is defined as

\[
\hat{\Theta} \equiv \text{argmin}(D - M(\Theta))'W(D - M(\Theta))
\]

where \( D \) stands for data moments and \( M(\Theta) \) denotes the model moments. \( W \) is a weighting matrix which is computed as the inverse of the bootstrapped variance-covariance matrix of the data moments.\(^{48}\) There are three parameters that are calibrated outside the model.

**Parameters calibrated outside the model:** Discount factor \( \beta \) is set to 0.85, consistent with the annual interest rate of 15% in Colombia (Bond et al. (2015), Coşar et al. (2016)). Iceberg trade cost \( d \) is set to 2.5, following Coşar et al. (2016).\(^{49}\) Import tariff \( \tau \) is set to 1.21, the average import tariff in Colombia before trade liberalization (Attanasio et al. (2004)).

This leaves us with 15 parameters to estimate. Overall, 31 moments are targeted to estimate these parameters. Data moments as well as the weighting matrix are computed using Colombian manufacturing plant-level data from 1983-1990. These annual data cover all the manufacturing plants with at least 10 employees.

Table 4 summarizes the data- and model-based statistics. Since labor is homogeneous in my model but not in the data, I compute the “effective labor” as follows. There are six categories of workers employed at the plants: unskilled workers, apprentices, foreign technicians, local technicians, skilled workers, and management staff. To measure the effective labor, the average wage of each type of worker across all plants and all time periods is calculated. Then, each type of worker is weighted by its average wage relative to the average wage of the unskilled workers. The sum of these weighted workers is called the effective labor. Hence, in what follows, I use effective labor to measure the employment at each plant.

As is always the case in SMM estimation, all parameters of the model are jointly estimated. However, a particular set of moments play a key role in estimating each particular parameter. Here, I provide the set of moments that are particularly useful to estimate each parameter of the model.

**Demand parameters \( \sigma \) and \( \alpha \):** Recall the production function of the intermediate producer with productivity \( \phi \) and \( l \) workers:

\(^{48}\)I use cluster bootstrap as I am using panel data.

\(^{49}\)Coşar et al. (2016) use the estimates of Eaton and Kortum (2002) who estimate the tariff equivalent of iceberg trade cost for the Colombian economy to be between 123 and 174 percent.
Table 4: Data- versus model-based statistics

<table>
<thead>
<tr>
<th>Moment</th>
<th>Data</th>
<th>V.D.E. Model</th>
<th>C.D.E. Model</th>
</tr>
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<tbody>
<tr>
<td>$E(\log l_t)$</td>
<td>3.707</td>
<td>3.732</td>
<td>3.771</td>
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<tr>
<td>$E(\log R_t)$</td>
<td>5.515</td>
<td>5.105</td>
<td>5.108</td>
</tr>
<tr>
<td>$E(I_t^x)$</td>
<td>0.117</td>
<td>0.081</td>
<td>0.079</td>
</tr>
<tr>
<td>export share of sale among exporters (mean)</td>
<td>0.201</td>
<td>0.216</td>
<td>0.115</td>
</tr>
<tr>
<td>std. of export share of sale across exporters</td>
<td>0.278</td>
<td>0.219</td>
<td>0</td>
</tr>
<tr>
<td>$\text{var}(\log l_t)$</td>
<td>1.021</td>
<td>1.007</td>
<td>0.976</td>
</tr>
<tr>
<td>$\text{var}(\log R_t)$</td>
<td>2.628</td>
<td>2.984</td>
<td>2.445</td>
</tr>
<tr>
<td>$\text{cov}(\log l_t, \log R_t)$</td>
<td>1.343</td>
<td>1.515</td>
<td>1.388</td>
</tr>
<tr>
<td>$\text{cov}(\log l_t, I_t^x)$</td>
<td>0.131</td>
<td>0.149</td>
<td>0.147</td>
</tr>
<tr>
<td>$\text{cov}(\log R_t, I_t^x)$</td>
<td>0.211</td>
<td>0.251</td>
<td>0.244</td>
</tr>
<tr>
<td>$\text{cov}(\log l_t, \log l_{t+1})$</td>
<td>0.998</td>
<td>0.856</td>
<td>0.896</td>
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<tr>
<td>$\text{cov}(\log l_t, \log R_{t+1})$</td>
<td>1.345</td>
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<tr>
<td>$\text{cov}(\log l_t, I_{t+1}^x)$</td>
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<td>0.142</td>
<td>0.144</td>
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*size distribution*

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<th>C.D.E. Model</th>
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</thead>
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<td>60th percentile</td>
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<td>45.613</td>
<td>45.613</td>
</tr>
<tr>
<td>80th percentile</td>
<td>88.012</td>
<td>93.602</td>
<td>106.931</td>
</tr>
</tbody>
</table>

*material share of sale*

<table>
<thead>
<tr>
<th></th>
<th>Data</th>
<th>V.D.E. Model</th>
<th>C.D.E. Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>25th percentile</td>
<td>0.456</td>
<td>0.573</td>
<td>0.594</td>
</tr>
<tr>
<td>50th percentile</td>
<td>0.585</td>
<td>0.592</td>
<td>0.594</td>
</tr>
<tr>
<td>75th percentile</td>
<td>0.712</td>
<td>0.634</td>
<td>0.594</td>
</tr>
<tr>
<td>std. of material share of sale</td>
<td>0.201</td>
<td>0.061</td>
<td>0</td>
</tr>
<tr>
<td>std. of log wages</td>
<td>0.519</td>
<td>0.451</td>
<td>0.485</td>
</tr>
<tr>
<td>exit rate</td>
<td>0.098</td>
<td>0.121</td>
<td>0.114</td>
</tr>
<tr>
<td>job turnover</td>
<td>0.221</td>
<td>0.198</td>
<td>0.237</td>
</tr>
<tr>
<td>job turnover among continuing plants</td>
<td>0.111</td>
<td>0.129</td>
<td>0.136</td>
</tr>
</tbody>
</table>
\[ q(\phi, l) = \phi M(\phi, l)^{\eta l^{1-\eta}} \]

where \( M(\phi, l) \) is the material usage of the firm. Note that material is the static input of firms, i.e., there is no adjustment cost associated with adjusting material. As shown in Section 4, this intermediate producer faces the following demand elasticity in market \( i \):

\[ \varepsilon_i(\phi, l) = \sigma \left( 1 + \frac{\alpha}{q_i(\phi, l)} \right) \quad (62) \]

where \( q_i(\phi, l) \) is the quantity sold in market \( i \). This firm’s maximization problem implies the following first order condition (see Appendix F for more details):

\[ \frac{\varepsilon_i(\phi, l)}{\varepsilon_i(\phi, l) - 1} = \eta \frac{p_i(\phi, l)q_i(\phi, l)}{PM_i(\phi, l)} \quad (63) \]

where \( p_i(\phi, l) \) is the optimal price charge by this firm in market \( i \), \( P \) is the unit price of material, and \( M_i(\phi, l) \) is the material usage needed to produce the associated output to be sold in market \( i \). Equation (63) says that the markup that this firm charges in market \( i \) (i.e., the left-hand-side) is equal to the ratio of the elasticity of output with respect to the static input \( (\eta) \) over the material share of sale in market \( i \) \( (\frac{PM_i(\phi, l)}{p_i(\phi, l)q_i(\phi, l)}) \). The intuition is that, since material is the static input, the gap between the material elasticity of output and material share of sale has to be due to markup. Combining equations (62) and (63) shows that both demand parameters \( \sigma \) and \( \alpha \) influence the material share of sale: given the technology parameter \( \eta \), as \( \sigma \) or \( \alpha \) rises, the whole distribution of material share of sale shifts to the right. This is because as \( \sigma \) or \( \alpha \) rises, firms face higher demand elasticities and, therefore, charge lower markups.

As equation (62) shows, if \( \alpha = 0 \), the demand elasticity faced by firms would be the same both across firms and across markets. Moreover, equation (63) shows that, under the assumption of \( \alpha = 0 \), there would be no dispersion in material share of sale; given \( \sigma \) and \( \eta \), the dispersion in material share of sale rises with \( \alpha \). Based on this intuition, I target the 25th, 50th, and 75th percentile of the distribution of material share of sale, as well as the standard deviation of material share of sale to learn about these two demand parameters.

Furthermore, as mentioned above, if one imposes \( \alpha = 0 \), the demand elasticity that firms face would be the same both across firms and across markets. As Appendix G proves, only in such a world all exporting firms would have the same export share of sale. As equation (62) shows, a non-zero \( \alpha \) implies that demand elasticities vary both across firms and across markets. Hence, a non-zero \( \alpha \) implies that there is a dispersion in export share of sale across...
exporting firms. My simulation exercises show that as $\alpha$ rises, so does the dispersion in export share of sale across exporting firms. Therefore, I target the standard deviation of export share of sale across exporters to learn about the demand parameter $\alpha$, and also to test whether data reject the assumption of constant demand elasticity (i.e., $\alpha = 0$). Finally, note that these two demand parameters also influence many other moments of the model. For instance, the fraction of firms that decide to export and also the mean of plant-level export share of sale crucially depend on these demand parameters: as $\alpha$ or $\sigma$ rises, fewer firms find it profitable to export, and moreover, export share of sale among exporters fall. Furthermore, firm size distribution as well as $\text{cov} (\log l_t, \log R_t)$ are influenced by demand parameters $\sigma$ and $\alpha$.

There are few points worth mentioning here. First, some of the dispersion in material share of sale might be due to cross-industry technology differences. However, it turns out that the dispersion in material share of sale across all firms is quite similar to the dispersion within industries: while the dispersion is 0.19 across all firms, the within-industry dispersion ranges from 0.14 to 0.21. Hence, up to the assumption that the production technology is Cobb-Douglas and is the same for all firms within each industry, targeting the distribution of material share of sale to learn about the demand parameters seems plausible. Moreover, note that the production technology as well as the demand side of the model nests a wide range of studies in both the international trade and macro literature.

Second, as the demand elasticity equation (62) implies, larger firms tend to face lower demand elasticities, and, therefore, have lower material share of sale. So one expects to observe a negative correlation between size and material share of sale. This size-material share of sale association would be one of the non-targeted moments of the model which will be explored below. Note that through the lens of this model, if one imposes the constant demand elasticity assumption (i.e. $\alpha = 0$), there would be no correlation between size and material share of sale. Moreover, the dispersion in material share of sale would be zero in the constant demand elasticity model. As a result, these two statistics would be the ones that distinguish between the variable versus constant demand elasticity models. Finally, as a robustness exercise, I plan to estimate the markup distribution using De Loecker and Warzynski (2012) approach and then, directly target this distribution to learn about the demand parameters $\sigma$ and $\alpha$.

**Labor adjustment costs and matching friction:** I use the 20th, 40th, 60th, and 80th percentile of size distribution, job turnover rate among continuing plants, $\text{cov}(\log l_t, \log R_t)$, and wage dispersion to learn about labor adjustment cost parameters $c_f$ and $c_v$ and the
matching friction $\rho$. Before explaining the intuition, I first describe how to compute job turnover rate. Annual job turnover rate is computed based on equation (59). The job turnover in Table 4 is the cross-year average of the annual turnover rates. I use two measures of job turnover. While one includes continuing plants only (called job turnover among continuing plants), the other one includes entry and exit as well (called job turnover). The difference between these two measures of job turnover is due to job creation/destruction by entry/exit.

As will be discussed also in the quantitative section 5, a reduction in labor adjustment costs affects the firm size distribution by shifting employment toward larger plants. Let’s first discuss the effects of firing cost reduction on firm size distribution. By reducing the expected cost of firing workers later, a reduction in the firing cost $c_f$ induces firms to employ more workers. Moreover, since larger firms are less exposed to the risk of exit compared to small firms, larger firms benefit more than small firms from firing cost reduction. This is because the model assumes that if a firm exits the market, it is not required to pay the firing cost. Hence, firing cost reduction shifts firm size distribution to the right. The hiring cost parameter $c_\upsilon$ also influences firm size distribution: a reduction in the convex hiring cost induces firms to expand more when hitting by positive productivity shocks.

Labor adjustment costs influence job turnover. On the one hand, since larger firms are more stable, reducing labor adjustment costs tends to reduce job turnover by shifting employment to 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, and thereby, job turnover tends to rise (Ljungqvist (2002) and Mortensen and Pissarides (1999)). Matching friction parameter $\rho$ affects firms’ responsive to their idiosyncratic shocks. To see why, as explained below the matching function (38), a larger $\rho$ implies a higher vacancy filling rate, given the labor market tightness $\theta$. Having a higher vacancy filling rate, firms respond more to their transitory shocks. Hence, the matching friction parameter $\rho$ influences job turnover rate as well as $\text{cov}(\log l_t, \log R_t)$. Note that $\text{cov}(\log l_t, \log R_t)$ partly captures the employment responses to revenue shocks (i.e., productivity shocks in this paper).

In addition to firm size distribution and job turnover, wage dispersion is also influenced by the hiring cost parameter $c_\upsilon$; a rise in $c_\upsilon$ raises the wage dispersion. To see why, note that due to the convex hiring cost, it is not optimal for the expanding firms to reach their long-run desired size right away. As a result, there are heterogeneous rents (across the firm size distribution) to be split while the expanding firms are transiting to their desired size (see the detailed discussion below equation (46) in Section 4.7). As the (convex) hiring cost
rises, the heterogeneity of firms’ surplus across expanding firms rises (see equation (46)), and because of wage bargaining, so does the wage dispersion in the economy.

**Production function:** Given the demand elasticity parameters $\sigma$ and $\alpha$, the covariance between employment and revenue (denoted by $R$ in Table 4) is governed by material elasticity of output $\eta$. Firms’ revenues are expressed in thousands of 1977 pesos.

**Productivity process:** Means, variances, and covariances of employment, revenue, and export indicator function $I^x$ help us learn about the parameters of the AR(1) process $\gamma$ and $\sigma_\phi$.

**Workers’ outside option and bargaining power:** The job turnover rate helps learn about workers’ outside option $b_u$: as $b_u$ rises, firms hitting a bad shock are not able to lower wages by much, since payments to workers have to be above workers’ outside option. Hence, firms have to adjust their workforce. Furthermore, wage dispersion helps learn about workers’ outside option as well as bargaining power. The intuition is that firms have to pay at least the workers’ outside option. As workers’ outside option rises, the range of “feasible” wages falls, and therefore, wage dispersion falls. Moreover, as workers’ bargaining power rises, firms’ heterogeneity translates into wage heterogeneity. As a result, wage heterogeneity rises with workers’ bargaining power. Note that as the labor in data is measured by effective labor, the notion of wage also refers to the wage per effective labor. Hence, wage dispersion in this paper is the “residual” wage dispersion.

**Exogenous exit rate:** The firms’ exit rate as well as job turnover due to entry and exit helps learn about $\lambda$. 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 and fixed production cost:** The sunk entry cost $f_e$ and the fixed production cost $f_d$ affects the overall size of the economy. The reason being aggregate demand shifter $A_H$ is such that free entry condition (43) holds with equality. So the mean of employment and the mean of revenue helps learn about these costs. Moreover, the fixed production cost influences the firms’ exit rate.

**Fixed exporting cost and aggregate demand shifter in the Foreign economy:** Fraction of plants that export, revenue share of export among exporters, and covariance of exporting indicator function $I^x$ and revenue help us learn about these two parameters.
5.2.1 Estimated Parameters, Model Fit, and Validation

Now that the intuition behind the set of targeted moments is explained, I turn to the estimation procedure. Note that there are two versions of the model being estimated here: one imposes constant demand elasticity (i.e., $\alpha = 0$) and the other one allows for variable demand elasticity (i.e., I estimate $\alpha$ rather than imposing $\alpha = 0$). Call the former C.D.E. (Constant Demand Elasticity) version of the model and the latter V.D.E. (Variable Demand Elasticity) model. The goal of estimating these two models separately is to show the key role that the endogenous responses of demand elasticities play when the economy hit by an aggregate shock. The counterfactual analysis in the next section will pursue this objective. To estimate both versions of the model, I target the same moments in Table 4 and let the estimator defined in (61) estimate the model.

Overall, both models fit the data quite well. The main difference between these two models is that the C.D.E. model can not generate any dispersion in the material share of sale across firms. As explained before, the heterogeneity in material share of sale is used to learn about the demand parameter $\alpha$. Hence, by construction, when this parameter is imposed to be zero in the C.D.E. model, all the heterogeneity in material share of sale is killed. However, the median of this distribution is almost perfectly matched in both models. Moreover, note that even the V.D.E. model does not perfectly match the material share distribution. This is because, as explained in the identification part, $\sigma$ and $\alpha$ govern not only the material share distribution, but also many other model moments, including fraction of exporters and export share of sale among exporters. The optimization procedure picks the values for the parameters $\sigma$ and $\alpha$ which result in the best fit of the entire model.

As explained before, using the data on the six categories of workers, labor is measured in effective units. Hence, the notion of wage in the data refers to the wage per effective labor. This means that the worker heterogeneity is controlled for to the extent possible. As a result, the wage dispersion reported in Table 4 measures the residual wage dispersion. As Table 4 reports, there is a considerable residual wage inequality in the data and both models are able to match it quite well. The fact that both models are able to match the observed residual wage dispersion is due to the convex hiring cost: due to the convex vacancy posting cost, the expanding firms are not able to reach their desired long-run size right away. As a result, there are rents to be split while the expanding firms are transiting to their desired size. In fact, in a model that the vacancy posting cost is linear, the firms that hit by a good productivity shock expand to the point that there is no rent generated at the firm, and, as

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50In each category of worker, however, there might be some unobservable heterogeneity which the data do not allow to control for.
a result, all firms pay the workers’ reservation wage (see Felbermayr et al. (2011)).

The V.D.E. model has 15 parameters to estimate, whereas the C.D.E. version has one less parameter (as \( \alpha \) is imposed to be zero). The parameter estimates are reported in Table 5. Standard errors are constructed using the SMM asymptotic variance-covariance matrix.\(^{51}\)

The estimated \( \sigma \) and \( \alpha \) in the V.D.E. model imply that the markups are bounded above by 30 percent. These demand elasticities are in line with the literature (e.g., De Loecker and Warzynski (2012), Coşar et al. (2016), De Loecker et al. (2016)), and Eslava et al. (2004)). De Loecker and Warzynski (2012) estimate the markups for the Slovenian firms ranging from 1.13 to 1.28. Eslava et al. (2004) estimate the average demand elasticities for the pre-liberalization episode in Colombia to be 3.17. As reported by De Loecker and Warzynski (2012) for the Slovenian firms, exporters tend to charge higher markups. Note that the commonly used constant demand elasticity models are not able to generate this fact. In this paper, however, exporters are, on average, larger and therefore, they face lower demand elasticities. As a result, exporters charge higher markups.

As Table 5 shows, the estimate of \( \sigma \) in the C.D.E. model is lower than that in the V.D.E. model. This is due to the fact that while \( \sigma \) is the average demand elasticity in the C.D.E. model (which is constant), this parameter in the V.D.E. model is the lowest demand elasticity which the most productive firms in the economy face.

The estimated value for the persistence of the productivity shocks shows that the productivity process is pretty persistent. While productivity seems to be less persistent in the United States (Foster et al. (2008)), this high persistence is in line with the empirical literature on the Colombian economy, e.g., Eslava et al. (2010) and Coşar et al. (2016).

The estimated matching friction in the V.D.E. model is not far from the estimates in the literature: Coşar et al. (2016) estimate 1.83 for Colombia and Cosar (2013) calibrates this parameter to 2.16 for Brazil. As mentioned in the introduction, the models that do not allow for the endogenous responses in demand elasticities tend to overestimate the labor market frictions. Note that the total labor adjustment costs paid by firms in the C.D.E. model is estimated to be 17 percent higher than the V.D.E. model. This is intuitive: assuming demand elasticity is constant, all inaction or limited action on the employment margin by firms facing a productivity shock is attributed to the labor market frictions. However, allowing for variable demand elasticity, a firm hit by a productivity shock not only adjusts

\[^{51}\text{The SMM asymptotic variance-covariance matrix is given by } (1 + \frac{1}{S})(GW^{-1}G')^{-1}, \text{ where } S \text{ is the number of simulations, } W \text{ is the weighting matrix, } G' := \frac{\partial g(\Theta)}{\partial \Theta}|_{\Theta = \hat{\Theta}} \text{ where } g(\Theta) := D - M(\Theta) \text{ is the difference between data and model moments and } \hat{\Theta} \text{ is the vector of estimated parameters.}\]
Table 5: Estimated parameters using Simulated Method of Moments

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Variable Elasticity</th>
<th>Constant Elasticity</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\sigma$</td>
<td>demand elasticity parameter</td>
<td>4.498</td>
<td>7.021</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.015)</td>
<td>(0.025)</td>
</tr>
<tr>
<td>$\alpha$</td>
<td>demand elasticity parameter</td>
<td>4.825</td>
<td>0 (imposed)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.074)</td>
<td></td>
</tr>
<tr>
<td>$c_v$</td>
<td>hiring cost</td>
<td>5.037</td>
<td>3.668</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.032)</td>
<td>(0.024)</td>
</tr>
<tr>
<td>$c_f$</td>
<td>firing cost</td>
<td>0.474</td>
<td>0.844</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.003)</td>
<td>(0.008)</td>
</tr>
<tr>
<td>$\rho$</td>
<td>matching friction</td>
<td>2.605</td>
<td>3.253</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.012)</td>
<td>(0.031)</td>
</tr>
<tr>
<td>$A_F^*$</td>
<td>aggregate demand shifter in market F</td>
<td>4928.861</td>
<td>1454.282</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(347.28)</td>
<td>(137.63)</td>
</tr>
<tr>
<td>$\eta$</td>
<td>material elasticity of output</td>
<td>0.726</td>
<td>0.693</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.003)</td>
<td>(0.002)</td>
</tr>
<tr>
<td>$f_d$</td>
<td>fixed production cost</td>
<td>11.169</td>
<td>6.849</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.083)</td>
<td>(0.049)</td>
</tr>
<tr>
<td>$f_x$</td>
<td>fixed exporting cost</td>
<td>81.994</td>
<td>30.145</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.749)</td>
<td>(0.211)</td>
</tr>
<tr>
<td>$f_e$</td>
<td>sunk entry cost</td>
<td>148.881</td>
<td>146.752</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(2.342)</td>
<td>(1.971)</td>
</tr>
<tr>
<td>$\gamma$</td>
<td>persistence of productivity shocks</td>
<td>0.939</td>
<td>0.911</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.001)</td>
<td>(0.001)</td>
</tr>
<tr>
<td>$\sigma_\phi$</td>
<td>std. of productivity shocks</td>
<td>0.249</td>
<td>0.229</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.0008)</td>
<td>(0.001)</td>
</tr>
<tr>
<td>$b_u$</td>
<td>workers’ outside option</td>
<td>0.901</td>
<td>0.775</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.005)</td>
<td>(0.002)</td>
</tr>
<tr>
<td>$\lambda$</td>
<td>death shock</td>
<td>0.035</td>
<td>0.064</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.0002)</td>
<td>(0.0005)</td>
</tr>
<tr>
<td>$\xi$</td>
<td>workers’ bargaining power</td>
<td>0.446</td>
<td>0.466</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.004)</td>
<td>(0.003)</td>
</tr>
</tbody>
</table>

Notes: Standard errors are in parenthesis. The “Variable Elasticity” and “Constant Elasticity” columns correspond to the estimated parameters of the variable demand elasticity and constant demand elasticity models, respectively.
Table 6: Non-targeted Moments

<table>
<thead>
<tr>
<th></th>
<th>Data</th>
<th>V.D.E. Model</th>
<th>C.D.E. Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>regress material share of sale on log(labor)</td>
<td>-0.006</td>
<td>-0.034</td>
<td>0</td>
</tr>
<tr>
<td>mean of log wage</td>
<td>0.154</td>
<td>0.223</td>
<td>0.201</td>
</tr>
<tr>
<td>corr wages and employment</td>
<td>0.395</td>
<td>0.343</td>
<td>0.387</td>
</tr>
<tr>
<td>fraction of firms with employment inaction</td>
<td>0.112</td>
<td>0.108</td>
<td>0.116</td>
</tr>
</tbody>
</table>

Notes: Standard errors are in parenthesis. The “V.D.E.” and “C.D.E.” columns correspond to the variable demand elasticity and constant demand elasticity models, respectively. These statistics are computed using the same data with which I estimated the model.

its labor force, but also changes its markup (as the firm now faces a different demand elasticity). In other words, the V.D.E. model implies that reducing (raising) markup and laying off (hiring) workers are substitutable for one another. As a result, by imposing constant demand elasticity, one overestimates the labor market frictions.

5.2.2 Non-targeted Moments

Table 6 shows how the model performs in generating some non-targeted statistics. First, the data show that larger firms have lower material share of sale expenditure. While this can not be explained by the C.D.E. version of the model, the V.D.E. model generates a negative association between these two. In the model, larger firms face lower demand elasticities and charge higher markups. Due to the assumption that all firms use the same Cobb-Douglas production function, higher markups translate into lower material share of sale.

While the wage dispersion is targeted in the estimation procedure, the mean wages is not. Both models do a reasonable job in generating this moment. Moreover, in the data, there is a positive correlation between wages and employment. In both models, this positive correlation between wages and employment comes from the fact that, due to the non-linear cost of posting vacancies, it is not optimal for the expanding firms to reach their long-run desired size right away. As a result, there are rents to be split while the expanding firms are transiting to their desired size. In fact, in a model with linear vacancy posting cost, all expanding firms would pay the same wage, and therefore, the size-wage correlation would be very limited.52 As will be discussed in the counterfactual analysis, this positive size-wage association has a very important implication for both job turnover and unemployment.

52Notice that even if vacancy posting cost was linear, non-contracting firms would pay higher wages than contracting firms do. This is because the marginal surplus in non-contracting firms would still be positive, but the same for all non-contracting firms; see the discussion below equation 46 in Section 4.7. Hence, there would be a limited degree of size-wage correlation in that world.
consequences of trade openness. Finally, 11 percent of firms do not adjust their workforce from this period to the next. Both models do well in generating this firm dynamics statistics.

5.3 Counterfactual Analysis

This section performs the counterfactual analysis based on the estimated model from the previous section. The main goal of this section is twofold. The first objective is to determine to what extent the variable demand elasticity model is able to capture the observed increase in job turnover and unemployment following the trade liberalization in Colombia. The second aim is to show that allowing for endogenous responses in demand elasticities play a crucial role in deriving the counterfactual outcomes.

As mentioned before, Colombia underwent a trade liberalization as well as labor market deregulation in the early 1990s. Starting from 1991, Colombia reduced not only import tariffs, but also non-tariff barriers and licensing reforms (see Attanasio et al. (2004)). As for tariff barriers, the average import tariffs are reduced from 21 percent to around 11 percent (Attanasio et al. (2004)). I simulate the effects of this reduction in import tariffs by reducing the parameter \( \tau \) by 10 percentage point, from 1.21 to 1.11, in both C.D.E. and V.D.E. models. As for non-tariff barriers and licensing reforms, since there is no direct way to measure the reduction in non-tariff costs, I proceed as follows. Total export share of revenue in the Colombian economy rises by almost 150 percent from the pre-reform period 1983-1990 to the post-reform period 2000-2012.\(^{53}\) I reduce the iceberg trade cost \( d \) such that both models match the same rise in total export share of revenue. This exercise leads to reducing iceberg trade costs from 2.5 to 2.23 (11 percent reduction) in the V.D.E. model and from 2.5 to 2.19 (12.5 percent reduction) in the C.D.E. model. Finally, the effects of labor market deregulation are simulated by reducing the labor firing cost \( c_f \) by 50\% (Heckman and Pages (2000)) in both models.

Table 7 reports the counterfactual results. To explore to what extent the endogenous responses in demand elasticities derive the counterfactual results, I do the counterfactual analysis twice: I hit both the V.D.E. and C.D.E. models with the counterfactual shocks described above. The first (last) three columns report the results using the variable (constant) demand elasticity model. The “Base” columns correspond to the initial steady state of the models. The “Open” columns report the counterfactual results associated with the reduction in import tariffs and iceberg trade costs, in the fashion described above. Under the “Firing & Open” columns, I report the counterfactual results corresponding to the case in which I

\(^{53}\)Note that in the plant-level data that are currently available, export sales are not reported from 1992-1999.
reduce the labor firing cost, import tariffs, and iceberg trade costs. For ease of comparison, the baseline values for all of the statistics (except the size distribution) are normalized to one.

Table 7: Counterfactual Results

<table>
<thead>
<tr>
<th>Variable</th>
<th>Demand Elasticity</th>
<th>Constant Demand Elasticity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Base</td>
<td>Open</td>
</tr>
<tr>
<td>firing cost</td>
<td>0.474</td>
<td>0.474</td>
</tr>
<tr>
<td>iceberg cost</td>
<td>2.5</td>
<td>2.23</td>
</tr>
<tr>
<td>import tariffs</td>
<td>1.21</td>
<td>1.11</td>
</tr>
<tr>
<td>job turnover</td>
<td>1.0</td>
<td>1.08</td>
</tr>
<tr>
<td>job turnover (continuing)</td>
<td>1.0</td>
<td>1.06</td>
</tr>
<tr>
<td>unemployment</td>
<td>1.0</td>
<td>1.17</td>
</tr>
<tr>
<td>size distribution</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15th percentile</td>
<td>15.31</td>
<td>13.05</td>
</tr>
<tr>
<td>20th percentile</td>
<td>17.96</td>
<td>17.03</td>
</tr>
<tr>
<td>40th percentile</td>
<td>28.24</td>
<td>29.79</td>
</tr>
<tr>
<td>60th percentile</td>
<td>45.61</td>
<td>54.95</td>
</tr>
<tr>
<td>80th percentile</td>
<td>93.60</td>
<td>118.94</td>
</tr>
<tr>
<td>measure of domestic producers</td>
<td>1.0</td>
<td>0.82</td>
</tr>
<tr>
<td>exit rate</td>
<td>1.0</td>
<td>1.32</td>
</tr>
<tr>
<td>labor market tightness</td>
<td>1.0</td>
<td>0.83</td>
</tr>
<tr>
<td>workers’ exp. value of match</td>
<td>1.0</td>
<td>1.08</td>
</tr>
<tr>
<td>std. of log wages</td>
<td>1.0</td>
<td>1.11</td>
</tr>
<tr>
<td>std. of (D market) markup dist.</td>
<td>1.0</td>
<td>0.93</td>
</tr>
<tr>
<td>welfare</td>
<td>1.0</td>
<td>1.14</td>
</tr>
</tbody>
</table>

5.3.1 Job Turnover, Firm Size Distribution, and Exit Rate

First, consider the effect of openness (columns 2 and 5) on job turnover. The increase in job turnover under the V.D.E. model is 8%, which is four times larger than the increase in job turnover in the C.D.E. model. Openness influences job turnover through two mechanisms. First, to the extent that openness affects firm size distribution, it causes demand elasticities to change (see equation (15)) and therefore, influences job turnover. Second, openness shifts employment toward larger firms which pay higher wages. This, in turn, reduces labor market tightness. A reduction in labor market tightness makes employment adjustment less costly.
for firms. I discuss both mechanisms in turn.

The first mechanism works as follows. Trade openness influences demand elasticities through changing the firms’ sizes (see equation (15)). In the V.D.E. model, on the one hand, small firms get even smaller by openness. As a result, these firms face higher demand elasticities, and therefore, respond more to their productivity shocks. This channel tends to raise the job turnover rate. On the other hand, larger firms get larger, face lower labor elasticities of revenue, and given the labor market tightness, become less responsive to their idiosyncratic shocks. This tends to reduce job turnover. As for the second mechanism, note that the same change in the firm size distribution tends to reduce the labor market tightness: openness shifts employment toward larger plants which pay higher wages (see the non-targeted moments in section 5.2.2). Moreover, the rents generated at larger (exporting) firms jump after trade liberalization because larger firms get easier access to the Foreign market. These two forces raise the expected value of finding a job at the intermediate sector, which in turn, reduces labor market tightness. In a less tight labor market, a vacancy fills up with a higher probability, and therefore, firms have more incentive to adjust their workforce when they hit by a shock. This mechanism tends to raise job turnover within each size bin. Note that having a general equilibrium model is crucial to investigate the effects of changes in both firm size distribution and labor market tightness on various labor market outcomes, e.g., job turnover and unemployment. To summarize, openness tends to raise job turnover through two channels: small firms get smaller and become more responsive to shocks, and labor market tightness falls. However, openness tends to reduce job turnover due to the fact that employment shifts toward larger more stable plants.

Table 7 shows the channels that tend to raise job turnover after openness dominate the one that tends to reduce it. As a result, openness raises job turnover. The same responsiveness channel described above leads to a higher exit rate by openness in the V.D.E. model. Note that the rise in job turnover in the V.D.E. model is not entirely due to the rise in the exit rate: job turnover among continuing firms also rises by openness. Note that, as no rise is observed in the C.D.E. model, the rise in job turnover among continuing firms in the V.D.E. model is entirely due to the variable demand elasticity channel.

Now I turn to explore the effects of trade liberalization on firm size distribution. Because

---

54 Note that large firms that get larger are exporters. These exporters face two demand elasticities, one at Home and one in the Foreign market. Trade liberalization raises demand elasticities in the Home market, but it reduces demand elasticities in the Foreign market. While the former raises labor elasticity of revenue, the latter reduces it. Overall, trade liberalization reduces labor elasticity of revenue for these firms. Recall from Section 3 that labor elasticity of revenue is what governs firms’ responsiveness to idiosyncratic shocks.
of the endogenous responses in demand elasticities, openness has a stronger effect on the firm size distribution under the V.D.E. than the C.D.E. model. Since less efficient firms respond more to their negative productivity shocks, jobs reallocate toward the larger more efficient firms. Hence, openness makes the firm size distribution more dispersed in the V.D.E. compared to the C.D.E. model. As Table 8 shows, the V.D.E. model does a much better job to generate the change in the firm size distribution after trade liberalization.

The combined effect of openness and labor market deregulation is reported in columns 3 and 6. As discussed in the estimation part, a reduction in labor adjustment costs influences job turnover through two competing forces. On the one hand, firing cost reduction affects the firm size distribution by shifting the employment toward the larger plants, and thereby, reduces job turnover. On the other hand, reducing labor adjustment costs creates more incentive for firms to adjust their workforce in response to transitory productivity shocks, and therefore, job turnover tends to rise (Ljungqvist (2002) and Mortensen and Pissarides (1999)). Table 7 shows that the former dominates the latter: job turnover rates in columns 3 and 6 are lower than those in columns 2 and 5, respectively.

As Figure 3 shows, the average job turnover rate in Colombia in the 2000-2012 period is around 25% higher compared to the pre-reform episode. Interestingly, column 6 shows that the C.D.E. model is not able to generate the observed rise in job turnover following the policy reforms in Colombia. Indeed, in line with Coşar et al. (2016), the C.D.E. model predicts a fall in job turnover following the reforms. However, the V.D.E. model is able to partly generate the observed drastic rise in job turnover in Colombia. Hence, taking the endogenous responses of demand elasticities into account is both qualitatively and quantitatively important to explain the rise in job volatility accompanied trade liberalization in Colombia.

Since the change in the firm size distribution is at the heart of the channels discussed above, it is of interest to show whether the V.D.E. or the C.D.E. model could capture what indeed happened to the firm size distribution after the reforms in Colombia. Table 8 reports the size distribution in the data as well as in the V.D.E. and C.D.E. models for both pre-reforms and post-reforms episodes. As explained before, using the six categories of labor reported in the pre-1991 data, labor is measured in “effective units” both in the pre-reforms data and in both models. However, the data after 1992 do not report the detailed information about the types of workers employed at each plant. Hence, to make the post-reform size distribution comparable to the pre-reform as well as to the models, I proceed as follows.

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55 I exclude the 1992-1999 years to better approximate the new “steady state” of the Colombian economy. However, averaging across the whole 1992-2012 period would lead to a similar number.
Table 8: Firm Size Distribution

<table>
<thead>
<tr>
<th>size distribution</th>
<th>Data</th>
<th>V.D.E. Model</th>
<th>C.D.E. Model</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre</td>
<td>Post</td>
<td>Pre</td>
</tr>
<tr>
<td>15th percentile</td>
<td>15.95</td>
<td>14.00</td>
<td>15.30</td>
</tr>
<tr>
<td>20th percentile</td>
<td>17.50</td>
<td>15.15</td>
<td>17.96</td>
</tr>
<tr>
<td>40th percentile</td>
<td>25.80</td>
<td>26.65</td>
<td>28.24</td>
</tr>
<tr>
<td>60th percentile</td>
<td>42.16</td>
<td>48.82</td>
<td>45.61</td>
</tr>
<tr>
<td>80th percentile</td>
<td>88.01</td>
<td>114.81</td>
<td>93.60</td>
</tr>
<tr>
<td>85th percentile</td>
<td>118.17</td>
<td>156.56</td>
<td>125.45</td>
</tr>
</tbody>
</table>

Notes: “Pre” and “Post” columns refer to the pre- and post-reform episodes, respectively. The pre- and post-reform data statistics are calculated as the average across the years 1983-1990 and 1992-2012, respectively. As explained in the text, for the post-reform data statistics, I convert the number of workers to effective labor units using the fitted curve in the pre-reform episode.

Using the pre-reform 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-reform plant-level data to effective labor units. Therefore, all the numbers reported in Table 8 are in terms of effective labor rather than number of employees.

As the first two columns of Table 8 show, the reforms in Colombia resulted in a more dispersed firm size distribution: small firms get smaller, employment shifts toward larger firms, and larger firms get even larger. While the V.D.E. model does a reasonably nice job to predict all of these patterns, the C.D.E. model fails to do so. Indeed, the firm size distribution does not respond much to the reforms. In particular, the C.D.E. model is not able to generate the fact that small firms get smaller by the reforms in Colombia. Moreover, while the 80th percentile of the firm size distribution rises by almost 30 percent, the C.D.E. model captures only 5 percent of this rise. Since the V.D.E. model does a much better job in predicting the firm size distribution after the reforms, it is also much more successful to explain the rise in job turnover (and unemployment, as will be discussed below) through the channels explained above.

5.3.2 Unemployment and Wage Inequality

Now consider the effect of openness on unemployment. While unemployment rises after trade liberalization in both models, this effect is almost three times larger in the V.D.E.
model, compared to the C.D.E. model. Trade liberalization raises unemployment in the V.D.E. model through two channels. First, trade liberalization shifts employment toward larger plants, which pay higher wages (see the non-targeted moments in section 5.2.2). As a result, workers’ expected value of being matched with a firm \( (W^m) \) rises, which in turn, reduces the labor market tightness. This reduction in labor market tightness reduces job finding rate, and therefore, tends to raise unemployment (see equation (114) in Appendix D). Second, as mentioned before, firms hitting by negative shocks shed more workers after trade liberalization, because they face more elastic demand curves after trade liberalization. This, in turn, raises inflow into the unemployment pool (see equation (108) in Appendix D), and therefore, number of job seekers rises (see equation (110)). This rise in the number of job applicants tends to raise unemployment rate (see equation (114) in Appendix D). Note that both of these two mechanisms are much stronger in the V.D.E. than the C.D.E. model; this is basically because, as mentioned before, trade liberalization raises firms’ responsiveness to idiosyncratic shocks in the V.D.E. model much more than it does in the C.D.E. model. Interestingly, the C.D.E. model is not able to generate the observed increase in unemployment in Colombia shown in Figure 3.

Comparing the columns “Open” to “Firing and Open”, one observes that the rise in unemployment is less pronounced when I introduce the firing cost reduction into the counterfactual experiment. This is because reducing firing cost tends to reduce unemployment. A reduction in firing cost activates two competing forces that influence unemployment. On the one hand, the composition effect tends to raise unemployment; by shifting employment toward larger plants which pay higher wages, firing cost reduction reduces the labor market tightness, and therefore, unemployment tends to rise. On the other hand, by reducing the expected cost of firing workers later, a reduction in the firing cost induces firms to employ more workers, which tends to reduce unemployment. The counterfactual results in Table 7 show that the latter dominates the former. Moreover, the fact that firing cost reduction induces firms to carry more workers reduces the marginal revenue product of workers, putting downward pressure on wages. As a result, the expected value of finding a job in the intermediate sector falls, and therefore, labor market tightness rises. This is why the rise in unemployment in columns 3 and 6 are lower than that of columns 2 and 4.

While both models show that wage dispersion also rises after trade liberalization, this effect is much stronger in the V.D.E. model, compared to the C.D.E. model. The firm size distribution, as explained above, gets more dispersed after trade liberalization. The fact that larger firms pay higher wages, as well as the fact that generated rents at larger (exporting) firms jump after trade liberalization, translates the dispersion in size distribution into wage
inequality. This is consistent with the rise in wage inequality in Colombia; Attanasio et al. (2004) document that the standard deviation of log wages rises by about 15% from 1990 to 1998, and moreover, the same rise is observed when they look at wage inequality within education categories.\footnote{Note that Attanasio et al. (2004) divide the workers into different groups based on their education, and look at the wage inequality within each group. Hence, their measure is comparable to my measure of residual wage inequality.} Note that, in theory, openness does not necessarily raise wage inequality. As shown by Helpman et al. (2017), as more and more workers are hired by larger firms after openness, wage inequality may start to fall at some point.

5.3.3 Welfare

One main focus of trade literature is to study gains from trade liberalization. Here I compute the welfare consequences of trade liberalization using both versions of the model. Before describing the channels through which trade liberalization affects welfare, I need to define welfare. Recall that consumers gain utility only by consuming the homogeneous final good $M$ (see consumers’ per-period utility function (11)). Here, I define welfare as the sum of the life-time utility of all individuals in the Home economy:

$$\text{welfare} = \int_0^1 U_j dj$$

(64)

There are various channels through which trade liberalization influences welfare. First, by forcing less efficient firms to exit the market, trade liberalization reduces the measure of domestic varieties (i.e., firms).\footnote{Recall that the measure of imported varieties is assumed to be fixed.} On the one hand, this makes resources more concentrated at more efficient firms, which tends to raise welfare. On the other hand, however, having access to less varieties tend to raise the aggregate price index, due to “love of varieties.” Second, firms get access to cheaper intermediate inputs after trade liberalization, which is a source of welfare gain. Third, in the V.D.E. model, trade liberalization affects welfare by influencing the markup distribution. As Table 7 shows for the V.D.E. model, trade liberalization reduces the dispersion in the markups charged by domestic firms in the Home economy. This in turn reduces the distortionary wedges between firms’ marginal revenue product of labor, which means labor misallocation falls in the economy (Hsieh and Klenow (2009)). Since the markup distribution is degenerate in constant demand elasticity models, this channel is absent in this class of models, including the C.D.E. version of the model presented in this paper. It remains to explain why, in the V.D.E. model, markup distribution gets more dispersed after trade liberalization. Note that, on the one hand, trade liberalization enhances competition in the domestic market. This makes small firms even smaller (see Table 8), and as a result, these firms face larger demand elasticities (see equation 62). Hence, these
firms charge lower markups after trade liberalization. On the other hand, after trade liberalization, large firms get larger, face lower demand elasticities, and charge higher markups.

Finally, the rise in job turnover after openness leads to more frequent reallocation of jobs from less to more efficient firms, which may be a source of welfare gain. However, in this class of models that wages are the solution to Nash bargaining on the marginal surplus, firms tend to overhire workers (compared to the efficient allocation) to push the marginal revenue product of labor down (Stole and Zwiebel (1996), Brügemann et al. (2017), and Kaas and Kircher (2015)). As a result, the rise in job turnover may exacerbate the overhiring problem at the large firms. Hence, it is ambiguous whether this rise in job turnover leads to a more efficient outcome. Overall, as Table 7 shows, welfare rises by trade liberalization in both models. Moreover, welfare gains from trade is almost 20% larger in the V.D.E. model compared to the C.D.E. model. This is because, after trade liberalization, firms respond more to their idiosyncratic shocks in the V.D.E. model, compared to the C.D.E. model. This, despite its potential negative consequences for welfare, creates more gains from trade liberalization.

6 Concluding Remarks

This paper shows that because openness affects demand elasticities, it influences productivity through several channels. First, higher demand elasticities make firms’ employment decisions more responsive to their idiosyncratic productivity shocks. This causes aggregate job turnover to rise, and thereby tends to raise unemployment. But second, this same increase in job turnover means that workers are moved more frequently from less to more efficient firms. Finally, to the extent that openness reduces the cross-firm dispersion in markups, it likewise tends to reduce the distortionary wedges between firms’ marginal revenue products. The counterfactual analysis shows a 10 percentage point reduction in import tariffs combined with a 12 percent reduction in the iceberg trade cost raises job turnover and unemployment (in steady state) by roughly 8 and 17 percent, respectively. These effects would be almost four times smaller if demand elasticities were not allowed to respond to openness. The counterfactual analysis of this paper shows that a constant demand elasticity model is not able to generate the observed rise in job turnover and unemployment following trade liberalization in Colombia. Moreover, gains from trade are almost 20 percent larger if one allows demand elasticities to respond to openness.

In this paper, job turnover affects welfare through several channels. First, there is an allocative efficiency gain associated with higher job turnover: higher job turnover results in
jobs more frequently reallocating from less to more efficient firms. Second, however, due to the wage bargaining process, higher job turnover may induce firms to overhire workers, which tends to reduce efficiency. Third, higher job turnover shifts employment toward larger firms that pay higher wages, which in turn reduces the labor market tightness and raises the unemployment rate. This higher unemployment might be a source of inefficiency. In addition to the channels incorporated in this model, there are other mechanisms through which job turnover would influence welfare, which are outside the scope of this paper. First, if workers are risk averse and they do not have access to perfect insurance markets, higher job turnover can hurt workers' welfare. Second, as reported by Farber (1996), the risks of earnings losses are disproportionately born by less-educated workers in the U.S. economy. Hence, higher turnover in the labor market may have important distributional implications, which pertains to ongoing political issue in the United States. Finally, each job requires some firm-specific training and skills which cannot be carried over by workers to a new job. As a result, when a job is destroyed, these firm-specific skills would no longer be useful. Therefore, higher job turnover may result in welfare loss, depending on the importance of firm-specific skills. Quantifying these alternative channels can be future lines of research.

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58 Farber (1996) shows that less-educated workers in the U.S. economy after displacement, will be less likely to find a job than highly educated workers. Furthermore, the latter group experience a lower wage cut after re-employment compared to the former group.

59 This paper abstracts away from ex-ante worker heterogeneity. This is, however, an avenue for my future research.
References


57


Appendices

A Demand Elasticity vs Firms’ Responsiveness: Another Perspective

Section 3 of the paper provided a simple model to show firms with a lower labor elasticity of revenue are more responsive to shocks. This section expresses the same idea via a different, but of course closely related, angle. As discussed in Section 2, trade liberalization makes the demand faced by firms more elastic. The fundamental law of factor demand, discussed in Hamermesh (1996), shows how derived labor demand elasticity and output demand elasticity are linked together:

\[ \frac{\partial l}{\partial w} = -(1-s)\sigma_{l,all} - s\left| \frac{\partial q}{\partial p} \right| \]

(65)

where the LHS is 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 \( \left| \frac{\partial q}{\partial p} \right| \) is output demand elasticity. This equation shows as output demand becomes more elastic, so does labor demand. This is intuitive: changes in wage (via affecting marginal cost of production and, in turn, output price) has a larger effect on the quantity demanded, and so on labor demand, when output demand is more elastic. Hence, labor demand gets more elastic after trade liberalization, provided that output demand elasticity rises. Now, the claim is that firms are more sensitive to their revenue shocks when they face a more elastic labor demand. Figure A.1 shows this graphically. Suppose we have two different sectors with different labor demand curves \( D_1 \) and \( D_2 \). They face the same labor supply \( S \) and, initially, they are at the same equilibrium \( A \). Now, suppose the same positive revenue shock hits both sectors. Since a revenue shock changes the marginal product revenue of labor, both labor demand curves shift upward with the same magnitude. The new equilibria are \( B \) and \( C \) for the sectors with less and more elastic labor demand, respectively. Notice that the same revenue shock changes employment by more when labor demand is more elastic.

60 In other words, instead of arguing that labor elasticity of revenue is affected by changes in output demand elasticity, here I take the perspective that labor demand elasticity responds to changes in output demand elasticity. These two perspectives are closely connected as labor elasticity of revenue and labor demand elasticity are two sides of the same coin.

61 Note that even if one believes the opposite, i.e. trade liberalization results in higher markups as in, e.g., De Loecker et al. (2016), the main mechanism of the paper goes through, but in the opposite direction: trade liberalization reduces firms’ responsiveness to shocks via reducing demand elasticity. So one expects to see a fall in job turnover in the new steady state of such economy.

62 Equivalently, you could think of the same sector before and after trade liberalization.
**B Final Good Producers Problem**

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

\[
\min_{q(\nu) \geq 0} p(\nu)q(\nu) \quad \text{s.t.} \quad \Psi \left[ M = \int_0^{1+1} (q(\nu) + \alpha) \frac{\sigma-1}{\sigma} \, d\nu \right]^\frac{1}{\sigma-1} \]

where \( \Psi \) is the Lagrange multiplier. The F.O.C.s yield (\( \forall q(\nu) > 0 \))

\[
(q(\nu) + \alpha) \frac{\sigma-1}{\sigma} \int_0^{1+1} (q(\nu) + \alpha) \frac{\sigma-1}{\sigma} \, d\nu \]

\[
= \frac{p(\nu)}{\Psi} \]

Multiplying both sides by \((q(\nu) + \alpha)\) and use the definition of \( M \) yields

\[
(q(\nu) + \alpha)^{\frac{\sigma-1}{\sigma}} M^{\frac{1}{\sigma}} = \frac{p(\nu)(q(\nu) + \alpha)}{\Psi} \]

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

\[
M^{\frac{1}{\sigma}} \int_0^{1+1} (q(\nu) + \alpha)^{\frac{\sigma-1}{\sigma}} \mathbf{1}_{q(\nu) > 0} \, d\nu = \int_0^{1+1} \frac{p(\nu)(q(\nu) + \alpha)\mathbf{1}_{q(\nu) > 0}}{\Psi} \, d\nu \]

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

\[
M^{\frac{\sigma-1}{\sigma}} = \int_0^{1+1} (q(\nu) + \alpha)^{\frac{\sigma-1}{\sigma}} \mathbf{1}_{q(\nu) > 0} \, d\nu + (1 - N_H)\alpha^{\frac{\sigma-1}{\sigma}} \]

Combining the last two equations delivers the Lagrange multiplier.
\[
\Psi = \int_{0}^{1} p(\nu)(q(\nu) + \alpha) \mathbf{1}_{q(\nu) > 0} \, d\nu \quad \frac{1}{M(1 - M^{\frac{1-\sigma}{\sigma}} (1 - N_H) \alpha^{\frac{\sigma-1}{\sigma}})}
\]  

(71)

To find the demand for each variety \( \nu \), rearrange the terms in equation (67) and use the definition of \( M \) to get

\[
(q(\nu) + \alpha)^{\frac{1}{\sigma}} = \frac{M^{\frac{-1}{\sigma}}}{\Psi} p(\nu)
\]

(72)

Rearranging the terms yields

\[
q(\nu) = M \Psi^\sigma p(\nu)^{-\sigma} - \alpha
\]

(73)

Defining the aggregate demand shifter \( A := M \Psi^\sigma \) delivers the demand for variety \( \nu \) as expressed in the text

\[
q(\nu) = Ap(\nu)^{-\sigma} - \alpha
\]

(74)

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

\[
\varepsilon(\nu) = -\frac{\partial q(\nu)}{\partial p(\nu)} \frac{p(\nu)}{q(\nu)} = -\frac{\sigma Ap(\nu)^{-\sigma}}{q(\nu)} = \frac{\sigma Ap(\nu)^{-\sigma} - \sigma \alpha + \sigma \alpha}{q(\nu)} = \frac{\sigma q(\nu) + \sigma \alpha}{q(\nu)} = \sigma(1 + \frac{\alpha}{q(\nu)})
\]
C An Alternative Model to Generate Variable Demand Elasticity

C.1 Environment

The environment is exactly the same as the model presented in the text. There are two countries in the world, Home (or H) and rest of the world (or F). Home is a small open economy. There are two types of goods: intermediate goods, which are tradable, and the final good, which is non-tradable. The final good producers bundle the intermediate goods (both domestic and imported) and make the final good to be sold to consumers as well as intermediate good producers (both domestic and Foreign) in a perfectly competitive market. Labor is not used in producing the final good. Each intermediate good producer employs workers and the final good to produce a particular variety with proprietary technology. These firms are subject to idiosyncratic productivity shocks. Intermediate producers sell their goods to the final good producers in an oligopoly market. Firms hire workers in a frictional labor market. There is a unit measure of homogeneous infinitely lived workers who own the firms. Workers are risk-neutral.

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) consumers as well as intermediate good producers. The final good is produced according to the following commonly available technology:

\[
M = \left[ \int_0^1 Q(\nu)^{\sigma-1} d\nu \right]^{\frac{1}{\sigma-1}}
\]  

(75)

where \( \sigma \) is the elasticity of substitution. Similar to the Atkeson and Burstein (2008) structure, I assume that each good \( \nu \) is a CES aggregate of a Foreign and (potentially) a domestic variety:

\[
Q(\nu) = \left[ q_{HH}(\nu)^{\sigma'-1} + q_{FH}(\nu)^{\sigma'-1} \right]^{\frac{\sigma'}{\sigma'-1}}
\]

(76)

where subscript \( iH \) refers to the goods produced in country \( i \) and sold at Home. I assume all products \([0, 1]\) produced by Foreign and exported to Home. However, an endogenous subset of goods \([0, N_H]\) produced by Home and may be exported to Foreign, where \( N_H \) is an equilibrium object. The elasticity of substitution between the domestic and Foreign varieties

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\(^{63}\)I also call it “Foreign” in what follows.

\(^{64}\)Recall that the final good is non-tradable.

\(^{65}\)Rather than assuming a duopoly, Atkeson and Burstein (2008) allow for more than two competitors. The section C.2.1 below explains why this paper imposes duopoly.
within the same good $\nu$ is $\sigma'$.\footnote{It is natural to think that the elasticity of substitution between varieties of a particular good $\nu$ is greater than that between different goods, i.e. $\sigma' \geq \sigma$. This implies that larger firms charge higher markups, which is in line with the empirical literature: among others, see Atkin et al. (2015) for Pakistan; De Loecker and Warzynski (2012) for Slovenia; De Loecker et al. (2016) for India; Edmond et al. (2015) for Taiwan.} Within each good $\nu$, Home and Foreign varieties compete in prices.\footnote{Another version of the model assuming Cournot competition produces similar qualitative outcomes.} Parameters $\sigma$ and $\sigma'$ govern the price elasticity of demand (i.e. demand elasticity) faced by the intermediate producers. This will be elaborated on below.

I assume that the homogeneous final good is produced by a unit measure of producers and sold in a perfectly competitive market. These producers set the price $P$ that, in equilibrium, results in zero profit. As for consumers, I assume per-period utility of consumer $j$ at time $t$ is equal to her consumption of this final good:

$$U_{jt} = M(I_{jt})$$ (77)

where consumer $j$’s demand for final good depends on her income $I_{jt}$. Consumers maximize the expected present value of their utility stream:

$$U_j = \sum_{t=1}^{\infty} \beta^{t-1} U_{jt}$$ (78)

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

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 (10). Solving the cost minimization problem of the Home final good producers implies that these producers demand the following amount of the intermediate good $\nu$ from the Home variety:

$$q_{HH}(\nu) = A_H P_H(\nu)^{\sigma' - \sigma} p_{HH}(\nu)^{-\sigma'}$$ (79)

where $A_H$ is the Home aggregate demand shifter, $P_H(\nu)$ is the price index for good $\nu$ to be defined below, and $p_{HH}(\nu)$ is the price that the Home variety of good $\nu$ charges at Home. The price index for good $\nu$ is defined as

$$P_H(\nu) = [p_{HH}(\nu)^{1-\sigma'} + p_{FH}(\nu)^{1-\sigma'}]^{-\frac{1}{1-\sigma'}}$$ (80)

where $p_{FH}(\nu)$ is the price that the Foreign variety of good $\nu$ charges at Home. Similarly,
as derived in equation (85) below, a counterpart of this demand equation holds for Foreign demand of this Home variety. Using these two demand equations and following Atkeson and Burstein (2008), one shows that the Home variety of good \( \nu \) faces the following demand elasticity in market \( i \):

\[
\varepsilon_i(\nu) = s_i(\nu)\sigma + (1 - s_i(\nu))\sigma' \tag{81}
\]

where \( \varepsilon_i(\nu) \) is the (absolute value of) demand elasticity that the Home variety of good \( \nu \) faces in market \( i \), and \( s_i(\nu) \) is share of the Home variety from total sales of good \( \nu \) in market \( i \).

Few points are in order. First, as \( \sigma \) or \( \sigma' \) rises, intermediate good producers face more elastic demand curves. Second, fixing the productivity of the Foreign variety producer, more productive domestic producers have a larger market share, and therefore, face lower demand elasticities and charge higher markups, which is in line with the literature. Furthermore, trade liberalization makes the domestic market more accessible to Foreign producers, and therefore, reduces the share of domestic producers at Home. Hence, as can be seen from a numerical example in Figure C.1, trade liberalization tends to raise the demand elasticities faced by domestic producers at Home.\(^{69}\) Finally, in the special case of \( \sigma' = \sigma \), we are back in the constant demand elasticity world in which all intermediate producers face the same demand elasticity, which is invariant to trade liberalization. The demand structure employed here nests the commonly used workhorse of international trade and Macro models: imposing \( \sigma = \sigma' \), we are back in the monopolistic competition world with CES preferences. Hence, the demand structure used here is more general than that class of models. A nice feature of this structure is that the main mechanism of the model, which is the responses of demand elasticities to trade liberalization, can be simply shut down to study its implications.

\section*{C.2.1 Discussion}

Atkeson and Burstein (2008) and Edmond et al. (2015) use a similar demand structure, but with multiple producers within each good \( \nu \). This is affordable in a static framework like ones used by the aforementioned papers, or even in a dynamic setup with no labor adjustment cost. However, as can be seen from the firm’s vacancy posting problem, allowing for more than one producer from the Home country in this paper would require solving a dynamic vacancy posting game, on top of the static pricing game. Given the fact that even the current model is computationally very expensive, the computational burden of allowing for more than one Home variety makes this infeasible. Moreover, the current duopoly structure

\(^{69}\)Note, however, that in the case of a bilateral trade liberalization, domestic exporters get more access to the Foreign market after liberalization. Hence, domestic exporters face a lower demand elasticity in the Foreign market after trade liberalization.
is similar to Bernard et al. (2003), but slightly more general since here I assume a finite, rather than an infinite, elasticity of substitution within each good.

### C.3 Intermediate Good Producers

Each intermediate producer receives an idiosyncratic productivity shock, and employs labor and the final good to produce its particular variety using the following proprietary technology:

\[
q(\phi, l) = \phi M(\phi, l) \eta l^{1-n}
\]  

(82)

where \( \phi \) is productivity, \( l \) is the number of workers employed at the firm, \( M(\phi, l) \) is the composite final good (call it material) defined in equation (10) demanded by the firm \((\phi, l)\), and \( \eta \) is the elasticity of output with respect to material. Intermediate producers are subject to idiosyncratic productivity shocks which follow a stationary Markov process

\[
\ln\phi' = \gamma \ln\phi + \varepsilon, \quad \varepsilon \sim N(0, \sigma^2_\phi)
\]  

(83)

where \( \gamma \) is the persistence of the productivity process and \( \sigma_\phi \) is the variance of the shock.
C.4 Firms’ Static Problem

Final good producers decide only about how much to demand for each variety $\nu$ based on the demand equation (79). The rest of this section focuses on the decisions made by the domestic intermediate good producers. The Foreign firms’ problem is discussed in the last part of this section. Hence, the word “firms” in what follows refers to the domestic intermediate producers.

Firms carry two state variables over time: productivity and the number of workers. Productivity is a state variable since it follows a Markov process. Labor is the other state variable since the hiring cost is non-linear. Moreover, labor market features search and matching friction, à la Mortensen and Pissarides (1994). For an incumbent firm starting this period with the last period productivity and employment $(\phi, l)$ as its state variables, the timing of the events is as follows:

- exit decision
- pay $f_d$ to draw $\phi'$
- death shock
- post vacancies/fire
- bargain on $w(\phi', l')$
- hire, fire
- update state to $(\phi', l')$
- close market
- bargain on wage
- decide to export, how much to buy, and prices to charge in the Home and, if exporting, in the Foreign market.

First, the new productivity shock $\phi'$ realizes. Then, some firms either decide to exit or exogenously hit by a death shock and exit the market. After entrants replaced the exiters, all existing firms decide whether to expand or contract. To expand, they post some vacancies and match with an endogenous number of workers, determined in equilibrium. After hiring/firing, state of the firm updates to $(\phi', l')$. Then the labor market closes. Since labor market is frictional, there exists rent produced at the firms. As a result, firms and workers bargain on the wage. As the last action within each period, firms decide about whether to export, how much material to buy, and prices to charge in the Home and, if exporting, in the Foreign market. In sum, firms decide whether to exit, whether to hire or fire and by how much, composite material to buy, exporting, and prices to charge in each market. Firms solve for these decision variables backward: at the first stage, given the wage and number of workers, firms decide about prices, composite material and export decision. The second stage solves for the wage bargaining given the number of workers. At the third stage, firm solves a dynamic vacancy posting problem to determine the number of workers. Labor market description, wage bargaining process, and dynamic vacancy posting problem are the same as the ones presented in the text, see Sections 4.5 - 4.7. Hence, here I just describe firms’ static pricing problem.

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70Labor adjustment costs in this model is the same as the model presented in the text. See Section 4.5.
Before turning to the firms’ pricing problem, recall that the demand curve that the Home variety of intermediate good $\nu$ faces at Home is

$$ q_{HH}(\nu) = A_H p_H(\nu)^{\sigma'-\sigma} p_{HH}(\nu)^{-\sigma'} $$  \hspace{1cm} (84) $$

Similarly, the Foreign demand for this Home variety can be expressed as

$$ q_{HF}(\nu) = A_F^* p_F^*(\nu)^{\sigma'-\sigma} p_{HF}^*(\nu)^{-\sigma'} $$  \hspace{1cm} (85) $$

where an asterisk indicates that a variable is expressed in terms of the Foreign numeraire (to be explained below), $A_i$ is the aggregate demand shifter in the country $i$, and $q_{Hi}(\nu)$ and $p_{Hi}(\nu)$ are the demand for and the price of the Home variety of good $\nu$ sold in country $i$, respectively.

Firms’ pricing decision is a static problem. At this stage, given the number of workers and the negotiated wage (discussed in Sections 4.5 and 4.7, respectively), a Home firm producing good $\nu$ with productivity $\phi$ and $l$ workers decides about exporting, prices and the material usage by solving the following static optimization problem:\(^{71}\)

$$ \Pi(\phi, l) = \max_{p_{HH}, p_{HF}, M, I^x} [p_{HH} q_{HH} + p_{HF} q_{HF} I^x - PM - f_d - f_x I^x] $$  \hspace{1cm} (86) $$

subject to:

$$ q_{HH} + I^x q_{HF} d \leq \phi M^\eta l^{1-\eta} $$  \hspace{1cm} (87) $$

$$ q_{HH} = A_H p_H(\nu)^{\sigma'-\sigma} p_{HH}^{\sigma'} $$  \hspace{1cm} (88) $$

$$ q_{HF} = A_F^* p_F^*(\nu)^{\sigma'-\sigma} (p_{HF}^*)^{-\sigma'} $$  \hspace{1cm} (89) $$

$$ p_{HF}^* = \frac{p_{HF} \tau}{e} $$  \hspace{1cm} (90) $$

where $p_{Hi}$ is the price that the Home variety producer receives from serving market $i$, $I^x$ is an indicator function which takes 1 if the firm exports and zero otherwise, $P$ is the price of the homogeneous final good (defined below), $f_d$ is fixed cost of production, $f_x$ is fixed cost of serving the Foreign market, $d$ is iceberg trade cost for shipping goods from one country to the other, $\tau$ is import tariff imposed by both Home and Foreign, $P_i(\nu)$ is the CES price index of good $\nu$ in country $i$ (defined below), and an asterisk indicates that a variable is expressed in terms of the Foreign numeraire. I assume there are two numeraires in this

\(^{71}\)For ease of nation, I suppress the dependence of all decision variables on $(\phi, l)$. 

69
model, one in the Home and one in the Foreign market, and \( e \) is the relative price of the former to the latter (I call it “exchange rate” in what follows). For future reference, define firm’s revenue (\( R \)) as sum of the first two terms in (86). Fixed costs are paid in terms of a homogeneous home-produced good. Note that international trade is subject to fixed cost, iceberg cost, and tariff. The first constraint is the feasibility constraint. The second and third constraints are the demand for this good in the Home and Foreign countries, respectively. The last constraint relates the price that the firm receives from exporting (\( p_{HF}^* \)) to the price that Foreign consumers face in the market (\( p_{HF}^* \)). Notice that since the firm and its matched workers \( l \) have already negotiated and agreed to a particular wage (discussed in Section 4.7), the wage bill does not enter the problem above. The CES price indices \( P_H(\nu) \) and \( P_F^*(\nu) \) are defined as

\[
P_H(\nu) = [p_{HH}^{1-\sigma'} + (p_{FH}^*e)^{1-\sigma'}]^{1-\sigma'}
\]

\[
P_F^*(\nu) = [p_{FF}^{1-\sigma'} + (p_{HF}^*e)^{1-\sigma'}]^{1-\sigma'}
\]

where \( p_{Fi}^* \) is the price that the Foreign variety producer receives from serving market \( i \). The price of the homogeneous final good is a CES aggregate of the prices of different goods:

\[
P = \left[ \int P_H(\nu)^{1-\sigma} d\nu \right]^{1-\sigma}
\]

Similarly, the problem of the Foreign firms producing good \( \nu \) can be formulated as follows:

\[
\Pi_F(\nu) = \max_{p_{FH},p_{FF}} \left[ p_{FF}^*q_{FF} + p_{FH}^*q_{FH} - MC \times q \right]
\]

s.t.

\[
q_{FF} + q_{FH}d \leq q
\]

\[
q_{FH} = A_HP_H(\nu)^{\sigma'-\sigma}p_{FH}^{-\sigma'}
\]

\[
q_{FF} = A_F^*P_F^*(\nu)^{\sigma'-\sigma}(p_{FF}^*)^{-\sigma'}
\]

\[
p_{FH} = p_{FH}^*e
\]

where \( MC \) is the marginal cost of production for all Foreign firms, normalized to one. The relative price of the numeraires \( e \) moves around so that the normalizations in Home and Foreign are consistent. The last constraint relates the price that the Foreign firm receives from serving the Home market (\( p_{FH}^* \)) to the price that Home consumers face in the market
The pricing decision of firms does not have a closed form solution unless \( \sigma' = \sigma \), i.e., demand elasticities are the same both across firms and across markets. In the variable demand elasticity case, however, prices, material usage, and exporting decision are solved for numerically. When prices are solved for, total demand can be derived using the demand equations (23) and (24) and then, the material usage can be computed simply using the production function:

\[
M(\phi, l) = (\phi l^{1-\eta})^{-\frac{1}{\eta}} (q_{HH} + I^{x}q_{HF}d)^{\frac{1}{\eta}}
\]  

By comparing the profit of serving only the domestic market and the profit of serving both Home and Foreign markets, firms decide whether to export.\(^\text{72}\) This concludes the description of firms’ static problem. Note that the rest of the model, i.e., labor market and wage bargaining, firms’ vacancy posting problem, entry, equilibrium definition, and the numerical algorithm to solve for the equilibrium, remains the same as the model presented in the text (see Sections 4.5 - 4.8).

\section*{C.5 Identification and Quantitative Analysis}

I estimate this model, like the model presented in the text, using Simulated Method of Moments (SMM). The set of parameters to be estimated remains the same as those in (60), except that the demand parameter \( \alpha \) is replaced with \( \sigma' \). Since this model differs with the model in the text in its demand structure only, it suffices to describe the identification strategy to estimate the demand parameters \( \sigma \) and \( \sigma' \).

The identification strategy for the demand parameters \( \sigma \) and \( \sigma' \) resembles the one presented in the text. Recall the production function of the Home intermediate producer of good \( \nu \) with productivity \( \phi \) and \( l \) workers:

\[
q(\nu) = \phi M(\nu)^{\eta} l^{1-\eta}
\]  

where \( M(\nu) \) is the material usage of this firm. Note that material is the static input of firms, i.e., there is no adjustment cost associated with adjusting material. Moreover, recall that the Home variety of good \( \nu \) faces the following demand elasticity in market \( i \):

\[
\varepsilon_i(\nu) = s_i(\nu) \sigma + (1 - s_i(\nu)) \sigma'
\]  

where \( \varepsilon_i(\nu) \) is the (absolute value of) demand elasticity that the Home variety of good \( \nu \) faces

\(\text{72}\)Note that if a firm decides to serve only the Foreign market, it has to pay both fixed cost of production \( f_d \) and fixed exporting cost \( f_x \). Hence, no firm decides to serve only the Foreign market in equilibrium.
in market $i$, and $s_i(\nu)$ is share of the Home variety from total sales of good $\nu$ in market $i$. This firm’s maximization problem implies the following first order condition (see Appendix F for more details):

$$\frac{\varepsilon_i(\nu)}{\varepsilon_i(\nu) - 1} = \eta \frac{p_i(\nu)q_i(\nu)}{PM_i(\nu)}$$ (102)

where $p_i(\nu)$ is the optimal price charge by this firm in market $i$, $P$ is the unit price of material, and $M_i(\nu)$ is the material usage needed to produce the output $q_i(\nu)$ to be sold in market $i$. Equation (102) says that the markup that this firm charges in market $i$ (i.e., the left-hand-side) is equal to the ratio of the elasticity of output with respect to the static input ($\eta$) over the material share of sale in market $i$ ($PM_i(\phi,l)$). The intuition is that, since material is the static input, the gap between the material elasticity of output and material share of sale has to be due to markup. Combining equations (101) and (102) shows that both demand parameters $\sigma$ and $\sigma'$ influence the material share of sale: given the technology parameter $\eta$, as $\sigma$ or $\sigma'$ rises, the whole distribution of material share of sale shifts to the right. This is because as $\sigma$ or $\sigma'$ rises, firms face higher demand elasticities and, therefore, charge lower markups.

As equation (101) shows, if $\sigma = \sigma'$, the demand elasticity faced by firms would be the same both across firms and across markets. Moreover, equation (102) shows that, under the assumption of $\sigma = \sigma'$, there would be no dispersion in material share of sale; given $\sigma$ and $\eta$, the dispersion in material share of sale rises with $\sigma'$. Based on this identification strategy, I target the 25th, 50th, and 75th percentile of the distribution of material share of sale, as well as the standard deviation of material share of sale to learn about these two demand parameters.

Furthermore, as mentioned above, if one imposes $\sigma = \sigma'$, the demand elasticity that firms face would be the same both across firms and across markets. As Appendix G proves, only in such a world all exporting firms would have the same export share of sale. As equation (101) shows, $\sigma \neq \sigma'$ implies that demand elasticities vary both across firms and across markets. Hence, if $\sigma \neq \sigma'$, there would be a dispersion in export share of sale across exporting firms. My simulation exercises show that as $\sigma' - \sigma$ rises, so does the dispersion in export share of sale across exporting firms. Therefore, I target the standard deviation of export share of sale across exporters to learn about the difference between demand parameters $\sigma$ and $\sigma'$, and also to test whether data reject the assumption of constant demand elasticity (i.e., $\sigma = \sigma'$). Finally, note that these two demand parameters also influence many other moments of the model. For instance, the fraction of firms that decide to export and also the mean of plant-level export share of sale crucially depend on these demand parameters: as $\sigma$ or $\sigma'$ rises, fewer firms find it profitable to export, and moreover, export share of sale among ex-
porters fall. Furthermore, firm size distribution is influenced by demand parameters $\sigma$ and $\sigma'$.

There are few points worth mentioning here. First, some of the dispersion in material share of sale might be due to cross-industry technology differences. However, it turns out that the dispersion in material share of sale across all firms is quite similar to the dispersion within industries: while the dispersion is 0.19 across all firms, the within-industry dispersion ranges from 0.14 to 0.21. Hence, up to the assumption that the production technology is Cobb-Douglas and is the same for all firms within each industry, targeting the distribution of material share of sale to learn about the demand parameters seems plausible. Moreover, note that the production technology as well as the demand side of the model nests a wide range of studies in both the international trade and macro literature.

Second, as the demand elasticity equation (101) implies, larger firms tend to face lower demand elasticities, and, therefore, have lower material share of sale. So one expects to observe a negative correlation between size and material share of sale. This size-material share of sale association would be one of the non-targeted moments of the model which will be explored below. Note that through the lens of this model, if one imposes the constant demand elasticity assumption (i.e., $\sigma = \sigma'$), there would be no correlation between size and material share of sale. Moreover, the dispersion in material share of sale would be zero in the constant demand elasticity model. As a result, these two statistics would be the ones that distinguish between the variable versus constant demand elasticity models. Finally, as a robustness exercise, I plan to estimate the markup distribution using De Loecker and Warzynski (2012) approach and then, directly target this distribution to learn about the demand parameters $\sigma$ and $\sigma'$.

Now that I described the identification strategy to estimate demand parameters $\sigma$ and $\sigma'$, I present estimation procedure and results. First, note that the moments used here to learn about the demand parameters $\sigma$ and $\sigma'$ are the same as those used to learn about the demand parameters $\sigma$ and $\alpha$ in the model presented in the text. Hence, the whole set of data moments targeted here is the same as those presented in Table 4. Moreover, like the model presented in the text, there are two versions of the model being estimated here: one imposes constant demand elasticity (i.e., $\sigma = \sigma'$) and the other one allows for variable demand elasticity (i.e., I estimate both $\sigma$ and $\sigma'$ rather than imposing $\sigma = \sigma'$). Call the former C.D.E. (Constant Demand Elasticity) version of the model and the latter V.D.E. (Variable Demand Elasticity) model. The goal of estimating these two models separately is to show the key role that the endogenous responses of demand elasticities play when the economy hit by an aggregate shock. The counterfactual analysis that follows will pursue this objective.
To estimate both versions of the model, I target the same moments in Table 4 and let the estimator defined in (61) estimate the model. Note, however, that when I impose constant demand elasticity in this model, the model becomes exactly the same as the C.D.E. version of the model presented in the text (i.e., the one that imposes $\alpha = 0$). Hence, the estimated parameters for the C.D.E. version of this model are the same as those presented under the column “Constant Elasticity” in Table 5, where $\sigma' = \sigma$ and also there is no $\alpha$ in this model (see Table C.1 below). It remains to estimate the V.D.E. model. Table C.1 reports the estimation results for both versions of the model. As in the text, standard errors are constructed using the SMM asymptotic variance-covariance matrix.

The estimation results in Table C.1 show that the demand parameters $\sigma$ and $\sigma'$ are significantly different from each other, i.e., we live in a variable demand elasticity world. Now that we have the estimated parameters for both versions of this model, we are ready to perform the counterfactual analysis. The main goal of this exercise is twofold. The first objective is to determine to what extent the variable demand elasticity model is able to capture the observed increase in job turnover and unemployment following the trade liberalization in Colombia. The second aim is to show that allowing for endogenous responses in demand elasticities play a crucial role in deriving the counterfactual outcomes.

As mentioned in the text, Colombia underwent a trade liberalization as well as labor market deregulation in the early 1990s. Starting from 1991, Colombia reduced not only import tariffs, but also non-tariff barriers and licensing reforms (see Attanasio et al. (2004)). As for tariff barriers, the average import tariffs are reduced from 21 percent to around 11 percent (Attanasio et al. (2004)). I simulate the effects of this reduction in import tariffs by reducing the parameter $\tau$ by 10 percentage point, from 1.21 to 1.11, in both C.D.E. and V.D.E. models. As for non-tariff barriers and licensing reforms, since there is no direct way to measure the reduction in non-tariff costs, I proceed as follows. Total export share of revenue in the Colombian economy rises by almost 150 percent from the pre-reform period 1983-1990 to the post-reform period 2000-2012.\(^73\) I reduce the iceberg trade cost $d$ such that both models match the same rise in total export share of revenue. This exercise leads to reducing the iceberg trade cost from 2.5 to 2.2 (12 percent reduction) in the V.D.E. model and from 2.5 to 2.19 (12.5 percent reduction) in the C.D.E. model. Finally, the effects of labor market deregulation are simulated by reducing the labor firing cost $c_f$ by 50% (Heckman and Pages (2000)) in both models.

\(^73\)Note that in the plant-level data that are currently available, exports are not reported from 1992-1999.
Table C.1: Estimated parameters using Simulated Method of Moments

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Variable Elasticity</th>
<th>Constant Elasticity</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\sigma$</td>
<td>demand elasticity parameter</td>
<td>4.951</td>
<td>7.021</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.021)</td>
<td>(0.025)</td>
</tr>
<tr>
<td>$\sigma'$</td>
<td>demand elasticity parameter</td>
<td>14.231</td>
<td>(imposed to be $= \sigma$)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.321)</td>
<td></td>
</tr>
<tr>
<td>$c_v$</td>
<td>hiring cost</td>
<td>4.287</td>
<td>3.668</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.026)</td>
<td>(0.024)</td>
</tr>
<tr>
<td>$c_f$</td>
<td>firing cost</td>
<td>0.635</td>
<td>0.844</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.004)</td>
<td>(0.008)</td>
</tr>
<tr>
<td>$\rho$</td>
<td>matching friction</td>
<td>2.316</td>
<td>3.253</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.019)</td>
<td>(0.031)</td>
</tr>
<tr>
<td>$A^*_F$</td>
<td>aggregate demand shifter in market F</td>
<td>3846.861</td>
<td>1454.282</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(259.17)</td>
<td>(137.63)</td>
</tr>
<tr>
<td>$\eta$</td>
<td>material elasticity of output</td>
<td>0.734</td>
<td>0.693</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.003)</td>
<td>(0.002)</td>
</tr>
<tr>
<td>$f_d$</td>
<td>fixed production cost</td>
<td>9.437</td>
<td>6.849</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.076)</td>
<td>(0.049)</td>
</tr>
<tr>
<td>$f_x$</td>
<td>fixed exporting cost</td>
<td>60.409</td>
<td>30.145</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.595)</td>
<td>(0.211)</td>
</tr>
<tr>
<td>$f_e$</td>
<td>sunk entry cost</td>
<td>195.362</td>
<td>146.752</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(2.971)</td>
<td>(1.971)</td>
</tr>
<tr>
<td>$\gamma$</td>
<td>persistence of productivity shocks</td>
<td>0.927</td>
<td>0.911</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.001)</td>
<td>(0.001)</td>
</tr>
<tr>
<td>$\sigma_\phi$</td>
<td>std. of productivity shocks</td>
<td>0.241</td>
<td>0.229</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.0009)</td>
<td>(0.001)</td>
</tr>
<tr>
<td>$b_u$</td>
<td>workers’ outside option</td>
<td>0.882</td>
<td>0.775</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.004)</td>
<td>(0.002)</td>
</tr>
<tr>
<td>$\lambda$</td>
<td>death shock</td>
<td>0.011</td>
<td>0.064</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.0001)</td>
<td>(0.0005)</td>
</tr>
<tr>
<td>$\xi$</td>
<td>workers’ bargaining power</td>
<td>0.494</td>
<td>0.466</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.005)</td>
<td>(0.003)</td>
</tr>
</tbody>
</table>

Notes: Standard errors are in parenthesis. The “Variable Elasticity” and “Constant Elasticity” columns correspond to the estimated parameters of the variable demand elasticity and constant demand elasticity models, respectively.
Table C.2 reports the counterfactual results. For the sake of brevity, I report the results for job turnover and unemployment only. The counterfactual results using this model resemble the results presented in the text. In particular, as Table C.2 shows, both unemployment and job turnover rise by trade liberalization in the V.D.E. model, and this increase is much more than what the C.D.E. version of the model predicts.

<table>
<thead>
<tr>
<th></th>
<th>V.D.E. model</th>
<th>C.D.E. model</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre</td>
<td>Post</td>
</tr>
<tr>
<td>job turnover</td>
<td>1.0</td>
<td>1.10</td>
</tr>
<tr>
<td>unemployment</td>
<td>1.0</td>
<td>1.16</td>
</tr>
</tbody>
</table>
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 \( P \), a measure of domestic intermediate producers \( N_H \), a measure of entrants \( N_e \), an aggregate income \( I \), a measure of employees \( L_T \) working for intermediate producers, a measure of unemployed individuals \( L_U \), a measure of entrants \( N_e \), an aggregate income \( I \), a measure of employees \( L_T \) working for intermediate producers, a measure of home producers \( N_H \), a measure of entrants \( N_e \), an aggregate income \( I \), a measure of home producers \( N_H \), a measure of unemployed individuals \( L_U \), a measure of home producers \( N_H \), a measure of unemployed individuals \( L_U \), a measure of workers at home \( L_H \), the labor market tightness \( \theta \), the job finding rate \( m(\theta) \), the exchange rate \( e \), the employment policy function \( l'(\phi, l) \), continuation policy function \( I_c(\phi, l) \), firing policy function \( I_f(\phi, l) \), firing wage schedule \( w_f(\phi, l) \), non-firing wage schedule \( w_{nf}(\phi, l) \), export policy function \( I_x(\phi, l) \), prices \( p^{HH}(\phi, l) \) and \( p^{HF}(\phi, l) \) charged by domestic intermediate producers, quantities \( q^{HH}(\phi, l) \) and \( q^{HF}(\phi, l) \) produced by domestic intermediate producers, price \( p^{*FH} \) charged by foreign producers in the domestic market, quantity \( q^{FH} \) sold by foreign producers in the home economy, 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 workforce. 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:

\[
G(\phi', l) = \begin{cases} 
\frac{N_e}{N_H} J^0(\phi') + (1 - \lambda) \int I_c(\phi, l) J(\phi, l) T(\phi' | \phi) d\phi & l = l_e \\
(1 - \lambda) \int I_c(\phi, l) J(\phi, l) T(\phi' | \phi) d\phi & l \neq l_e 
\end{cases} 
\]  

(103)

where \( T(\phi' | \phi) \) is the transition density of the productivity Markov process, \( J^0(.) \) is the ergodic distribution implied by the productivity Markov process, \( l_e \) is the number of workers that entrants start with upon entry, and \( \lambda \) is the exogenous death rate. The first term of the first equation in (103) corresponds to the entrants, all of which 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:

\[
N_e = N_H \left[ \lambda \int_{\text{exogenous exit}} + (1 - \lambda) \int_{\text{endogenous exit}} \int_\phi \int_l (1 - I_c(\phi, l)) J(\phi, l) dld\phi \right] 
\]  

(104)

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

$$J(\phi, L) = \frac{\int_{l} G(\phi, l) \mathbf{1}_{T(\phi, l) = L} dl}{\int_{\phi} \int_{l} G(\phi, l) \mathbf{1}_{T(\phi, l) = L} dl d\phi}$$  \hspace{1cm} (105)$$

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 good producers,\(^74\)

$$L_T = N_H \int_{\phi} \int_{l} lJ(\phi, l) dld\phi$$  \hspace{1cm} (106)$$

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

$$U_{\text{inflow \begin{align} \text{begin}}} = \lambda L_T + (1 - \lambda) N_H \int_{\phi} \int_{l} (1 - I^c(\phi, l)) lJ(\phi, l) dld\phi$$  \hspace{1cm} (107)$$

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

$$U_{\text{inflow \begin{align} \text{mid}}} = N_H \int_{\phi} \int_{l} I^f(\phi, l)(l - l'(\phi, l)) G(\phi, l) dld\phi$$  \hspace{1cm} (108)$$

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

$$U_{\text{inflow \begin{align} \text{}} = U_{\text{inflow \begin{align} \text{begin}}} + U_{\text{inflow \begin{align} \text{mid}}}$$  \hspace{1cm} (109)$$

Sum of the inflow to the unemployment pool as well as unemployed individuals from last period search for a job at the intermediate sector

$$\text{job seekers} = U_{\text{inflow \begin{align} \text{}} + L_U$$  \hspace{1cm} (110)$$

where $L_U$ is the measure of unemployed individuals. An endogenous fraction of these applicants (which is the job finding rate) find a job.\(^75\) Hence, outflow from the unemployment pool can be written as follows:

\(^74\)Recall that final good producers do not hire labor.

\(^75\)Note that in equilibrium, workers are indifferent between working at the tradable or non-tradable sector. Hence, no non-tradable worker decides to search for a job at the tradable sector.
\[ U_{\text{outflow}} = (U_{\text{inflow}} + L_U)m(\theta) \] (111)

In equilibrium, inflow to and outflow from the unemployment pool are equal so that the measure of unemployed individuals is constant. Therefore, rearranging equation (111) yields

\[ L_U = 1 - \frac{m(\theta)}{m(\theta)} U_{\text{inflow}} \] (112)

Now that we have \( L_T \) and \( L_U \) from equations (106) and (112), respectively, the measure of individuals who decide to home-produce equals

\[ L_H = 1 - L_T - L_U \] (113)

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

\[ \text{unemployment rate} = \frac{L_U}{L_U + L_T} \] (114)

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 \( p_{HH}(\phi, l) \) and \( p_{HF}(\phi, l) \), quantities \( q_{HH}(\phi, l) \) and \( q_{HF}(\phi, l) \), and export decision \( I^x(\phi, l) \) solve the domestic intermediate producers’ problem in (21). Moreover, the price \( p_{FH}^* \) and the quantity \( q_{FH} \) solve the foreign firms’ problem in (94).

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

\[ EX = \int_{\phi} \int_{l} p_{HF}(\phi, l)q_{HF}(\phi, l)I^x(\phi, l)J(\phi, l)dl d\phi \] (115)

\[ IM = A_H e(p_{FH}^*)^{1-\sigma}(\tau e)^{-\sigma} - \alpha e p_{FH}^* \] (116)

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

\[ M^* = [N_H \int_{\phi} \int_{l} (q_{HH}(\phi, l) + \alpha)^{\frac{\sigma-1}{\sigma}} J(\phi, l)dl d\phi + (1 - N_H)\alpha^{\frac{\sigma-1}{\sigma}} (q_{FH} + \alpha)^{\frac{\sigma-1}{\sigma}}]^{\frac{\sigma}{\sigma-1}} \] (117)
where $N_H$ is the measure of active domestic intermediate producers who produce a positive quantity. Recall that the final good is demanded by both consumers and intermediate good producers. Hence, total demand of the final good can be expressed as

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

(118)

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

$$I = N_H \int_{\phi} \int_{l} \Pi(\phi, l)J(\phi, l)dl d\phi - N_H \int_{\phi} \int_{l} C(l, l'(\phi, l))G(\phi, l)dl d\phi - N_e f_e + IM(\tau - 1) + PM - N_H \int_{\phi} \int_{l} p_{HH}(\phi, l)q_{HH}(\phi, l)J(\phi, l)dl d\phi - q_{FH} p_{FH} \tau e + b_u L_U + L_H$$

(119)

where $\Pi(\phi, l)$ is defined in (21). 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 fifth, sixth, and seventh terms are final producers’ sale, cost of domestic inputs, and cost of foreign inputs, respectively. The last two terms are the total production by unemployed individuals as well as home-producers.

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

$$L_h + b_u L_U = \underbrace{N_e f_e}_{\text{supply}} + \underbrace{N_H \int_{\phi} \int_{l} C(l, l'(\phi, l))G(\phi, l)dl d\phi}_{\text{entry cost}} + \underbrace{N_H f_d}_{\text{labor adjustment cost}} + \underbrace{N_H f_x \int_{\phi} \int_{l} \Pi(\phi, l)J(\phi, l)dl d\phi}_{\text{fixed prod. cost}} + \underbrace{N_H f_x \int_{\phi} \int_{l} \Pi(\phi, l)J(\phi, l)dl d\phi}_{\text{fixed exporting cost}}$$

(120)

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

$$V^e := \int V^C(\phi, l_e) dJ^0(\phi) = f_e$$

(121)

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

\[ W^a = W^h = W^u \]
E Numerical Algorithm to Solve for Stationary Equilibrium

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

**Step 1:** Guess the equilibrium objects $A_H$, $w_f(\phi, l)$, $w_{nf}(\phi, l)$, $\theta$, $e$, $P$, and $N_H$.

**Step 2:** Given all the aggregate equilibrium objects, compute the value function $V(\phi, l)$ in (35). Then, compute the value of entry $V^e$ in (42). 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:** Recall that in equilibrium $W^h = W^u$. First, use equation (51) to compute the value of unemployment $W^u$. Then, use (56)-(57) to compute the value function $W^e(\phi, l)$. Then, use equation (47) to compute the firing wage schedule $w_f(\phi, l)$. If the firing wage schedule does not match the initial guess, go back to step 1 with the new firing wage schedule. Repeat steps 1-3 until the $w_f(\phi, l)$ converges.

**Step 4:** First, use equation (48) to calculate the non-firing wage schedule $w_{nf}(\phi, l)$. To do so, since I have discretized the state space, compute the surplus generated by the last worker as

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

(123)

where $\Delta$ is size of the employment grid. This is a recursive formulation that can be easily computed. The marginal surplus generated at a firm with the minimum employment $l_e$ is

$$S^F(\phi, l_e) = [\Pi(\phi, l_e) - w_{nf}(\phi, l_e)l_e + \beta V(\phi, l_e)] - [-f_d]$$

(124)

Notice that, in a firm with $l_e$ workers, if the marginal worker quits the firm, 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 (49)-(50) to compute the non-firing wage schedule $w_{nf}(\phi, l)$. If the non-firing wage schedule does not match the initial guess, go back to step 1 with the new non-firing wage schedule. Repeat steps 1-4 until $w_{nf}(\phi, l)$ 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 (52). If $W^a$ exceeds (falls behind) $W^u$, reduce (raise) labor market tightness and go back to step 1. Iterate steps 1-5 until $W^a$ equals $W^u$.

**Step 6:** Compute total exports and total imports using (115)-(116). If total exports exceed (fall behind) total imports, reduce (raise) the exchange rate $e$ and go back to step 1. Iterate steps 1-6 until total exports equal total imports.

**Step 7:** Compute the supply of and demand for the final good using (117)-(118). If the supply exceeds (falls behind) the demand, reduce (raise) the price $P$ and go back to step 1. Iterate steps 1-7 until the supply equals the demand.

**Step 8:** Use equation (120) 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 1-8 until the supply equals the demand.
F Derivation of Markups

To estimate the parameters governing demand elasticities in the model, i.e. $\sigma$ and $\alpha$, I use the distribution of material share of sale. The idea is that, as this section shows, given the material elasticity of output $\eta$, 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:

$$Q = Q(s^1, ..., s^n, d^1, ..., d^m, \phi) \quad (125)$$

where $s^i$ is a static (freely adjustable) input, $d^i$ a dynamic (costly adjustable) input, and $\phi$ 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:

$$L = \sum_{i=1}^{n} p^{s_i} s_i + \sum_{i=1}^{m} p^{d_i} d_i + \lambda(Q - Q(.)) \quad (126)$$

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

$$p^{s_i} = \lambda \frac{\partial Q(.)}{\partial s^i} \quad (127)$$

where $\lambda$ is Lagrange multiplier. Rearranging terms yields:

$$\frac{P}{\lambda} = \left( \frac{\partial Q(.)}{\partial s^i} s^i \right) \frac{PQ}{Q} P^{s_i} s^i \quad (128)$$

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.\footnote{This approach doesn’t allow for dynamic pricing, which is consistent with the model presented in Section 4.}
G Relation between Export Share of Revenue and Demand Elasticity

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

$$q_{iJ} = A_J p_{iJ}^{-\sigma_{iJ}}$$  \(129\)

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:

$$\max_{p_{iH}, p_{iF}} \left[ p_{iH} q_{iH} + p_{iF} q_{iF} \right]$$  \(130\)

s.t.

$$\lambda (q_{iH} + q_{iF} d) \leq Q$$  \(131\)

where $d$ is the iceberg trade cost, $Q$ is the firm’s total production, and $\lambda$ is the Lagrange multiplier. Substituting the demand equations (129) into (130) yields the following F.O.C.s:

$$p_{iH} = \frac{\sigma_{iH}}{\sigma_{iH} - 1} \lambda$$  \(132\)

$$p_{iF} = \frac{\sigma_{iF}}{\sigma_{iF} - 1} \lambda d$$  \(133\)

Using the first F.O.C. to remove $\lambda$ yields

$$p_{iF} = \psi_i p_{iH} d$$  \(134\)

where

$$\psi_i = \frac{\sigma_{iF}}{\sigma_{iF} - 1} \frac{\sigma_{iH} - 1}{\sigma_{iH}}$$  \(135\)

Now, using the demand equations (129), let’s derive the Export Share of Sale (ESS) for the Home exporter $i$:

$$\text{ESS}_i = \frac{p_{iF} q_{iF}}{p_{iH} q_{iH} + p_{iF} q_{iF}} = \frac{A_F p_{iF}^{1-\sigma_{iF}}}{A_H p_{iH}^{1-\sigma_{iH}} + A_F p_{iF}^{1-\sigma_{iF}}}$$  \(136\)

Using equation (134) in (136) yields
\[ \text{ESS}_i = \frac{A_F p_{iH}^{1-\sigma_iF} (\psi_i d)^{1-\sigma_iF}}{A_H p_{iH}^{1-\sigma_iH} + A_F p_{iH}^{1-\sigma_iF} (\psi_i d)^{1-\sigma_iF}} = \frac{A_F p_{iH}^{1-\sigma_iF} (\psi_i d)^{1-\sigma_iF}}{A_F p_{iH}^{1-\sigma_iF} (\psi_i d)^{1-\sigma_iF} \left( \frac{A_H p_{iH}^{\sigma_iF-\sigma_iH} (\psi_i d)^{\sigma_iF-1}}{A_H p_{iH}} \right) + 1} \]

(137)

which yields

\[ \text{ESS}_i = \frac{1}{\frac{A_H p_{iH}^{\sigma_iF-\sigma_iH} (\psi_i d)^{\sigma_iF-1}}{A_H} + 1} \]

(138)

Notice that, in general, export share of sale 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 share of sale:

\[ \forall i : \text{ESS}_i = \frac{1}{\frac{A_H p_{iH}^{\sigma_iF-\sigma_iH} (\psi_i d)^{\sigma_iF-1}}{A_H} + 1} \]

(139)

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 (138) shows that the export share of sale varies across firms:

\[ \text{ESS}_i = \frac{1}{\frac{A_H p_{iH}^{\sigma_iF-\sigma_iH} (\psi d)^{\sigma_iF-1}}{A_H} + 1} \]

(140)

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., \( \sigma_iH = \sigma_iF = \sigma_i \), export share of sale would vary across firms:

\[ \text{ESS}_i = \frac{1}{\frac{A_H p_{iH}^{\sigma_iF-\sigma_iH} (\psi d)^{\sigma_iF-1}}{A_H} + 1} \]

(141)

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