Firm Dynamics, Job Turnover, and Wage Distributions in an Open Economy

(second draft)

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Abstract

This paper explores the effects of tariffs, trade costs, and firing costs on firm dynamics and labor markets outcomes. Tne analysis is based on a general equilibrium model with labor market search frictions, wage bargaining, severance costs, firm-specific productivity shocks, and endogenous entry/exit decisions.

Firing costs reduce firms' profits and discourage them from quickly adjusting their employment levels in response to idiosyncratic shocks. Tariffs and other trade costs reduce rents for efficient firms and increase rents for inefficient firms, as in Melitz (2003). These well-known effects interact with idiosyncratic productivity shocks and with scale economies in hiring costs to determine the equilibrium size distribution of firms, entry/exit rates, job turnover rates, rate of informality, and cross-firm wage distributions.

After fitting this model to Colombian micro data on establishments and households, we use counter-factual simulations to isolate the effects of that country's trade liberalization and labor market reforms circa 1990. We find that since tariff cuts shifted jobs toward large, stable firms, they *reduced* job turnover and informality in the long run. Similarly, since firms pay higher wages when they wish to rapidly expand, the shift of jobs toward such firms compressed the top end of the wage distribution. On the other hand, Colombia's cuts in firing costs led some large inefficient producers to contract, increased average wages, and drove up job turnover rates and informality.

1 Introduction

Job insecurity, high unemployment, large informal sectors, and wage inequality are long-standing concerns in Latin America. During the 1990s, following a wave of trade liberalization episodes and labor market reforms, these problems grew worse for many countries in the region.[1] But the extent to which trade and labor policy reforms contributed to deteriorating labor market conditions remains an open question. Several other forces were also in play, including skill-biased technological change, privatization, and macroeconomic shocks (Interamerican Development Bank, 2004).

To better isolate the effects of openness and labor market policies on workers in these countries, we formulate a dynamic structural model of trade with labor market frictions. Then we fit our model to plant-level panel data and household survey data from Colombia—a country that substantially reduced tariffs and firing costs during the late 1980s and early 1990s. Finally, we use counterfactual simulations to estimate the effects of tariff reductions, better access to foreign markets, and reductions in firing costs on job turnover patterns and the wage distribution.

Openness affects labor markets in our model because it increases rents for efficient firms and reduces rents for inefficient firms, as in Melitz (2003). These well-known effects interact with idiosyncratic productivity shocks, search frictions, firing costs, and scale economies in hiring costs to induce adjustments in the equilibrium job turnover rate, unemployment rate, and wage distribution as trade barriers are dismantled.

Our model shares some features with a number of recent trade models that describe the effects of openness on labor markets in static settings (Helpman and Itskhoki (2007); Helpman,

[1] Inter-American Development Bank (2004) summarizes the deterioration in Latin American labor market conditions and notes that "Between the mid-1980s and the beginning of the 1990s, countries in Latin America began trade liberalization programs, with reductions of at least 15 percentage points in the average tariff rate, which fell from an average of 48.9 percent in the pre-reform years to 10.7 percent in 1999." (p. 137). Heckman and Pages (2004) survey labor market regulations in Latin America, observing that "the new openness to international trade increased the demand for labor market flexibility." They point to Argentina, Colombia, Ecuador, Nicaragua and Peru as examples of countries that fit this pattern. Haltiwanger et al (2004) document the association between job turnover and openness in Latin America. Goldberg and Pavcnik (2007) survey the evidence linking openness to wage inequality and informality in Latin America and other developing regions.

et al (2008); Egger and Kreickemeier (2007); Amiti and Davis (2008); Davis and Harrigan (2008); Felbermayr et al (2008).[2] In particular, it embodies Melitz's (2003) basic insight that openness compounds the advantages enjoyed by relatively efficient firms. However we depart from this literature in two fundamental ways. First, we assume that firms experience ongoing, idiosyncratic productivity shocks (as in Hopenhayn (1992) and Hopenhayn and Rogerson (1993)), and they respond by adjusting their vacancy postings, lay-offs and exit decisions (as in Bertola and Caballero (1994), Bertola and Garibaldi (2001), and Koeniger and Prat (2007)).[3] Second, we fit our model to micro data and use it to perform counterfactual experiments. In addition to characterizing the effects of trade and labor policies on workers at different types of firms, this exercise yields findings on the magnitude of vacancy posting costs, the costs of creating a new firm, and various other parameters of interest.

While we do not pretend to capture all of the channels through which openness and firing costs can affect labor market outcomes, our focus on firm-level entry, exit and idiosyncratic productivity shocks is supported by existing empirical evidence on the sources of job turnover and wage heterogeneity. Studies of job creation and job destruction invariably find that most reallocation is due to idiosyncratic (rather than industry-wide) adjustments (Davis et al (1998); Roberts (1996); Inter-American Development Bank (2004)). "This is true even in Latin America's highly volatile macro environment" where producer entry and exit alone account for 30-40 percent of job creation and destruction (Inter-American Development Bank (2004), chapter 2). Further, as Goldberg and Pavcnik (2007) note, if openness has had a

[2] Several less-related linkages between openness and labor market outcomes have been modeled in the recent trade literature. One strand of this literature emphasizes the changes in skill-premia and/or unemployment rates that result from trade-induced changes in the relative demand for different types of labor (e.g., Albrecht and Vroman, 2002; Yeaple, 2005; Davidson et al, 2006). Another characterizes the adjustments in wages, unemployment and labor turnover patterns that derive from trade-induced changes in sectoral output prices (e.g., Kambourov, 2006; Artuc, Chaudhuri and McClaren, 2008). And finally, some studies have focussed on cross-country differences in the flexibility of labor markets as a source of comparative advantage (Davidson et al, 1999; Cunat and Melitz, 2007; Helpman and Itskhoki, 2008).

[3] Other recent papers that study firm dynamics and labor market frictions in a closed economy context include Cooper et al (2007), Hobijn and Sahin (2007), and Lentz and Mortensen (2008). Utar (2008) studies firm dynamics and labor market fricttions in an import-competing industry that takes the wage rate as given.

significant effect on job flows, it has mainly been through *intra*-sectoral effects: "Most studies of trade liberalization in developing countries find little evidence in support of [trade-induced labor] reallocation across sectors." Finally, while cross-worker differences in wages are obviously partly due to differences in worker characteristics, much is attributable to labor market frictions and firm heterogeneity.[4]

2 The Model

The model extends Bertola and Cabellero (1994) and Bertola and Garibaldi (2001) to a general equilibrium setting with fully articulated product markets, international trade, arbitrary (stationary) Markov processes for productivity shocks and endogenous firm entry and exit.

2.1 Preferences

We consider an economy populated by a fixed supply of homogeneous, infinitely-lived worker-consumers who purchase two types of output: homogeneous services and differentiated industrial goods. These agents derive no disutility from work, and their consumption preferences are given by:

$$\mathcal{U} = \sum_{t=1}^{\infty} \left(\frac{1}{1+r} \right)^t U(s_t^c, q_t^c),$$

where r is the rate of time preference, s_t^c is consumption of services, and q_t^c is an index of industrial good consumption. Their momentary utility function U takes the form

$$U(s_t^c, q_t^c) = \frac{(s_t^c)^{1-\gamma} (q_t^c)^{\gamma}}{(1-\gamma)^{1-\gamma} \gamma^{\gamma}}, \tag{1}$$

where $\gamma \in (0,1)$ and their preferences over individual industrial goods are given by:

$$q_t^c = \left(\int_0^{N_t} q_t^c(n)^{\frac{\sigma-1}{\sigma}} dn \right)^{\frac{\sigma}{\sigma-1}}. \tag{2}$$

[4]Studying data from France and the United States, Abowd, et al (1999) and Abowd, et al (2002) show that roughly half of the cross-worker variation in compensation in French workers is due to employer effects. The only study of employer-employee data in developing countries we are aware of is Menezes-Filho and Muendler (2007). This paper does not report results on sources of wage variation.

Here N_t measures the mass of differentiated good varieties at time t, $q_t^c(n)$ is consumption of good n at time t and $\sigma > 1$ is the elasticity of substitution between varieties.

Services are non-traded, but N_F of the N_t differentiated goods are produced abroad. Suppressing time subscripts, and letting $p_F(n)$ be the foreign-currency denominated f.o.b. price of imported variety n, the exact price index for imported goods is $P_F = \tau_m \tau_c k \left[\int_0^{N_F} p_F(n)^{1-\sigma} dn\right]^{1/(1-\sigma)}$, where k is the price of foreign currency, $(\tau_c - 1)$ is the iceberg transport cost per unit shipped and $(\tau_m - 1)$ is the *ad valorem* tariff rate on imports. Similarly, letting $p_H(n)$ be the price of domestic variety n, the exact price index for domestic goods is $P_H = \left(\int_{N_F}^{N} p_H(n)^{1-\sigma} dn\right)^{1/(1-\sigma)}$.

Several normalizations simplify notation. First, since the set of available foreign varieties and their f.o.b. prices are exogenous to our model, we fix $\left[\int_0^{N_F} p_F(n)^{1-\sigma} dn\right]^{1/(1-\sigma)} = 1$ by choice of foreign currency units. This allows us to write the exact price index for the composite industrial good q^c as

$$P = [P_H^{1-\sigma} + (\tau_m \tau_c k)^{1-\sigma}]^{\frac{1}{1-\sigma}}. \tag{3}$$

Second, without loss of generality we choose the price of services to be our numeraire.

Disallowing savings, utility maximization implies that worker i with income I_i demands $q_{Hi}^c(n) = \frac{\gamma I_i}{P} \left(\frac{p_H(n)}{P}\right)^{-\sigma}$ units of domestic variety n and $q_{Fi}^c(n') = \frac{\gamma I_i}{P} \left(\frac{\tau_m \tau_c k p_F(n')}{P}\right)^{-\sigma}$ units of imported variety n'. Aggregating over worker-consumers, these expressions in turn imply that total domestic demand for domestic variety n is

$$q_H^c(n) = \int_0^1 q_{Hi}^c(n) di = D_H p_H(n)^{-\sigma}, \tag{4}$$

where $D_H = \gamma P^{\sigma-1} \int_0^1 I_i di$ and the mass of domestic worker-consumers is normalized to measure 1. Similarly, total domestic demand for imported good n is

$$q_F^c(n) = \int_0^1 q_{Hi}^c(n) di = D_H \left[\tau_m \tau_c k p_F(n)\right]^{-\sigma}. \tag{5}$$

2.2 Production Technologies

Services are supplied by service-sector firms and, less efficiently, by unemployed workers engaged in home production. Regardless of their source, services are produced with labor alone, homogeneous across suppliers, and sold in competitive product markets. Firms that supply services use a common constant returns technology, and face no hiring or firing costs. So with an appropriate choice of output units we may write their combined supply of services as

$$S = L_S, \tag{6}$$

where L_S is labor employed in the service sector. Workers who home-produce service goods each generate $b < 1$ units of output.

Industrial goods cannot be home-produced. They must be supplied by industrial-sector firms, which pay a sunk start-up cost to initiate production of a single variety of output. Each firm produces its output using labor alone and competes in the monopolistically competitive product market. Unlike service-sector firms, suppliers of industrial goods are subject to ongoing idiosyncratic productivity shocks, and they must create costly vacancies in order to attract new workers. (The shocks they face can equally well be thought of as affecting the relative appeal of their products.) In the industrial sector, output of producers with productivity level z is given by

$$q(z, l) = zl^{\alpha}, \tag{7}$$

where l is the labor input and $\alpha > 0$. Productivity is firm-specific, independent across firms, and serially correlated. Its evolution is characterized by the transition density $h(z'|z)$, which is common to all firms. Productivity shocks together with firms' employment policies and entry/exit policies determine the steady state distribution of firms across (z, l), which we denote by $f(z, l)$.

Producer dynamics in the industrial sector resemble those in Hopenhayn and Rogerson (1993) in that firms react to their productivity shocks by optimally hiring, firing or exiting.

Also, new firms enter whenever their expected future profit stream exceeds the entry costs they face. However, unlike Hopenhayn and Rogerson (1993), we assume hiring in the industrial sector is subject to search frictions captured by a standard matching function. Labor market frictions generate rents that are bargained over between worker and firms, and firms end up paying different wages depending on their current productivity and labor force, as well as whether they are hiring or firing workers. Further, workers maximize the present value of their expected welfare by making forward-looking decisions concerning which sector to work in and what job offers to accept. We now describe the functioning of labor markets in more detail.

2.3 Labor Markets and the Matching Technology

The service sector labor market is frictionless so, given that the price of services is unity, the service sector wage is $w_s = 1$. Search frictions make things more complicated in the industrial sector. Each period the number of new matches between unemployed workers and vacancy posting firms is given by

$$M(V, L_u) = \frac{V L_u}{(V^\theta + L_u^\theta)^{1/\theta}},$$

where L_u is the measure of unemployed workers searching in industrial sector and V is the measure of vacancies in industry.[5] Consequently, industrial firms fill each vacancy they post with probability

$$\phi_f(V, L_u) = \frac{M(V, L_u)}{V} = \frac{L_u}{(V^\theta + L_u^\theta)^{1/\theta}},$$

while unemployed workers searching for industrial jobs find matches with probability

$$\phi_w(V, L_u) = \frac{M(V, L_u)}{L_u} = \frac{V}{(V^\theta + L_u^\theta)^{1/\theta}}.$$

Each worker decides whether to participate in the industrial labor market at the beginning of each period. Those who are already employed in the industrial sector can continue with

[5] The functional form of the matching function follows den Haan et al. (2000). It is constant returns to scale, and increasing in both arguments. In contrast to the standard Cobb-Douglas form, it has no scale parameter and the implied matching rates are bounded between zero and one.

their current job unless their employer lays them off or shuts down entirely. (They can also quit in order to move to the service sector or to search for other industrial sector jobs, although in equilibrium none find it optimal to do so.) Those not currently employed in the industrial sector—including those who just lost their jobs at contracting or exiting firms—can forego certain employment with a service sector firm in order to search for a higher-wage industrial sector job, but they risk remaining unemployed if they fail to match with an industrial sector producer.[6] Those who end up unemployed subsist during the current period by home-producing services.

Each period, industrial sector firms decide whether to exit, fire some workers, maintain their existing work force, or hire workers. Firms that shed labor pay a firing cost c_f per worker dismissed, and they pay the workers they retain according to a bargaining game. Firms that post vacancies fill them at a rate determined by labor market tightness, then they too bargain with their employees to determine wages. Finally, given the service technology (6), workers who opted for employment in the service sector are employed with certainty at the wage $w_s = 1$, and workers who sought industrial sector jobs but failed to find them home-produce services at a wage of b.

2.4 Incumbent Firm's Problem

We now describe the firm's problem in more detail. Given the demand function (4) and the production function (7), any producer with productivity z who chooses employment level l will earn revenues

$$r_d(z, l, \eta) = D_H^{\frac{1}{\sigma}} \left[(1-\eta) z l^{\alpha}\right]^{\left(\frac{\sigma-1}{\sigma}\right)}, \tag{8}$$

from its domestic sales if a fraction $1-\eta$ of its output is sold domestically. Similarly, a firm that exports the fraction η of its output generates export revenues

[6] The notion that workers trade job security in a low wage sector for the opportunity to search in a higher wage sector traces back at least to the Harris and Todaro (1970) model.

$$r_x(z,l,\eta) = kD_F^{\frac{1}{\sigma}} \left[\frac{\eta}{\tau_c} z l^{\alpha}\right]^{\frac{\sigma-1}{\sigma}},$$

where $D_F = \gamma \left(\bar{P}_F\right)^{\sigma-1} I_F$, $\bar{P}_F$ is the exact price index for industrial goods available abroad and I_F is foreign income, both expressed in foreign currency. We assume the home country is too small to influence foreign market aggregates, so I_F, like $\bar{P}_F$, is exogenous to the model.

There are no start-up costs or adjustment costs associated with exporting, so firms choose η each period to maximize their total current revenues, net of fixed exporting costs, c_x. The associated revenue function is

$$r(z,l) = \max_{\eta \in [0,1]} \left\{ r_d(z,l,\eta) + r_x(z,l,\eta) - c_x \mathcal{I}^x(z,l) \right\}, \tag{9}$$

where

$$\eta^o = 1/\left(1 + \frac{\tau_c^{\sigma-1} D_H}{k^{\sigma} D_F}\right) \tag{10}$$

is the optimal fraction of output to export, *given* foreign market participation, $r_d(z,l,\eta)$ is the revenue generated by selling $(1-\eta)zl^{\alpha}$ units of output in the domestic market, and $\mathcal{I}^x(z,l)$ is an indicator function that takes a value of unity when $\eta > 0$. Whether the latter occurs simply depends upon zl^{α}, since the gains from foreign market participation increase monotonically with production.

Embedded in our general equilibrium model, this standard revenue function delivers a number of desirable features. First, it implies that for any given (z,l), the marginal revenue product of labor is larger when the economy is open. This is the underlying reason that productivity shocks induce larger adjustments in vacancy postings or firings when foreign markets are accessible. Second, since larger revenues at a given (z,l) mean more surplus to bargain over, it is also the reason that the wage paid by a firm that exports in state (z,l) is higher than what it is in the closed economy equilibrium. This result is consistent with the empirical finding that, controlling for employment, exporters pay higher wages (Bernard and Jensen (1999)). Third, combined with the fact that search frictions make marginal costs vary across firms with identical z values, it explains why productive efficiency is a noisy predictor for exporting status.[7] Fourth, re-interpreting z shocks to be product appeal indices rather than productivity indices, it explains why exporters manage to be larger than non-exporters, even though they charge higher prices and pay higher wages.[8] Finally, this expression implies that firms' exporting status affects their total revenue for a *given* amount of labor and a *given* productivity level. Thus, it provides a new interpretation for the common finding that measured productivity—i.e., deflated revenue per unit input bundle—is higher among exporters.[9] The reason this result emerges is that labor market frictions prevent firms from freely expanding as exporting opportunities arise.

What form do these frictions take? When choosing employment levels, firms weigh the associated revenue stream against wage costs, the effects of changes in l on the their continuation value, current firing and hiring costs. To characterize the latter, let the cost of posting v vacancies for a firm of size l be

$$C_h(l, v) = \left(\frac{c_h}{\lambda_1}\right)\left(\frac{v}{l^{\lambda_2}}\right)^{\lambda_1},$$

where c_h and $\lambda_1 > 1$ are positive parameters.[10] The parameter $\lambda_2 \in [0, 1]$ determines the strength of scale economies in hiring. If $\lambda_2 = 0$, there are no economies of scale and the cost of posting v vacancies is the same for all firms. On the other hand if $\lambda_2 = 1$, the cost of a given employment growth rate is the same for all firms. For any any $\lambda_2 > 0$, a given number of vacancies cost less for larger firms.

Firms in our model are large in the sense that cross-firm variation in realized arrival rates

[7] This fact has attracted some attention recently. Hallak and Sividasan (2008) explain it by assuming that (1) firms differ in terms of both their quality and their productivity efficiency, and (2) exporting requires that firms meet a minimum quality standard.

[8] Kugler and Verhoogen (2008) note that this pattern could alternatively be due to complementarities in production between worker ability and product quality.

[9] In support of this interpretation, De Loecker and Warzynski (2009) report evidence that mark-ups are higher among exporting firms.

[10] This specification generalizes Nilsena et al (2007), who set $\lambda_2 = 1 - 1/\lambda_1$. As discussed in Bertola and Caballero (1994) "convexity is necessary to obtain a well-defined vacancy-posting equilibrium when productivity is heterogeneous across firms, as firms with high productivity and low employment levels would want to post infinitely many vacancies for arbitrarily short intervals of time if such policies were not made prohibitively costly."

is ignorable. That is, all firms fill the same fraction ϕ_f of their posted vacancies. It follows that expansion from l to l' simply requires the posting of $v = \frac{l'-l}{\phi_f}$ vacancies, and we can write the cost of expanding from l to l' workers as

$$C_h(l, l') = \left(\frac{c_h}{\lambda_1}\right) \phi_f^{-\lambda_1} \left(\frac{l' - l}{l^{\lambda_2}}\right)^{\lambda_1}.$$

Clearly, when labor markets are slack, hiring is less costly because each vacancy is relatively likely to be filled.

When a firm reduces its workforce from to $l' < l$, it incurs firing costs equal to

$$C_f(l, l') = c_f(l - l').$$

Note, however, that these costs are proportional to the number of workers fired, so firms have no incentive to downsize gradually. Also, as will be discussed below, it is possible that a firm will find itself in a position where the marginal worker reduces operating profits, but it is more costly to fire her than retain her.

Regardless of whether a firm is expanding, contracting, or remaining at the same employment level, we assume that it bargains with each of its workers individually and continuously. This ensures, as in Stole and Zwiebel (1996) and Cahuc and Wasner (2000), that all workers at a given firm are paid the same wage at a given point in time. Details of the resulting wage schedules are deferred to section 2.7 below.

To derive firms' optimal employment policies, we first specify the sequencing of events within each period (Figure 1). An incumbent firm enters the current period with the productivity z and work force l levels that were determined in the previous period. Immediately the firm decides whether to stay in business or to exit. If it stays, it proceeds to an *interim stage* in which it observes its current-period productivity realization z'. Then, taking stock of its updated state, (z', l), the relevant wage schedules, and the sector-wide worker arrival rate, ϕ_f, it chooses its current period work force, l'. If the firm decides to hire ($l' > l$) workers, they are immediately available to produce output in the current period. If it fires workers ($l' \leq l$)

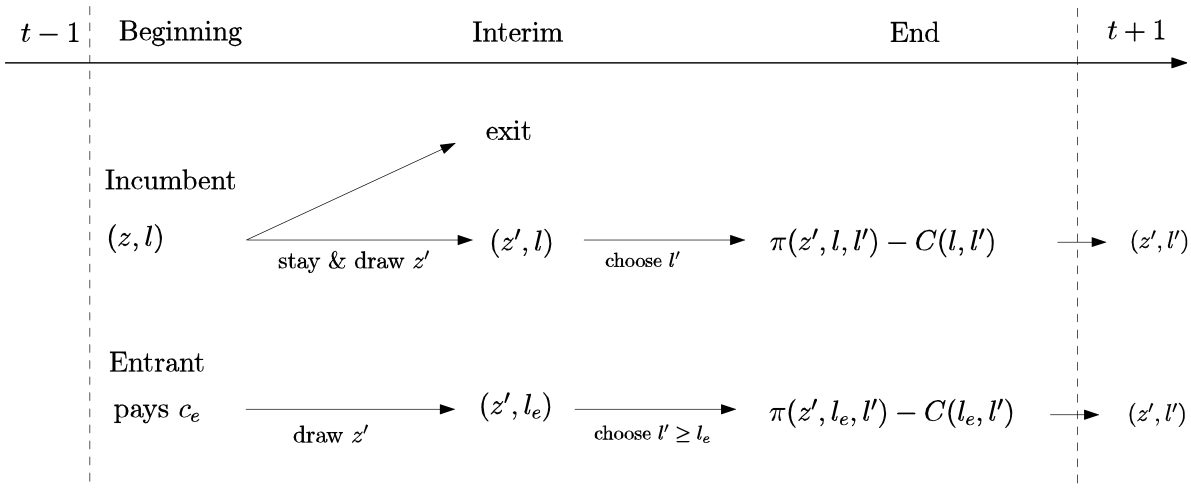

Figure 1: Within-period Sequencing of Events for Firms

it clears them from the payroll prior to production, although it incurs firing costs $C_f(l,l')$. Finally, revenues accrue and wages and other costs are paid at the end of the period.

Given the presence of search frictions, workers at hiring firms generate rents, and these are bargained over to determine wages. However, the marginal worker at a firing firm creates no rents and has no bargaining power. Hence expanding firms face different wage schedules from contracting or constant-employment firms, and current operating profits depend upon both l and l'. More precisely, defining $w_h(z',l')$ to be the wage function faced by a hiring firm and $w_f(z',l')$ to be the wage function faced by a non-hiring firm, profits before labor adjustment costs are

$$\pi(z',l,l') = \begin{cases} r(z',l') - w_h(z',l')l' - c_p & \text{if } l' > l \\ r(z',l') - w_f(z',l')l' - c_p & \text{otherwise.} \end{cases} \tag{11}$$

where c_p, the per-period fixed cost of operation, is common to all firms.

Using (11), the beginning-of-period value of a firm in state (z,l) is

$$\mathcal{V}(z,l) = \max\left\{0, \frac{1}{1+r} E_{z'|z} \max_{l'} [\pi(z',l,l') - C(l,l') + \mathcal{V}(z',l')]\right\}, \tag{12}$$

where the max of the term in square brackets is the value of the firm in the interim state (after it has realized its productivity shock), and

$$C(l,l') = \begin{cases} C_h(l,l'), & \text{if } l' > l, \\ C_f(l,l'), & \text{otherwise.} \end{cases} .$$

The solution to (12) implies an employment policy function,

$$l' = L(z', l), \tag{13}$$

an indicator function that distinguishes hiring from non-hiring firms,

$$\mathcal{I}^h(z', l) = \begin{cases} 1, & \text{if } L(z', l) > l, \\ 0, & \text{otherwise.} \end{cases} , \tag{14}$$

and an indicator function that characterizes firm's continuation/exit policy,

$$\mathcal{I}^c(z, l) = \begin{cases} 1, & \text{if } \mathcal{V}(z, l) > 0 \\ 0, & \text{otherwise.} \end{cases} . \tag{15}$$

2.5 Entry

In the steady state, a constant (endogenous) fraction μ_{exit} of firms exits the industry. These firms are replaced by an equal number of entrants, who find it optimal to pay a sunk entry cost of c_e and create new firms. Upon creating their firms, these entrants acquire $l_e > 0$ workers and learn their initial productivity, which is drawn from the density function $f_e(z)$ with support $[\underline{z}, \overline{z}]$. (The search costs for the initial l_e workers are included in c_e.) Thereafter entrants behave exactly like incumbent firms in the interim stage (see figure 1), with their interim state given by (z, l_e). So by the time they begin producing, most new entrants have adjusted their workforce (subject to search costs) in accordance with their initial productivity. Free entry implies that

$$\mathcal{V}_e = \int_{\underline{z}}^{\overline{z}} \mathcal{V}(z, l_e) f_e(z) dz \leq c_e, \tag{16}$$

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

2.6 Worker's Problem

Figure 2 presents the intra-period timing of events for workers. Consider first a worker who is employed by an industrial firm in state (z, l) at the beginning of the current period. This worker learns immediately whether her firm will continue operating. If it shuts down, she joins the pool of industrial job seekers (enters state u) in the interim stage. Otherwise, she enters the interim stage as an employee of the same firm that she worked for in the previous period. (No one voluntarily quits because, in equilibrium, firms always pay their workers at least their reservation wage.) Her firm then realizes its new productivity level z' and enters the interim state (z', l). At this point her firm decides whether to hire workers. If it expands its workforce to $l' > l$, she earns $w_h(z', l')$, and she is positioned to start the next period in state (z', l'). If the firm contracts or remains at the same employment level, she either loses her job and reverts to state u or she retains her job, earns $w_f(z', l')$, and starts next period in state (z', l'). All workers at contracting firms are equally likely to be laid off, so each loses her job with probability $p_f = (l - l')/l$.

Workers in state u are searching for industrial jobs. They are hired by entering and expanding firms that post vacancies. If they are matched with a firm, they receive the same wage as those who were already employed by the firm. If they are not matched, they support themselves by joining the informal sector and home-producing $b \in [0, 1)$ units of the service good. At the start of the next period, they can choose to work in the service sector (enter state s) or look for a job in the industrial sector (remain in state u). Likewise, workers who start the current period in the service sector choose between continuing to work at the service wage $w_s = 1$ and entering the pool of industrial job-seekers. As these workers have the option to choose either labor market, they are said to be in state o.

We now specify the value functions for the workers in the interim stage. Going to the service sector generates an end-of-period income of 1 and returns a worker to the o state at

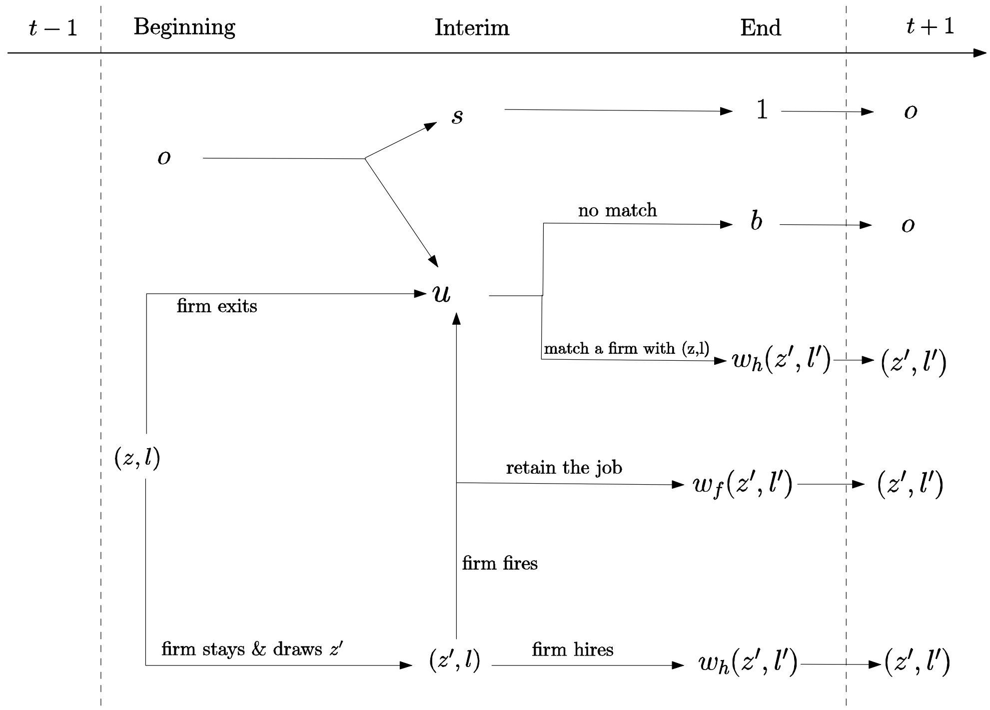

Figure 2: Within-period Sequencing of Events for Workers

the beginning of next period. Accordingly, the interim value of this choice is

$$J^s = \frac{1}{1+r}\left(1 + J^o\right), \tag{17}$$

Searching in the industrial sector exposes workers to the risk of spending the period unemployed, supporting themselves by home-producing b units of the service good. But it also opens the possibility of landing in a high-value job. Since the probability of finding a match is ϕ_w, the interim value of searching for an industrial job is

$$J^u = \frac{1}{1+r}\left[\phi_w E J_h^e + (1-\phi_w)(b + J^o)\right], \tag{18}$$

where EJ_h^e is the expected value of matching with a hiring firm.

The value of the sectoral choice is $J^o = \max\{J^s, J^u\}$ and, ruling out equilibria without service sector firms, workers must be equally attracted to both types of production:

$$J^o = J^s = J^u. \tag{19}$$

Combined with (17), this condition implies that J^o, J^s, and J^u are all equal to $1/r$.

The expected value of matching with an industrial job, EJ^e_h, depends on the distribution of hiring firms and the value of the jobs they offer. For workers who match with a hiring firm in the interim state (z', l), the interim period value is given by

$$J^e_h(z', l) = \frac{1}{1+r}\left[w_h(z', l') + J^e(z', l')\right], \tag{20}$$

where $l' = L(z', l)$ and $J^e(z', l')$ is the value of being employed at an industrial firm in state (z', l') at the start of the next period. Accordingly, the expected value of a match for a worker as perceived at the interim stage is

$$EJ^e_h = \int_{z'} \int_l J^e_h(z', l) g(z', l) dl dz', \tag{21}$$

where $g(z', l)$ is the density of vacancies across hiring firms

$$g(z', l) = \frac{v(z', l)\widetilde{f}(z', l)}{\int_{z'} \int_l v(z', l)\widetilde{f}(z', l) dl dz'}. \tag{22}$$

Here $v(z', l) = \mathcal{I}^h(z', l)\left[L(z', l) - l\right]/\phi_f$ gives the number of vacancies posted by a firm in interim state (z', l), and $\widetilde{f}(z', l)$ is the interim stage unconditional density of firms over (z', l). (The latter density is generally distinct from the end-of-period stationary distribution of firms, $f(z, l)$.)

It remains to specify the value of starting the period matched with an industrial firm, $J^e(z, l)$, which appears in (20) above. The value of being at a firm that exits immediately is simply the value of being unemployed, J^u. This is also the value of being at a non-hiring firm, since workers at these firms are indifferent between being fired and retained. Hence $J^e(z, l)$ can be written as

$$J^e(z, l) = \mathcal{I}^c(z, l) E_{z'|z}\left\{\mathcal{I}^h(z', l) J^e_h(z', l) + \left[1 - \mathcal{I}^h(z', l)\right] J^u\right\} + \left[1 - \mathcal{I}^c(z, l)\right] J^u \tag{23}$$

2.7 Wage Schedules

We now characterize the wage schedules. Consider first a hiring firm. After hiring firms have posted their vacancies and matching has taken place, the labor market closes. Firms then bargain with their workers simultaneously and on a one-to-one basis, treating each worker as the marginal one. At this point vacancy posting costs are already sunk and workers who walk away from the bargaining table cannot be replaced in the current period. Similarly, if an agreement between firm and the worker is not reached, the worker remains unemployed in the current period. These timing assumptions create rents to be split between the firm and the worker.

As detailed in Appendix 1, it follows that the wage schedule for hiring firms with an end-of-period state (z', l') is given by

$$w_h(z', l') = (1-\beta) r \frac{b + J_o}{1+r} + \Gamma(\alpha, \beta, \sigma) D^{\frac{1}{\sigma}} (z')^{\frac{\sigma-1}{\sigma}} (l')^{-\left[\frac{\alpha}{\sigma} + (1-\alpha)\right]} - \beta P_f(z', l') c_f, \tag{24}$$

where $r\frac{b+J_o}{1+r}$ is the flow value of unemployment for a worker who is bargaining with a firm at the end of the period, $\beta \in [0,1]$ measures the bargaining power of the firm, $P_f(z', l')$ is the probability of being fired next period, and $\Gamma(\alpha, \beta, \sigma) = \frac{\alpha\beta(\sigma-1)}{\sigma(1-\beta)+\alpha\beta(\sigma-1)}$ is a constant.[11] Worker in hiring firms get the marginal product of labor plus $(1-\beta)$ share of their outside option, while part of the firing cost is passed to them as lower wages.

The marginal worker at a non-hiring firm generates no rents, so the firing wage just matches her reservation value (see Appendix 1):

$$w_f(z', l') = rJ^u - \left[J^e(z', l') - J^u\right]. \tag{25}$$

Three assumptions lie behind this formulation. First, workers who quit do not trigger firing costs for their employers. They thus enjoy no bargaining power when, at their reservation wage, they contribute nothing to their employer's expected profit stream. Second, firms cannot use mixed strategies when bargaining with workers. Finally, workers who are fired

[11] This expression is analogous to equation (9) in Koeniger and Prat (2007).

are randomly chosen after the bargaining stage. The first assumption ensures that workers at contracting firms are paid no more than the reservation wage, and the remaining assumptions prevent firms from avoiding firing costs by paying *less* than reservation wages those workers they wish to shed.

Importantly, $w_f(z', l')$ does vary across firms, since those workers who continue with a firing firm may enjoy higher wages next period. This option to continue has positive value (captured by the bracketed term in (25)), so firing firms may pay their workers less than the flow value of being unemployed.

3 Equilibrium

Six basic conditions characterize our equilibrium. First, the distribution of firms over (z, l) states reproduces itself each period through the Markov processes on z, the policy functions (including hiring, firing, entry and exit), and the productivity draws that firms receive upon entry. Second, supply matches demand for services and for each differentiated good, where supplies are determined by employment and productivity levels in each type of good. Third, the flow of workers into unemployment matches the flow of workers out of unemployment—that is, the Beveridge condition holds. Fourth, aggregate income matches aggregate expenditure. Fifth, workers optimally choose the sector in which they are working or seeking work.

The final condition is trade balance. Given the exact price index for imported goods $P_F = \tau_m \tau_c k \left[\int_0^{N_F} p_F(n)^{1-\sigma} dn \right]^{1/(1-\sigma)}$, total domestic spending on imported varieties is given by

$$E_F = \tau_m \tau_c k \int_0^{N_F} p_F(n) q_F^c(n) dn = D_H \left[\tau_m \tau_c k \right]^{1-\sigma},$$

and domestic demand for foreign currency (expressed in domestic currency) is

$$R_F = \frac{E_F}{\tau_m} = \frac{D_H \left[\tau_m \tau_c k \right]^{1-\sigma}}{\tau_m} = D_H \tau_m^{-\sigma} \left[\tau_c k \right]^{1-\sigma}.$$

Tariff revenues collected by the home country government amount to $T = R_F(\tau_m - 1)$. We assume all tariff revenues are returned to worker/consumers in the form of lump-sum transfers.

Total export revenues are

$$R_x = N \int_z \int_{l_e}^{\infty} r_x(z,l,k)\mathcal{I}^x(z,l,k)f(z,l)dldz,$$

and since service goods are non-traded, balanced trade obtains when $R_F = R_x$. The exchange rate k moves to ensure that this condition holds. Appendix 2 provides further details.

4 Quantitative Analysis

4.1 An Application to Colombia

To explore the implications of our model, we use a combination of econometric estimation and calibration techniques to fit it to Colombian data. This country suits our purposes for several reasons. First, Colombia underwent a significant trade liberalization during the late 1980s and early 1990s, reducing its average nominal tariff rate from 21.5 percent to 11 percent (Table 1). Second, the Colombian Labor Market Reform of 1990 substantially reduced firing costs.[12] Third, despite stable average unemployment rates, these reforms were associated with an increase in job turnover rates from 21 percent to 23 percent, an increase in informal self-employment from 17.8 to 20.7, and an increase of 0.34 in the ratio of wages at the 90^{th} percentile to wages at the 10^{th} percentile, controlling for observable worker characteristics (Table 1). These patterns are typical of Latin American experiences. Finally, there was no wave of privatization in Colombia during the sample period, and although the country did experience some macro shocks, they were relatively mild. Thus the consequences of Colombia's liberalization and labor market reforms are relatively likely to come through in its data.

[12] Kugler (1999) summarizes the Colombian Labour Market Reform of 1990 as follows. "Prior to the reform, employers were mandated to pay severance of one month per year worked based on the salary at the time of separation (9.3% of the salary at the time of separation). . . . After 1990, employers were, instead, required to make a monthly contribution of 9.3% of the present salary to a capitalised fund, which would be accessible to the worker in the event of separation. The change in the legislation . . . eliminated the additional cost implied by the fact that, prior to the reform, the severance pay was based on the salary at the time of separation rather than on the current salary during each month. . . . [It also] reduced severance payments by eliminating the possibility for employees to withdraw funds for investments in education and housing which would only be credited to the employer in nominal terms at the time of separation. Finally, . . . [it] turned severance payments into a deferred compensation scheme." (p. 391)

Table 1: Trade Reforms and Labor Market Outcomes - Colombia*

Variable	pre-1990	post-1990
Average nominal import tariff	21.50	11.30
Severance cost per worker (as a multiple of monthly wages)	17	13
Job turnover rate	21.1	22.95
Economy-wide unemployment rate	9.99	9.87
Informal self-employment rate	17.79	20.68
Log wage gap (90^{th} versus 10^{th} percentile)	1.43	1.51

*Pre-liberalization data cover 1986-88 period for tariffs, 1978-91 for job turnover, 1988-91 for the unemployment rate, 1986-90 for wage inequality, and 1986-90 for informal sector self-employment. Post reform data are for 1992-98, 1992-99, 1992-98, 1992-99, 1992-98 periods, respectively. The tariff data come from Attanasio, Goldberg and Pavcnik (2004), Table 1a. Job turnover figures are based on DANE's annual industrial survey, which covers all manufacturing establishments with at least 10 workers. The log wage distribution is based on the residuals from a Mincerian regression of log wages on education, age, and sectoral and occupational dummies. The data set pools biennial household survey data from Colombia's national statistical agency (DANE) for the period 1986-98. Coefficients on all variables are allowed to shift through time in order to exclude changing skill premiums as a source of dispersion. The informal self employment rate is constructed from the same data base. It is the fraction of the work force that is self-employed, non-professional, and informal (i.e., not paying social security). Finally, firing costs are based on Figure 5 in Heckman and Pages (2004).

4.2 The Revenue Function and Productivity Process

The job turnover and unemployment/informality documented in Table 1 help us to calibrate our model, as we will discuss shortly. But the parameters that characterize the revenue function and the productivity process can be estimated econometrically using Colombia's annual industrial survey. Note that the revenue function (9) and CES preferences imply that log revenues (gross of fixed exporting costs) can be written as a function of employment, productivity and an index of market-wide demand,

$$d_H = \ln[D_H^{\frac{1}{\sigma}}(1-\eta^o)^{\frac{\sigma-1}{\sigma}}], \tag{26}$$

an index of the *percentage increase* in total demand associated with exporting,

$$d_F = \ln[(k^\sigma D_F)^{\frac{1}{\sigma}}(\eta^o/\tau_c)^{\frac{\sigma-1}{\sigma}}e^{-d_H}+1], \tag{27}$$

and an indicator for whether firm i is an exporter, $\mathcal{I}_{it}^x$:

$$\ln r_{it} = d_H + \mathcal{I}_{it}^x d_F + \frac{\sigma-1}{\sigma}\ln z_{it} + \alpha\frac{\sigma-1}{\sigma}\ln l_{it} \tag{28}$$

Further, assuming that $\ln(z)$ follows an exogenous AR(1) process,

$$\ln z_{it} = \rho \ln z_{it-1} + \epsilon_{it}, \tag{29}$$

equation (28) can be restated as:

$$\begin{aligned}\ln r_{it} \;=\;& (d_H + \mathcal{I}_{it}^x d_F) - \rho\left(d_H + \mathcal{I}_{it-1}^x d_F\right) + \rho \ln r_{it-1} \\ & -\alpha\rho\left(\frac{\sigma-1}{\sigma}\right)\ln l_{it-1} + \alpha\left(\frac{\sigma-1}{\sigma}\right)\ln l_{it} + \frac{\sigma-1}{\sigma}\epsilon_{it},\end{aligned} \tag{30}$$

If we could obtain consistent estimates of the coefficients that appear on the right-hand-side observable variables, these would allow us to infer consistent estimates of d_H, d_F, ρ, $\alpha\left(\frac{\sigma-1}{\sigma}\right)$, and $var(\epsilon)$. However, selection bias and simultaneity bias prevent us from consistently estimating (30) with ordinary least squares. The former problem occurs because by (15), firms choose whether to exit the market partly on the basis of their current productivity levels, so the ϵ_{it} realizations observed for active producers are not random draws from the unconditional distribution of $\epsilon' s$. The latter problem occurs because firms' current exporting decisions and employment levels are chosen after the current realization on ϵ is observed, so ϵ_{it} is correlated with both $\mathcal{I}_{it}^x$ and $\ln l_{it}$. Appendix 3 develops a generalized method of moments (GMM) estimator related to Olley and Pakes' (1996) that deals with both problems.

Applying this estimator to the set of all Colombian manufacturing plants observed for at least three years during the pre-liberalization period 1982 and 1991, we obtain the results summarized in Table 1 below.[13] Since σ is not identified separately from α, we fixed this

[13] The data are annual observations on all manufacturing firms with at least 10 workers. They were collected by Colombia's National Statistics Department (DANE) and cleaned as described in Roberts (1996). Given that fixed capital and intermediate inputs do not appear in our model, we define revenue to be the value of output net of intermediate input and capital costs. Annual capital costs are 10 percent of the book value of

parameter at a value typical of the literature: $\sigma = 5$. All remaining parameters are estimated with considerable precision. It should be noted, however, that the estimates are sensitive to choice of the instrument set, and to the weights we used on different types of workers—managers, technicians, skilled laborers, unskilled workers, and apprentices—when constructing the number of "effective" workers.[14]

Table 2: Revenue function and productivity process
(GMM estimates, given $\sigma = 5.0$)

parameter	estimate	std. error	z-ratio
α	0.592	0.057	10.41
ρ	0.848	0.007	118.73
σ_ε^2	1.668	0.042	39.54
d_H	1.682	0.047	35.78
d_F	0.213	0.004	51.31

4.3 Remaining Parameters

Several parameters are fixed using external sources. First, the real borrowing rate in Colombia fluctuated around 15 percent between late 1980s and early 2000s, so we set r to be 0.15 (Bond et al, 2008). Second, following den Haan, Ramey and Ramey (2000), we set the elasticity of the matching function, θ, to be 1.27. Third, as is common in the labor literature, we give equal bargaining power to firms and workers, setting $\beta = 0.5$. Finally, we set iceberg trade costs at $\tau_c - 1 = 1.50$ since Eaton and Kortum (2003) find that the tariff equivalent of iceberg costs falls between 123 percent and 174 percent. This τ_c value, along with our estimates for d_F and d_H, implies D_H and $k^\sigma D_F$.[15]

firms' capital stocks.

[14] The weights used for reported estimates are based on cross-plant mean wage premiums for each type of employee, relative to unskilled workers. Weighting means (using plant size as weights) yields a larger α value, although it has little effect on ρ.

[15] Equations (26), (27), and (10) imply $\exp(d_F) = (1 - \eta_0)^{-1}$, so we can impute η_0 from the estimated value of d_F. Substituting this value into $\exp(d_H) = D_H^{1/\sigma}(1 - \eta_0)^{(\sigma-1)/\sigma}$ yields D_H, given σ and the estimated value of d_H. Finally, given a value for τ_c, $k^\sigma D_F$ follows from (10).

Table 3: Parameters Fixed Before Simulating Moments

Parameter	Value	Description	Source
α	0.592	production function	GMM estimate (Table 2)
ρ	0.848	persistence of z process	GMM estimate (Table 2)
σ_ε	1.291	std. dev. of shocks to z	GMM estimate (Table 2)
$k^\sigma D_F$	635.6	foreign demand level	from GMM estimates (Table 2)
τ_c	2.50	iceberg trade costs	Eaton and Kortum (2003)
β	0.5	bargaining power	assumed (literature)
σ	5	elasticity of subs.	assumed (literature)
r	0.15	discount rate	Bond, et al (2008)
θ	1.27	elas. of matching function	den Haan et al (2000)

Table 3 collects the parameter values discussed thus far, and implies that 9 parameters remain to be determined: the fixed cost of operation, c_p, the fixed cost of exporting, c_x, the value of informal sector production, b, the value of entry, c_e, the initial size of new firms, l_e, the share of differentiated goods in total expenditures, γ, the parameters of the vacancy cost function, $(c_h, \lambda_1, \lambda_2)$, and the firing cost, c_f. We estimate the first 8 parameters using the simulated method of moments and thirteen targets that summarize key features of our model: the firm exit rate, the job turnover rate, the fraction of firms that export, the unemployment rate plus the informality rate, the autocorrelation of firms employment levels, correlation between firms' productivity and employment, and the employment growth rates among expanding firms at the different quintiles of the size distribution and the share of workers in the service sector.[16] As we estimate these 8 parameters, we also iterate on the value of c_f to ensure that the value of firing costs is equivalent to 17 months (1.4 model periods) of average wage in the benchmark economy. Our solution algorithm is summarized in Appendix 4.

While it is not possible to associate individual parameters with individual statistics, experiments do suggest that particular statistics play relatively key roles in identifying particular

[16] We do not calibrate to measures of wage dispersion because it is not possible for us to completely control for differences in worker characteristics when constructing data-based measures of wage heterogeneity. Interestingly, however, as will become evident in our discussion of policy experiments, our model economy is able to generate a high level of wage inequality within a labor search framework. This is traceable to the low job finding rate in our benchmark economy (about 12% per year), since with a low job finding rate workers are willing to take low wages. As noted by Hornstein, Krusell and Violante (2009), the standard search models deliver low wage inequality (compared to data) when they are calibrated to the high job finding rates observed in the U.S.

parameters. First, the fraction of firms that export is sensitive to fixed exporting costs, c_x, and the rate of firm turnover is very responsive to the per-period fixed costs of operating a business, c_p. Second, the quintile-specific job growth rates and the aggregate labor turnover rate are responsive to the parameters of the vacancy cost function $(c_h, \lambda_1, \lambda_2)$, with cross-quintile differences governed by the scale economies parameter, λ_2 and (for the smallest quintile) the initial size of new firms, l_e. Third, the share of workers in the service sector responds to the share of service goods in total expenditures, γ. Finally, the unemployment/informality rate is very responsive to the productivity of informal sector workers, b.

Table 4 shows the data-based statistics and their model-based simulated counterparts. Although we are using 8 parameters to try to match 13 statistics, the model does a nice job of fitting the data overall.[17] In particular, the model captures the contributions of firm entry/exit and intra-firm size adjustments to overall job turnover, the persistence in employment levels, the overall unemployment rate, and higher job turnover rate among small firms.[18]

[17] The metric of fit we used was the average $|1 - Y_i/X_i|$ where X_i is the ith data-based statistics and Y_i is the corresponding model-based statistic. At its minimized value, this metric was 0.105.

[18] The firm exit rate and the fraction of firms that export are calculated from Colombian plant level data for the pre-liberalization period, 1978-91. These data were collected by the Colombian National Administrative Department of Statistics (DANE) in its Annual Manufacturer Survey (EAM), which covers all establishments with at least 10 workers. The quintile-specific rates of job creation and the statistics $corr(l, l')$ and $corr(z, l)$ are based on the same data base and time period, using the technology estimates in Table 2 to calculate z. The job turnover rate is calculated from the Inter-American Development Bank's Job Flows Data Set for the 1978-1992 period, which in turn is based on the EAM. The unemployment rate is taken from Inter-American Development Bank (2004), and is based on DANE's biennial National Household Survey (ENH). The share of workers in the service sector and the informality rate are also calculated from the ENH, defining an informal sector worker to be someone who does not pay social security, is self-employed, has no employees, and is doing neither professional/technical nor managerial work.

Table 4: Calibration*
Data-based versus simulated statistics

Industry-wide Statistics	Data	Model	**Employment Growth Rates, by Quintile**	Data	Model
firm exit rate	0.091	0.079	<20th percentile	0.319	0.344
job turnover	0.211	0.222	20th-40th percentile	0.218	0.214
share of firms exporting	0.120	0.145	40th-60th percentile	0.191	0.181
unemployment +informality rate	0.278	0.288	60th-80th percentile	0.183	0.165
share of workers in Q sector	0.450	0.430	>80th percentile	0.157	0.135
$corr(l, l')$	0.95	1.039			
$corr(z, l')$	0.59	0.633			
$corr(z, l)$	0.57	0.637			

*The firm exit rate and the fraction of firms that export are calculated from Colombian plant level data for the pre-liberalization period, 1978-91. These data were collected by the Colombian National Administrative Department of Statistics (DANE) in its Annual Manufacturer Survey (EAM), which covers all establishments with at least 10 workers. The quintile-specific rates of job creation and the statistics $corr(l, l')$ and $corr(z, l)$ are based on the same data base and time period, using the technology estimates in Table 2 to calculate z. The job turnover rate is calculated from the Inter-American Development Bank's Job Flows Data Set for the 1978-1992 period, which in turn is based on the EAM. The unemployment rate is taken from Inter-American Development Bank (2004), and is based on DANE's biennial National Household Survey (ENH). The share of workers in the service sector and the informality rate are also calculated from the ENH, defining an informal sector worker to be someone who does not pay social security, is self-employed, has no employees, and is doing neither professional/technical nor managerial work.

Table 5 reports the parameter values associated with the calibration. Those expressed in monetary units are measured in terms of the 1990 average annual wage for a service sector worker, taken from the annual household survey, which amounted to roughly $1,300 US (1977), or about $4,500 current US dollars. Accordingly, our model implies that the fixed costs of operating a business amount to about $138,900, while the fixed costs of exporting are about $76,100. Note also that those who end up in the informal sector take about a 28 percent wage cut relative to what they could have earned if they had committed to working for a service sector firm. Finally, the parameters of the vacancy cost function imply both short-run convexities ($\lambda_1 = 2.32$) and modest scale economies ($\lambda_2 = 0.30$).[19] The latter, of course, is

[19] Our estimate for convexities in the hiring function is consistent with available evidence (e.g. Monika and

a reflection of the quintile-specific growth rates reported in Table 4 and the mean-reverting productivity process reported in Table 2. That is, if there were no scale effects, mean reversion would imply somewhat smaller growth rates among the largest firms that are posting vacancies, and slightly higher growth rates among the smallest firms that are posting vacancies.

Table 5: Calibrated Parameter Values
(based on method of simulated moments)

Parameter	Value	Description
c_p	30.87	fixed cost of oper.
c_h	0.75	posting cost scalar
c_x	16.91	fixed exporting cost
b	0.72	value of hhd. prod.
λ_1	2.32	convexity, vacancy cost function
λ_2	0.30	scale effect, vacancy cost function
γ	0.50	share of Q goods in total spending
l_e	3.82	initial size, entering firms
c_f	1.6	firing cost

4.4 Simulated effects of openness and firing costs

4.4.1 Tariff reductions

We are now prepared to examine the effects of trade reforms in our calibrated model. To do so we reduce the import tariff from 21 percent to 11 percent, mimicking the reforms documented in Table 1. This reduction in protection reduces the consumer price index for Q-goods, putting downward pressure on the profits of domestic Q-sector firms. But it also generates a real currency devaluation through the balanced trade condition and thereby increases the optimal export share η (by equation 10) and the fraction of firms that export. As in Melitz's (2003) model, this expansion is concentrated among large firms, so the right-hand tail of the firm size distribution becomes more skewed (Table 6).

Two forces link the firm size distribution to labor market outcomes. First, large firms enjoy scale economies in vacancy posting. Second, the estimated productivity process is mean-reverting, and this implies that large firms tend to experience relatively small productivity shocks. Table 7 shows that the productivity effect is dominant. As jobs shift toward larger

Yashiv 2003, and Yashiv 2006).

firms, job turnover declines by several points and, with less worker displacement, the rate of unemployment/informality falls. Further, fewer jobs are located at firms that wish to rapidly expand after the tariff reduction, and thus there are fewer firms willing to pay very high wages. This translates into less wage dispersion and lower average wages. In sum, contrary to popular belief, our simulations suggest that tariff reductions work *against* job turnover and wage inequality.[20] The results do, however, suggest that trade liberalization eliminated jobs at the high end of the wage distribution and in that sense imposed a cost on workers.

Table 6: Size Distribution Effects of Trade Costs and Severance Costs

	base case	reductions in:		
		tariffs	iceberg costs	firing costs
Tariffs (τ_m)	1.21	1.11	1.11	1.21
Iceberg costs (τ_c)	2.50	2.50	2.25	2.50
Firing costs (c_f)	1.60	1.60	1.60	1.20
20th percentile	14.9	15.5	15.9	11.2
40th percentile	31.4	32.3	36.1	22.5
60th percentile	62.8	63.0	58.5	48.6
80th percentile	105.0	131.1	105.2	90.9

[20] Our results on wage inequality also contrast with those of other recent models of trade with heterogeneous firms and search frictions. In those models liberalization increases profits for exporting firms and reduces profits for others. This spread in the profit distribution is passed back to workers, who share in firms' rents through bargaining. Relevant references include Helpman and Itskhoki, 2007; Helpman, et al, 2008; Egger and Kreickemeier, 2007; Amiti and Davis, 2008; Davis and Harrigan, 2008; Felbermayr et al, 2008.

Table 7: The Labor Market Effects of Trade Costs and Severance Costs

	base case	reductions in:		
		tariffs	iceberg costs	firing costs
Tariffs (τ_m)	1.21	1.11	1.11	1.21
Iceberg costs (τ_c)	2.50	2.50	2.25	2.50
Firing costs (c_f)	1.60	1.60	1.60	1.20
Share of firms exporting	0.145	0.176	0.210	0.143
Job turnover	0.222	0.199	0.202	0.231
Unemployment/informality	0.284	0.262	0.262	0.311
Log 90-10 wage ratio	2.033	1.789	1.952	2.055
Share labor in Q sector	0.429	0.425	0.416	0.444
Wage dispersion, Q sector	0.800	0.755	0.808	0.854
Average wage, Q sector	1.829	1.753	1.809	1.928
Variance, z	4.115	4.144	4.200	4.147
CPI, Q goods	4.347	4.281	4.153	4.385
Average indirect utility, $IP^{-\gamma}$	0.612	0.606	0.624	0.614

4.4.2 Iceberg costs

Of course, these predictions concerning the effects of tariff reductions do not match up well to what was actually observed in Colombia. Leaving aside labor market outcomes for the moment, one might begin by noting that the predicted increase in the share of producers who export was only from 14.8 to 17.8 percent with the reduction of tariffs, while the actual increase was from an average of 12 percent (for the period 1984-1990) to 18.2 percent in 1991 and 23.5 percent by 1996. Thus, at the same time as τ_m was falling, it is likely that other forces were encouraging trade, e.g., reductions in transport costs and changes in protection rates among trading partners.

To approximate the effects of these other trade-inducing forces, we next consider reductions in iceberg costs, τ_c. Column 3 in tables 6 and 7 reports the associated changes in the plant size distributions and aggregate statistics, respectively. The reductions in iceberg costs make imported varieties substantially cheaper, driving down the price index for Q-goods and causing firms to contract their domestic sales (Table 7). At the same time, despite the fact that more firms begin exporting, the firm size distribution shifts *leftward* (table 6). Accordingly, job turnover and wage heterogeneity increase slightly, so there is a sense in which globalization contributes to wage inequality after all.

It is puzzling that, unlike in the τ_m experiment, Melitzian forces do not dominate the shift in the firm size distribution here. The reason appears to be that, unlike in Melitz's (2003) model, size and productivity are not monotonically related to one another in our setting. Since hiring and firing costs prevent firms from rapidly adjusting their firm size in response to productivity shocks, some small firms are very productive. And when trade costs fall sufficiently, many of these firms are added to the ranks of exporters. (Modest reductions in trade costs—i.e., those associated with reductions in τ_m alone—do not entice small efficient firms into exporting because the associated increment to their profits falls short of fixed exporting costs.)

4.4.3 Firing costs

While Colombia's rising export share can be attributed to the combination of tariff reductions and falling iceberg costs, our model implies that these forces were *not* responsible for the increased job turnover, wage inequality and informality that beset Colombia in the 1990s. Our final counterfactual exercise explores the extent to which the 1990 labor market reforms induced these changes.

Column 4 of Table 6 report simulated changes in the size distribution of firms when firing costs are cut by 25 percent, as implied by Table 1. As firing costs fall jobs are shed mainly by large, inefficient firms (figure 3). This shifts the size distribution shifts leftward. Because employment is then concentrated among smaller firms, and because low firing costs cause firms of all sizes to hire and fire more freely, turnover rates increase by one percent points, about half of the increase observed in the data (Table 1).[21] The higher turnover rate also leads to more rents among expanding firms, driving up the average wage. The allure of higher average wages entices more workers to search for Q-sector jobs (as in Harris and Todaro 1970) and, in combination with the higher rate of job turnover, drives up the rate

[21] Additional experiments (not reported) show that if firing costs were cut by a factor of 50 percent rather than 25 percent, the predicted increase in job turnover would match the observed increase.

of informality/unemployment by 3 percentage points, accounting for most of the observed increase (Table 1).

Overall, whether a worker gains or loses from the reforms we consider above depends upon the type of firm at which she is currently employed, if any. The structure of our model ensures that all unemployed workers have the same discounted expected lifetime utility of $1/r = 6.67$, so the interesting question is how those who are affiliated with particular firms can expect to fare. We plot the changes in $J^e(z, l)$ values associated with the tariff reduction from $\tau_m = 1.21$ to $\tau_m = 1.11$ and the reduction in firing costs from $c_f = 1.6$ to $c_f = 1.2$ in figures 4 and 5, respectively. For the former case, workers at small firms do worse, workers at large, high productivity firms do better, and all others are unaffected. This is essentially because many small employers face new import competition but are too unproductive to benefit from export markets. For the latter case, it is productivity rather than size that matters most, since low firing costs increase the incentives for high productivity firms to expand by offering high wages, while low productivity firms pay employees their reservation wage regardless of c_f.

5 Summary

In Latin America, globalization and labor market reforms have been associated with less job security, more wage inequality, and more informality. We formulate a dynamic structural model that explains these patterns of association as a consequence of interactions between idiosyncratic productivity shocks, exporting incentives, and scale economies in hiring and firing workers. Simulations of our model imply that globalization is unlikely to have caused the deterioration in labor market conditions that Colombia experienced during the 1990s. However, the reductions in firing costs that Colombia implemented in 1990s do go some way toward explaining observed increases in job turnover, wage dispersion and informality. The unexplained remainder is likely attributable to macro shocks and skill-biased technological progress.

In addition to providing a lens through which to interpret recently-observed changes in Latin American labor markets, our paper makes several methodological contributions. First, we have generalized the representation of labor markets developed by Bertola and Caballero (1994) to an open economy setting with fully articulated product markets, multiple sectors, and continuous Markov processes for productivity shocks. Second, we have demonstrated how to quantify some welfare and distributional effects of openness and firing costs that had not yet been empirically explored. Finally, we have developed a means to characterize plant-level productivity processes that does not require us to observe a measure of physical output, matches a large set of stylized facts, and is robust with respect to simultaneity bias and selection bias.

Appendix 1: The Wage Functions

Hiring Wages In order to characterize wages in hiring firms, we first determine the total surplus for a firm and a worker that are matched in the end-of-period state (z', l'). At the time of bargaining, the surplus that the marginal worker generates for a firm is given by

$$\Pi^{firm}(z', l') = \frac{1}{1+r}\left[\frac{\partial\pi(z', l')}{\partial l'} + \frac{\partial\mathcal{V}(z', l')}{\partial l'}\right].$$

Note that at the time of bargaining, the vacancy posting and matching process are over and the costs of vacancy postings are sunk. As a result, if the bargaining fails, the firm is simply left with less workers. The surplus that a marginal worker generates consists of two parts: the current increase in the firms' profits, i.e. marginal revenue product net of wages, and the increment to the value of being in state (z', l') at the start of the next period. If the firm does not exit next period, i.e. if $\mathcal{V}(z', l') > 0$, the marginal worker will have a positive only if the firm expands. Otherwise, the firm will incur the dismissal cost c_f. If the firm exits, its expected marginal value from the current marginal hire will be zero.

Similarly, the surplus for the marginal worker who is matched by a hiring firm in the end-of-period state (z', l') is

$$\Pi^{work}(z', l') = \frac{1}{1+r}\left[w_h(z', l') + J^e(z', l')\right] - \frac{b + J^o}{1+r},$$

where the worker enjoys $w_h(z', l')$ in the current period, and starts next period in a firm with the beginning-of-period state (z', l'). Since at the time of bargaining the vacancy posting and matching process are over, if the bargaining fails, the worker is unemployed this period and starts next period in state o.

The worker and firm split the total surplus by Nash bargaining where the bargaining power of the firm is given by β, i.e.

$$\beta \Pi^{firm}(z',l') = (1-\beta)\Pi^{wor\ker}(z',l')$$

Wages are thus determined as a solution to the following equation

$$\begin{aligned} & \beta\left[\frac{\partial \pi(z',l')}{\partial l'} + \frac{\partial \mathcal{V}(z',l')}{\partial l'}\right] \\ = & \ (1-\beta)\left[w_h(z',l') + J^e(z',l') - (b+J^o)\right]. \end{aligned} \tag{31}$$

Adding and subtracting $(1-\beta)\frac{b+J^0}{1+r}$ on the the right hand side of (31) gives

$$\begin{aligned} & \beta\left[\frac{\partial \pi(z',l')}{\partial l'} + \frac{\partial \mathcal{V}(z',l')}{\partial l'}\right] \\ = & \ (1-\beta)\left\{w_h(z',l') - r\left(\frac{b+J^o}{1+r}\right) + \left[J^e(z',l') - \frac{b+J^o}{1+r}\right]\right\} \end{aligned} \tag{32}$$

where $r\left(\frac{b+J^o}{1+r}\right)$ is the flow value of being unemployed and $\left(J^e(z',l') - \frac{b+J^o}{1+r}\right)$ is the expected continuation value of employment at a (z',l')-type firm net of the continuation value of unemployment. Weighted by $(1-\beta)$, this latter term cancels with $\beta\frac{\partial \mathcal{V}(z',l')}{\partial l'}$, which appears on the left hand side of equation (31), since the worker gets the fraction $1-\beta$ of any future rents from the match while the firm gets β. In event of a contraction, the firm cannot enforce contracts that stipulate laid-off workers to pay their share of firing costs. Thus, worker's share of expected firing costs, $\beta P_f(z',l')c_f$, is subtracted from wages in the current period. Conditional on firing taking place, the possibility of losing one's job, $p_f(z',l)$, is

$$p_f(z',l) = \frac{l - L(z'.l)}{l}.$$

The probability of being fired next period is then given by

$$P_f(z', l') = \int \mathcal{I}^f(z'', l') p_f(z'', l') h(z''|z') dz.$$

Rearranging terms, equation (32) becomes

$$\frac{\partial w_h(z', l')}{\partial l'} \beta l' + w_h(z', l') - \beta \frac{\partial r(z', l')}{\partial l'} - (1-\beta) r \left(\frac{b + J^o}{1+r} \right) + \beta P_f(z', l') c_f = 0,$$

which is the same as Bertola and Garibaldi (2001)'s equation (10) when $c_f = 0$.

Using

$$\frac{\partial r(z', l')}{\partial l} = \alpha \frac{\sigma - 1}{\sigma} D^{\frac{1}{\sigma}} (z')^{\frac{\sigma-1}{\sigma}} (l')^{\alpha\left(\frac{\sigma-1}{\sigma}\right)-1},$$

the wage schedule for expanding firms is given by

$$w_h(z', l') = (1-\beta) r \left(\frac{b + J^o}{1+r} \right) + \Gamma(\alpha, \beta, \sigma) D^{\frac{1}{\sigma}} (z')^{\frac{\sigma-1}{\sigma}} (l')^{-\left[\frac{\alpha}{\sigma} + (1-\alpha)\right]} - \beta P_f(z', l') c_f,$$

where $\Gamma(\alpha, \beta, \sigma)$ is a function of the parameters of the problem

$$\Gamma(\alpha, \beta, \sigma) = \frac{\alpha\beta(\sigma - 1)}{\sigma(1-\beta) + \alpha\beta(\sigma - 1)}.$$

Firing Wages To derive the firing wage schedule, we begin by writing the value of employment at a firing firm in the interim stage as

$$J_f^e(z', l) = \frac{1}{1+r} \left[p_f(z', l)((1+r)J^u) + (1 - p_f(z', l)) \left(w_f(z', l') + J^e(z', l') \right) \right],$$

where $l' = L(z', l)$. This expression reflects the fact that workers who are not fired are paid just enough to retain them. Next we note that, since workers are indifferent between staying and leaving

$$w_f(z', l') + J^e(z', l') = (1+r)J^u,$$

and the wage schedule faced by firing firms can be written as

$$w_f(z', l') = rJ^u - [J^e(z', l') - J^u].$$

Note that as a hiring firm increases its employment level toward the point at which $\Pi^{firm}(z', l') = 0$, the hiring wage approaches $w_f(z', l')$ by (31).

Appendix 2: Steady State Open Economy Equilibrium

A steady state equilibrium for a small open economy consists of a measure of domestic differentiated goods N_H, an exact price index for composite good P, an aggregate quantity index for composite good Q, aggregate income I, a measure of workforce in services L_S, a measure of unemployed workers in differentiated goods sector L_u, unemployment rate in differentiated goods sector μ_u, job finding rate ϕ_w, vacancy filling rate ϕ_f, the exit rate μ_{exit}, the fraction of firms exporting μ_x, the measure of entrants M, the value functions and associated policy functions $\mathcal{V}(z,l)$, $L(z,l)$, $\mathcal{I}^h(z,l)$, $\mathcal{I}^c(z,l)$, $\mathcal{I}^x(z,l,k)$, J^o, J^u, J^s, and J^e; the wage schedules $w_h(z,l)$ and $w_f(z,l)$, exchange rate k, and end-of-the period and interim distributions $f(z,l)$ and $\widetilde{f}(z,l)$ such that

1. **Steady State Distributions:** In equilibrium, $f(z,l)$ and $\widetilde{f}(z',l)$ reproduce themselves through the Markov processes on z, the policy functions and the productivity draws upon entry. The interim distribution is defined as

$$\widetilde{f}(z,l) = \begin{cases} = \int_{\widehat{z}} h(z|\widehat{z}) f(\widehat{z},l) I^c(\widehat{z},l) d\widehat{z} \text{ if } l \neq l_e \\ = f_e(z) + \int_{\widehat{z}} h(z|\widehat{z}) f(\widehat{z},l) I^c(\widehat{z},l) d\widehat{z} \text{ if } l = l_e \end{cases}.$$

In turn, the end-of-the period distribution is

$$f(z,l) = \int_{\widehat{l}} \widetilde{f}(z,\widehat{l}) I_{(L(z,\widehat{l}),l)},$$

where $I_{(L(z,\widehat{l}),l)}$ is an indicator function with $I_{(L(z,\widehat{l}),l)} = 1$ if $L(z,\widehat{l}) = l$.

2. **Market Clearance in Sector S:** Demand for the $S-$sector goods comes from two sources: consumers spend a $(1-\gamma)$ fraction of aggregate income I on it, and firms demand it to pay their fixed operation costs, labor adjustment and entry costs. Then, the average labor adjustment cost is given by

$$\overline{c} = \int_z \int_l C(l, L(z,l) \widetilde{f}(z,l) dl dz.$$

Market clearance condition in this sector is then given by

$$L_S + b\mu_u L_Q = (1-\gamma)I + N_H(\bar{c} + c_p) + Mc_e,$$

where L_S and L_Q are the size of the workforce in the two sectors, and μ_u is the unemployment rate within the Q-sector.

3. **Labor Market:** With a normalized measure of workers, the size of the workforce in the Q-sector is $L_Q = 1 - L_{S.}$ Total production employment in the differentiated good sector is given by

$$E_Q = N_H \bar{l} = N_H \int_z \int_l l f(z,l) dl dz = (1-\mu_u)L_Q,$$

where

$$\bar{l} = \int_z \int_l l f(z,l) dl dz \tag{33}$$

is the average employment in diffrentiated goods sector. The measure of unemployed workers is then

$$L_u = L_Q - E_Q = \mu_u L_Q.$$

The equilibrium condition for the labor market in the $Q-$sector requires that flows out of employment equal the flows into employment. Every period, a fraction μ_l of workers in that sector are laid off due to exits and downsizing

$$\mu_l = \frac{\int_z \int_l l I^c(z,l) f(z,l) dl dz + \int_z \int_l (l - L(z,l))(1 - I^h(z,l)) l f(z,l) dl dz}{\int_z \int_l l f(z,l) dl dz}$$

Then, the equilibrium flow condition is

$$\mu_u L_Q \phi_w = (1-\mu_u) L_Q \mu_l,$$

which yields the usual Beveridge curve

$$\mu_u = \frac{\mu_l}{\mu_l + \phi_w}.$$

On vacancies side, the aggregate number of vacancies in this economy is given by

$$V = N_H \overline{v} = N_H \int_z \int_l v(z,l) \mathcal{I}^h(z,l) \frac{\widetilde{f}(z,l)}{\mu_h} dl dz,$$

where

$$\overline{v} = N_H \int_z \int_l v(z,l) \mathcal{I}^h(z,l) \frac{\widetilde{f}(z,l)}{\mu_h} dl dz, \tag{34}$$

is the average level of vacancies, and μ_h is the fraction of hiring firms:

$$\mu_h = \int_z \int_l \mathcal{I}^h(z,l) \widetilde{f}(z,l) dl dz.$$

The total number of vacancies, V, together with $L_u = \mu_u L_Q$, determines matching probabilities $\phi_f(V, L_u)$ and $\phi_w(V, L_u)$ that firms and workers take as given.

4. **Firm turnover:** In equilibrium, there is a positive mass of entry M every period so that the free entry condition (16) holds with equality. The fraction of firms exiting is implied by the steady state distribution and the exit policy function,

$$\mu_{exit} = \int_z \int_l [1 - \mathcal{I}^c(z,l)] f(z,l) dl dz,$$

and measure of exits equals that of entrants,

$$M = \mu_{exit} N_H.$$

5. **Income and Market Clearance for the Q-sector:** The domestic composite good

Q_H and its price are given by:

$$P_H = \left(N_H \int_z \int_l p_H(z,l)^{1-\sigma} f(z,l) dl dz \right)^{\frac{1}{1-\sigma}},$$

and

$$Q_H = \left(N_H \int_z \int_l q_H(z,l)^{\frac{\sigma-1}{\sigma}} f(z,l) dl dz \right)^{\frac{\sigma}{\sigma-1}}.$$

Spending on domestic varieties is $E_d = P_H Q_H$. A fraction γ of total income is spent on dometic and foreign differentiated goods:

$$\gamma I = E_d + E_F.$$

By Walras' Law, market clearance in the labor market and the S-sector implies the clearance of the Q-sector. We show that by writing aggregate income in the economy:

$$I = L_s + b\mu_u L_Q + W_Q + \Pi + T, \tag{35}$$

where L_S is employment (and income earned) in the S-sector, $\mu_u L_Q b$ is the income earned by the unemployed through home production, W_Q is the total wage bill, Π is total profits, and T is the tariff revenue. Let $\widetilde{\mathcal{I}}^h(z,l)$ be an indicator function which equals one if a firm in state (z,l) at the end of a period achieved this state by hiring in the interim stage. Π is total profits net of entry, vacancy and firing costs,

$$\begin{aligned} \Pi \;=\; & N_H \int_z \int_l [\widetilde{\mathcal{I}}^h(z,l) \left\{ r(z,l) - w_h(z,l) l \right\} \\ & + \left[1 - \widetilde{\mathcal{I}}^h(z,l) \right] \left\{ r(z,l) - w_f(z,l) l \right\}] f(z,l) dl dz \\ & - N_H \bar{c} - N_H c_p - M c_e \end{aligned} \tag{36}$$

and W_Q is the total wage bill in the Q-sector

$$W_Q = N_H \int_z \int_l \left\{ \widetilde{\mathcal{I}}^h(z,l) w_h(z,l) \cdot l + \left[1 - \widetilde{\mathcal{I}}^h(z,l)\right] w_f(z,l) l \right\} f(z,l) dl dz. \tag{37}$$

Since aggregate profits consists of profits from domestic and foreign sales

$$I = L_s + b\mu_u L_Q + W_Q + R_x + R_d - W_Q - N_H \overline{c} - N_H c_p - M c_e + T.$$

where R_x is total export revenue, R_d is revenue from domestic sales in differentiated goods sector, and $N_H \overline{c}, N_H c_p$ and $M c_e$ are aggregate labor adjustment costs, overhead and entry costs respectively. The market clearing condition for the service sector is given by

$$L_S + b\mu_u L_Q = (1 - \gamma) I + N_H \overline{c} + N_H c_p + M c_e,$$

which implies

$$\gamma I = R_d + R_x + T.$$

By domestic market clearance, $E_d = R_d$. Furthermore, since $R_F = E_F/\tau_m$ and $T = R_F(\tau_m - 1)$, we obtain the trade balance condition

$$R_x = R_F.$$

6. Workers are indifferent between taking a certain job in the undifferentiated sector and searching a job in industrial sector.

$$J^o = J^s = J^u. \tag{38}$$

Appendix 3: Estimating the Revenue Function and Productivity Process

The Revenue Function The equation we wish to estimate is:

$$\begin{aligned} \ln r_{it} &= \rho \ln r_{it-1} + (d_H + \mathcal{I}_{it}^x \cdot d_F) - \rho \left(d_H + \mathcal{I}_{it-1}^x \cdot d_F\right) \\ &\quad + \alpha \left(\frac{\sigma - 1}{\sigma}\right) \ln l_{it} - \alpha\rho \left(\frac{\sigma - 1}{\sigma}\right) \ln l_{it-1} + \left(\frac{\sigma - 1}{\sigma}\right) \epsilon_{it} \ . \end{aligned} \tag{A3.1}$$

But selection bias and simultaneity bias prevent us from consistently estimating this expression with ordinary least squares. The former problem occurs because firms choose whether to shut down partly on the basis of their ϵ_{it} realizations, and the latter problem occurs because firms' current exporting decisions ($\mathcal{I}_{it}^x$) and employment levels (l_{it}) depend upon their current productivity levels.

Selection Bias and Identification To deal with these problems, let $\mathcal{I}_{it}^c$ be an indicator variable that takes a value of 1 if the i^{th} firm continues to operate in period t, and 0 otherwise. Then, defining $\xi_{it} = \epsilon_{it} - E\left[\epsilon_{it} | \mathcal{I}_{it}^c = 1, \ln r_{it-1}, \ln \ell_{it-1}, \mathcal{I}_{it-1}^x\right]$, the revenue function can be re-formulated as:

$$\begin{aligned} \ln r_{it} &= \rho \ln r_{it-1} + d_H(1-\rho) + d_F(I_{it}^x - \rho \cdot I_{it-1}^x) + \alpha \frac{\sigma - 1}{\sigma} \ln \ell_{it} \\ &\quad - \alpha\rho \frac{\sigma - 1}{\sigma} \ln \ell_{it-1} + \frac{\sigma - 1}{\sigma} E\left[\epsilon_{it} | \mathcal{I}_{it}^c = 1, ...\right] + \frac{\sigma - 1}{\sigma} \xi_{it}, \end{aligned} \tag{A3.2}$$

where the error term ξ_{it} has zero mean and is orthogonal to $\ln r_{it-1}$, $\ln \ell_{it-1}$, $\mathcal{I}_{it-1}^x$, and $E\left[\epsilon_{it} | \mathcal{I}_{it}^c = 1, ...\right]$. Also, although it is correlated with current exporting decisions (I_{it}^x), ξ_{it} is orthogonal to $E\left[\mathcal{I}_{it}^x | \mathcal{I}_{it}^c = 1, \ln r_{it-1}, \ln \ell_{it-1}, \mathcal{I}_{it-1}^x\right]$. These implications of our model can be used as the basis for a generalized method of moments (GMM) estimator that identifies the parameters of equation (A3.1).[22] And the efficiency of this estimator can be improved by exploiting the moment condition $E\left(\mathcal{I}_{it}^x(1-e^{-d_F})-x_{it}\right)=0$, where $\mathcal{I}_{it}^x(1-e^{-d_F})$ is the share of exports in total sales implied by our model and x_{it} is the observed ratio of export revenues to total sales, which we treat as a noisy measure of true export intensity.

This estimation strategy requires that we calculate $E\left[\epsilon_{it}|\mathcal{I}_{it}^c=1,\ln r_{it-1},\ln \ell_{it-1},\mathcal{I}_{it-1}^x\right]$. To this end, recall that there is a threshold productivity level above which all firms with beginning-of-period employment level ℓ_{it-1} will continue operating. Denoting this threshold productivity level $g^*(\ell_{it-1})$, the continuation condition is $\ln z_{it}=\rho\ln z_{it-1}+\epsilon_{it}>g^*(\ell_{it-1})$. Or, since $\ln z_{it-1}=\frac{\sigma}{\sigma-1}\left[\ln r_{it-1}-(d_H+\mathcal{I}_{it-1}^x d_F)\right]-\alpha\ln l_{it-1}$ (by equation 28), continuation occurs when $\frac{\epsilon_{it}}{\sigma_\epsilon}>\frac{g^*(\ell_{it-1})-\rho\ln z_{it-1}}{\sigma_\epsilon}\overset{def}{=}g(r_{it-1},l_{it-1},\mathcal{I}_{it-1}^x)$, and the probability of continuation can be calculated as

$$p_{it}^C=1-\Phi\left[g(\ln r_{it-1},\ln l_{it-1},\mathcal{I}_{it-1}^x)\right], \tag{A3.3}$$

where $\epsilon_{it}\sim N(0,\sigma_\epsilon^2)$ and $\Phi()$ is the standard normal cumulative distribution. Treating $g(\cdot)$ as a flexible function of its arguments, it follows that p_{it}^C values can be imputed from estimates of the probit function (A3.3), and the conditional expectation of interest can be calculated using well-known properties of the normal distribution (e.g., Maddala, 1983):[23]

$$\begin{aligned} E\left[\epsilon_{it}|\mathcal{I}_{it}^c=1,\ln r_{it-1},\ln \ell_{it-1},\mathcal{I}_{it-1}^x\right] &= \sigma_\epsilon\cdot M_{it}, \\ var\left[\epsilon_{it}|\mathcal{I}_{it}^c=1,\ln r_{it-1},\ln \ell_{it-1},\mathcal{I}_{it-1}^x\right] &= \sigma_\epsilon^2\cdot\left(1-M_{it}\left[M_{it}-\Phi^{-1}(p_{it}^C)\right]\right), \end{aligned}$$

where $M_{it}=\frac{\phi(\Phi^{-1}(p_{it}^C))}{p_{it}^C}$ is the relevant Mills ratio and $\phi()=\Phi'(\ )$.

Our estimation strategy also requires that we calculate $E\left[\mathcal{I}_{it}^x|\mathcal{I}_{it}^c=1,\ln r_{it-1},\ln \ell_{it-1},\mathcal{I}_{it-1}^x\right]$.

[22] Identification further requires that these conditional expectations be non-linear functions of their arguments and/or that they condition on additional arguments that do not appear in equation (A3.2). Note that the dependence of $\ln \ell_{it}$ on ϵ_{it} does not prevent us from obtaining consistent estimates of these parameters because the coefficient on $\ln \ell_{it}$ can be inferred from the coefficients on $\ln \ell_{it-1}$ and $\ln r_{it-1}$.

[23] When estimating this probit, we use a flexible (translog) functional form for $g(r_{it-1},l_{it-1},I_{it-1}^X)$.

For this, note that firms above some threshold productivity level will choose to export, given (l_{it-1}, z_{it-1}). Thus, once again exploiting the normality of ϵ_{it}, we can write

$$E\left[\mathcal{I}_{it}^{x}|\mathcal{I}_{it}^{c}=1,\ln r_{it-1},\ln \ell_{it-1},\mathcal{I}_{it-1}^{x}\right]=p_{it}^{X}=1-\Phi\left[h(\ln r_{it-1},\ln l_{it-1},\mathcal{I}_{it-1}^{x})\right], \qquad \text{(A3.4)}$$

where p_{it}^{X} is the probability that firm i exports in period t and $h(r_{it-1}, l_{it-1}, \mathcal{I}_{it-1}^{x})$ is a flexible function of its arguments.[24] Hence $E\left[\mathcal{I}_{it}^{x}|\mathcal{I}_{it}^{c}=1,...\right]$ can be calculated by estimating the probit (A3.4) and retrieving the imputed p_{it}^{X} values. Clearly, identification here comes from the non-linear form of the probit function.[25]

The Moment Conditions To summarize, our GMM estimator is based on the moment conditions:

$$\begin{aligned}
E[\xi_{it}\ln r_{it-1}] &= 0,\ E[\xi_{it}\ln \ell_{it-1}]=0,\ E[\xi_{it}M_{it}]=0,\ E[\xi_{it}\mathcal{I}_{it-1}^{x}]=0,\\
E[\xi_{it}p_{it}^{X}] &= 0,\ E[\xi_{it}]=0, E[\nu_{it}^{\epsilon}]=0,\ E[\nu_{it}^{x}]=0.
\end{aligned}$$

where:

$$\begin{aligned}
\xi_{it} &= \frac{\sigma}{\sigma-1}\left[\ln r_{it}-d_H(1-\rho)-d_F(\mathcal{I}_{it}^{x}-\rho\mathcal{I}_{it-1}^{x})-\rho\ln r_{it-1}\right]+\alpha\rho\ln \ell_{it-1}-\alpha\ln \ell_{it}-\sigma_{\epsilon}\cdot M_{it},\\
\nu_{it}^{\epsilon} &= \xi_{it}^{2}-\sigma_{\epsilon}^{2}\cdot\left(1-M_{it}\left[M_{it}-\Phi^{-1}(p_{it})\right]\right),\\
\nu_{it}^{x} &= \mathcal{I}_{it}^{x}(1-e^{-d_X})-x_{it}.
\end{aligned}$$

While $\alpha\left(\frac{\sigma-1}{\sigma}\right)$, ρ, $\sigma_{\epsilon}^{2}, d_X$, and d_H can be estimated using the approach sketched above, α

[24] It is interesting that lagged exports help predict current exports here, even though we have assumed away sunk entry costs. The reason is that, by (28), lagged exports help to explain lagged productivity.

[25] Olley and Pakes (1996) develop a related strategy that posits a determinstic linkage between productivity shocks and investment levels. This allows them to get away from functional form as a basis for identification, but it is not an available option in the present setting.

and σ are not separately identified. We therefore set $\sigma = 5$, a value typical of the literature, and generate estimates for the remaining parameters. (Refer to Table 1 in the text.) Our results proved not to be sensitive to the inclusion of time dummies in A1.1. Accordingly, since our theoretical model presumes that the macro environment is stable, we focus our attention on the case in which they are omitted. As noted in section 4.2, however, the results did prove to be sensitive to the way in which our labor measure is constructed and to as the instrument set.

Appendix 4: Numerical Solution Algorithm

The following steps describe the solution algorithm. Since we provide the detailed description of workers and firms problems for the closed economy case, we refer to these equations below with an understanding that the revenue functions (and as a result hiring and firing ages as well as all the value functions) will be adjusted appropriately for the open economy case (9).

- Take τ, τ^m and D_F as given.
- Set $J^o = 1/r$.

1. Start with guesses for D_H, $w_f(z,l), \eta$ and ϕ_f. Given D_H, D_F and η, calculate $w_h(z,l)$ using equation (24).

2. Given D_H, $w_f(z,l), \eta$, ϕ_f and $w_h(z,l)$ calculate the value function for the firm, $\mathcal{V}(z,l)$, using equation (12) and find the associated decision rules for exit, hiring and exporting. Calculate the expected value of entry, $\mathcal{V}_e$, using equation (16). Compare $\mathcal{V}_e$ with c_e. If $\mathcal{V}_e > c_e$, decrease D_H (to make entry less valuable) and if $\mathcal{V}_e < c$, increase D_H (to make entry more valuable). Go back to Step 1 with the updated value of D_H and repeat until D_H converges.

3. Given $w_f(z,l), \eta$, ϕ_f and the converged value of D_H from step 2, update $w_f(z,l)$. To do this, first calculate $J^e(z',l')$ using equations (20) and (23), and imposing the equilibrium condition $J^u = J^o$. Given $J^e(z,l)$, update firing wage schedule using equation (25). Compare the updated firing wage schedule with the initial guess. If they are not close enough go back to Step 1 with the new firing wage schedule and repeat Steps 1 to 3 until w_f converges. Note that if firing wages are too high, then $J^e(z,l)$, the value of being in a firm at the start of a period, is high, since the firm is less likely to fire workers. A high value of $J^e(z,l)$, however, lower firing wages. Similarly, if the firing wages are too low, then J^e is low, which pushed firing wages up.

4. Given ϕ_f, the converged value of D_H step 2, the converged value of $w_f(z,l)$ from step 3, calculate the trade balance. In order to do this:

   (a) Given firms decisions, calculate $f(z,l)$ and $\widetilde{f}(z,l)$, the stationary probability distributions over (z,l) at the end and interim states, respectively.

   (b) Given $\widetilde{f}(z,l)$, calculate average number of vacancies and the average employment in differentiated goods sector using equations (34) and (33).

   (c) Take a guess for N_H. Given N_H and $\overline{v}$, calculate the mass of unemployed L_u in differentiated goods sector from

$$\phi_f(V,L_u) = \frac{M(V,L_u)}{V} = \frac{L_u}{((vN)^\theta + L_u^\theta)^{1/\theta}},$$

   which is one equation in one unknown. Given $N_H, \bar{l}$ and L_u , calculate the size of the workforce in the Q-sector is L_Q from

$$N_H\bar{l} = L_Q - L_u.$$

   Given N_H, $L_S = 1 - L_Q$, M (mass of entrants), and I (aggregate income), check if supply and demand is equal in the service sector

$$\underbrace{L_S + b(\mu_u L_u)}_{\text{supply}} = \underbrace{(1-\gamma)\, I + N_H\overline{c} + N_H c_f + M c_e}_{\text{demand}},$$

   If the supply is greater than the demand, decrease N_H and if supply is less than demand, increase N_H. Repeat until N_H converges. Repeat Step 4c until N_H converges.

   (d) Given the value of N_H from Step 4c, calculate exports and imports. If exports are larger than imports, lower η and if exports are less than imports, increase η. Go back to Step 1 with the updated value of η, and repeat until convergence.

5. Given the converged value of D_H step 2, the converged value of $w_f(z, l)$ from step 2, and the converged value of η from step 4, update ϕ_f. In order to do that, first calculate EJ_h^e using (20). Then find ϕ_w from

$$\phi_w = (1 - \phi_f^\theta)^{1/\theta}.$$

Given EJ_h^e and ϕ_w, calculate J^u using (18). If $J^o > J^u$, increase ϕ_f (to attract workers to differentiated goods sector) and if $J^o < J^u$, we lower ϕ_f (to make the differentiated goods sector less attractive). Go back to Step 1, and repeat until ϕ_f converges.

Estimation Code The above algorithm solves the model for a given set of exogenous parameter values, including the cost of entry c_e. When we estimate the benchmark model to obtain parameter estimates: i) we use the empirical value of η, ii) take the value of D_H estimated in the first stage where we estimate revenue function parameters, iii) set c_e such that free entry holds. This enables us to skip loops 2 and 4 in the calibration. When we do policy experiments by varying the parameters related to trade costs, the values of D_H and η change endogenously, so we use the complete algorithm to solve the model.

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Figure 3: Change in Employment Policy with Reduced Firing Costs

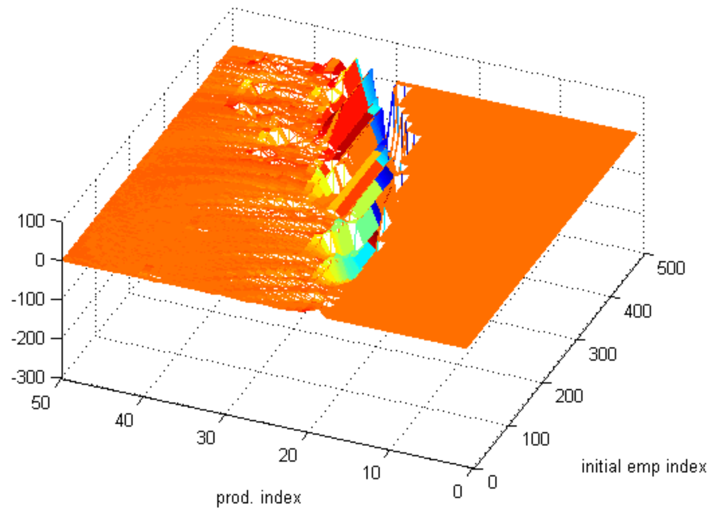

Figure 4: Tariff reduction and change in worker welfare

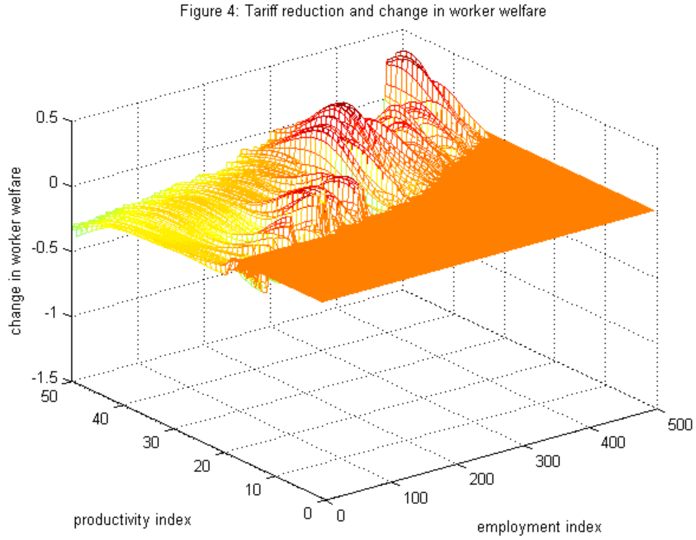

Figure 5: Change in J with Severance Cost Reduction