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ECONOMY

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**ABSTRACT**

This paper explores the effects of tariffs, trade costs, and firing costs on firm dynamics and labor markets outcomes. The analysis is based on a general equilibrium model with labor market search frictions, wage bargaining, firing 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 Colombia's tariff cuts, in isolation, would have shifted jobs toward large, stable firms, reducing job turnover and informality in the long run. Further, since firms pay higher wages when they wish to rapidly expand, the shift of jobs toward such firms would have compressed the top end of the wage distribution. On the other hand, Colombia's firing costs reductions, in isolation, would have led some large inefficient producers to contract, driving up job turnover rates and informality. Finally, however, the combination of tariff cuts and reduced firing costs that was implemented led to larger increases in turnover and informality than would have occurred if tariffs had been held fixed. The reason is that reduced firing costs made firms adjust their sales more dramatically in response to productivity shocks, while openness amplified this effect by making adjustments on the export margin more important.

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# 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 (Inter-American 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). And reductions in firing costs encourage firms to quickly adjust their employment levels in response to supply or demand shocks, as in Ljungqvist (2002) and Pissarides (2000). These well-known effects interact with idiosyncratic productivity shocks, search frictions, and scale economies in worker recruitment to induce adjustments in the equilibrium job turnover rate, unemployment rate, and wage distribution as policy reforms are implemented.

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[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.

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 (2010); Helpman et al (2010); 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

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[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 (2008)). Another characterizes the adjustments in wages, unemployment and labor turnover patterns that derive from trade-induced changes in sectoral output prices (e.g., Kambourov (2009), Artuc, Chaudhuri and McClaren (2010)). 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 (2010)).

[3]Other recent papers that study firm dynamics and labor market frictions in a closed economy context include Cooper et al (2007), Lentz and Mortensen (2008), and Hobijn and Sahin (2010). Utar (2008) studies firm dynamics and labor market fricttions in an import-competing industry that takes the wage rate as given.

(2004), chapter 2). Further, as Goldberg and Pavcnik (2007) note, if openness has had a 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), Bertola and Garibaldi (2001) and Koeniger and Prat (2007) 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

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

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[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. Menezes-Filho et al. (2008) use matched employer-employee data from Brazil and find that establishment fixed effects constitute a smaller share of overall wage variation in Brazil compared to France and the United States.

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

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

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

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

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## 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. (As in Melitz (2003), productivity variation can equally well be thought of as variation in product appeal.) 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

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[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 wages that are determined by Nash Bargaining. 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 sector 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 firm in state $(z, l)$ that sells some fraction $1 - \eta$ of its output domestically will generate home sales amounting to

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

Similarly, by exporting the remaining fraction $\eta$ such a firm will generate foreign sales of

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

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[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.

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 $I_F$ and $\bar{P}_F$ are exogenous to the model.

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

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

where $s_H(z,l,\eta)$ 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 $zl^\alpha$, since the gains from foreign market participation increase monotonically with production. *Given* foreign market participation, optimal fraction of output to export is given by

$$\eta^o = \frac{1}{1 + \frac{\tau_c^{\sigma-1} D_H}{k^\sigma D_F}}. \tag{10}$$

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

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[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.

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]

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 is ignorable. That is, all firms fill the same fraction $\phi_f$ 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

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

[9]The reason this result emerges is that labor market frictions prevent firms from freely expanding as exporting opportunities arise. 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 $\lambda_2 = 1 - 1/\lambda_1$. See also Monika and Yashiv 2003, and Yashiv 2006. 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."

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

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

All labor adjustment costs are in terms of the service good.[11] Note, however, that firing 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), Cahuc and Wasner (2000), and Cahuc, Marque, and Wasmer (2008) 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, $\phi_f$, 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 $(l' \leq l)$

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[11]As is standard in the literature (see Ljungqvist (2002) for a review), we assume that firing costs take the form of a resource cost and are not pure transfers from firms to workers.
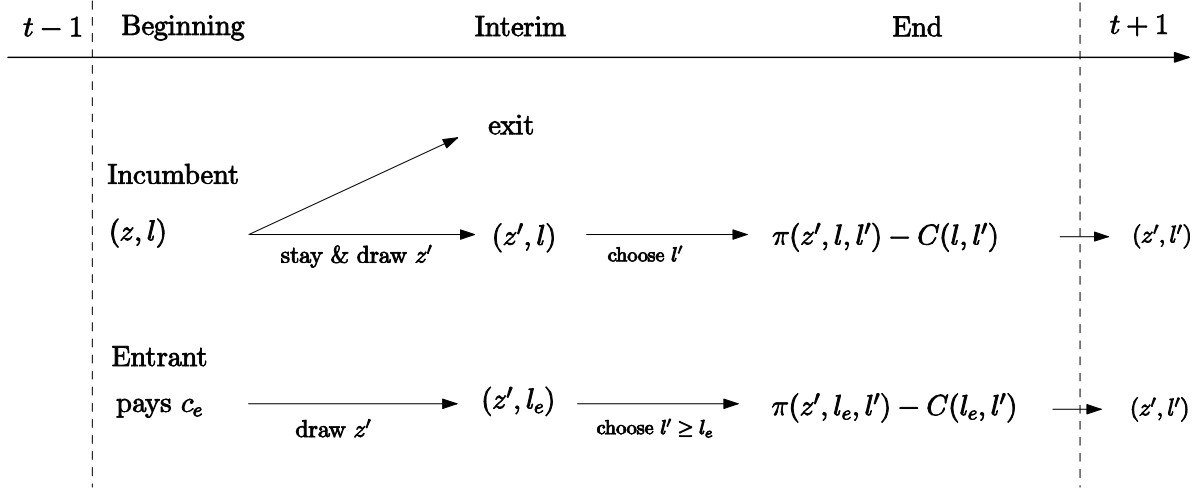
Figure 1: Within-period Sequencing of Events for Firms

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

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

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

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

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 $\mu_{exit}$ 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 ergodic distribution of the Markov process governing incumbents' productivity. We denote this density function by $f_e(z)$ and we assume it is identical to the ergodic $z$ distribution implied by $h(z'|z)$. 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

$$\mathcal{V}_e = \int_z \mathcal{V}(z, l_e) f_e(z) dz \le c_e, \tag{16}$$

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

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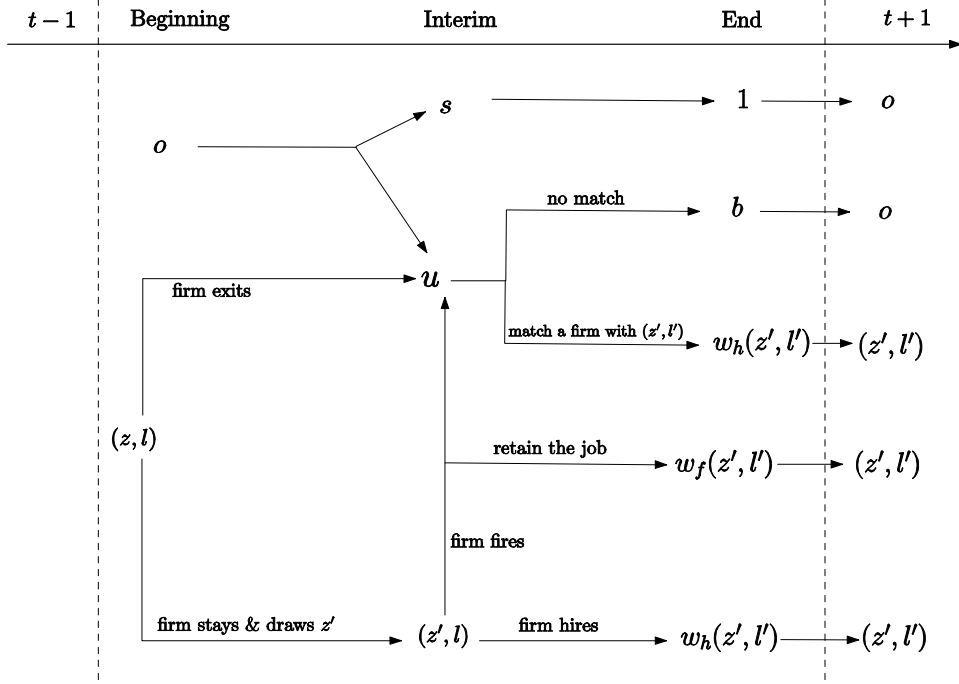
Figure 2: Within-period Sequencing of Events for Workers

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 $\phi_w$, the interim value of searching for an industrial job is

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

where $E J_h^e$ 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:

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

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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, $EJ_h^e$, 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

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

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

$$EJ_h^e = \int_{z'} \int_l J_h^e(z', l) g(z', l) dl dz', \tag{21}$$

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

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

15

## 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[12]

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

where

$$\Delta(z', l') = D_H^{\frac{1}{\sigma}}[1 - \eta^o \mathcal{I}^x(z', l')]^{\frac{\sigma-1}{\sigma}} + D_F^{\frac{1}{\sigma}}k\tau_c^{-\frac{\sigma-1}{\sigma}}[\eta^o \mathcal{I}^x(z', l')]^{\frac{\sigma-1}{\sigma}},$$

and

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

In (24), $r\frac{b+J_o}{1+r}$ 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. 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.[13]

The marginal worker at a non-hiring firm generates no rents, so the firing wage just matches

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

[13]As in Bartelo and Cabellero (1994), wages decline in firms' employment ($l'$), holding productivity ($z$) fixed. This reflects the diminishing marginal revenue product of labor, and induces firms to hoard labor and thereby by workers' wages low. Cahuc, Marque, and Wasmer (2008) discuss conditions under which overemployment result might hold at the macroeconomic level.

her reservation value (see Appendix 1)

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

Five 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, so trade is balanced. Fifth, workers optimally choose the sector in which they are working or seeking work. 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 11.3 percent (Table 1). Second, Colombia also implemented labor market reforms in 1990 that substantially reduced firing costs.[14] 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 8 percent 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.

## 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

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[14]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 in Colombia***

| Variable | pre-1990 | post-1990 |
|---|---|---|
| Average nominal import tariff | 21.50 | 11.30 |
| Firing costs 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).

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, $\mathcal{I}_{it}^x$:

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

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:

$$\ln s_{it} = (d_H + \mathcal{I}_{it}^x d_F) - \rho (d_H + \mathcal{I}_{it-1}^x d_F) + \rho \ln s_{it-1} \qquad (30)$$
$$- \alpha \rho \left( \frac{\sigma - 1}{\sigma} \right) \ln l_{it-1} + \alpha \left( \frac{\sigma - 1}{\sigma} \right) \ln l_{it} + \frac{\sigma - 1}{\sigma} \epsilon_{it},$$

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 $d_H$, $d_F$, $\rho$, $\alpha \left( \frac{\sigma-1}{\sigma} \right)$, 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 $\epsilon_{it}$ 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 $\epsilon$ is observed, so $\epsilon_{it}$ 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.[15] Since $\sigma$ is not identified separately from $\alpha$, we fixed this 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.[16]

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[15] 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 firms' capital stocks.

[16] 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 $\alpha$ value, although it has little effect on $\rho$.

Table 2: **Estimates for the Revenue Function and Productivity Process***

| Parameter | Estimate | Std. error | z-ratio |
|---|---|---|---|
| $\alpha$ | 0.592 | 0.057 | 10.41 |
| $\rho$ | 0.848 | 0.007 | 118.73 |
| $\sigma_\varepsilon^2$ | 1.668 | 0.042 | 39.54 |
| $d_H$ | 1.682 | 0.047 | 35.78 |
| $d_F$ | 0.213 | 0.004 | 51.31 |

* GMM estimates, given $\sigma = 5$

Table 3: **Parameters Fixed Before Simulating Moments**

| Parameter | Value | Description | Source |
|---|---|---|---|
| $\alpha$ | 0.592 | production function | GMM estimate (Table 2) |
| $\rho$ | 0.848 | persistence of $z$ process | GMM estimate (Table 2) |
| $\sigma_\varepsilon$ | 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) |
| $\tau_c$ | 2.50 | iceberg trade costs | Eaton and Kortum (2003) |
| $\beta$ | 0.5 | bargaining power | assumed (literature) |
| $\sigma$ | 5 | elasticity of substitution | assumed (literature) |
| $r$ | 0.15 | discount rate | Bond, et al (2008) |
| $\theta$ | 1.27 | elasticity of matching function | den Haan et al (2000) |

## 4.3   Remaining Parameters

We fix several parameters 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, $\theta$, 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 $\tau_c$ value, along with our estimates for $d_F$ and $d_H$, implies $D_H$ and $k^\sigma D_F$.[17]

Table 3 collects the parameter values discussed thus far, and implies that 10 parameters remain to be determined: the cost of creating a new firm, $c_e$, the fixed cost of operation, $c_p$, the fixed cost of exporting, $c_x$, the value of informal sector production, $b$, the firing cost in terms of service sector goods, $c_f$, the initial size of new firms, $l_e$, the share of differentiated

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[17]Equations (26), (27), and (10) imply $\exp(d_F) = (1 - \eta_0)^{-1}$, so we can impute $\eta_0$ 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 $\sigma$ and the estimated value of $d_H$. Finally, given a value for $\tau_c$, $k^\sigma D_F$ follows from (10).

goods in total expenditures, $\gamma$, and the parameters of the vacancy cost function, $(c_h, \lambda_1, \lambda_2)$. We estimate these parameters using the simulated method of moments and 14 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, firing cost (in terms of years of wages), 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.[18] 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 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, $\lambda_2$ 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, $\gamma$. Fourth, firing cost parameter $c_f$ determines average firing costs in terms of years of wages. Finally, the unemployment/informality rate is very responsive to the productivity of informal sector workers, $b$.

Table 4 reports the data-based statistics we use for calibration and their model-based simulated counterparts. Although we are using 10 parameters to try to match 14 statistics, the model does a nice job of fitting the data overall.[19] In particular, the model captures the

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[18] 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 and arrive at a measure of residual wage inequality. 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.

[19] The metric of fit we used was the average $|1 - Y_i/X_i|$ where $X_i$ is the $i^{th}$ data-based statistics and $Y_i$ is the corresponding model-based statistic. At its minimized value, this metric was 0.087.

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 S sector | 0.550 | 0.570 | >80th percentile | 0.157 | 0.135 |
| Firing cost (in years of wages) | 1.40 | 1.40 | | | |
| $corr(l,l')$ | 0.95 | 0.962 | | | |
| $corr(z,l')$ | 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. The firing cost in years of wages is based on Heckman and Pages (2004).

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.

Note that we use the sum of unemployment and informal self-employment as our data target. Since Colombia does not have an unemployment insurance system, it is common for unemployed workers to be self-employed at jobs with low entry costs (such as street vending) and keep searching for a salaried job. As a result, flows from informal self-employment into formal employment are substantial compared to flows from unemployment.[20]

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. This figure amounted to roughly $1,300 US (1977), or about $4,500 current US dollars. Accordingly, our model implies that the costs

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[20]Bosch and Maloney (2007) describe gross worker flows in the presence of informal labor markets in the context of Mexico, a country with a similar institutional setup.

Table 5: **Calibrated Parameter Values***

| Parameter | Value | Description |
|-----------|-------|-------------|
| $c_p$ | 30.87 | fixed cost of operation |
| $c_h$ | 2.11 | posting cost scalar |
| $c_x$ | 16.91 | fixed exporting cost |
| $b$ | 0.72 | value of home production |
| $\lambda_1$ | 2.32 | convexity, vacancy cost function |
| $\lambda_2$ | 0.30 | scale effect, vacancy cost function |
| $\gamma$ | 0.50 | share of Q goods in total spending |
| $l_e$ | 3.82 | initial size, entering firms |
| $c_e$ | 281.96 | entry cost for new firms |
| $c_f$ | 1.60 | firing cost in service sector goods |

* Based on method of simulated moments.

of creating a new firm are about \$1,267,000, the fixed costs of operating a business amount to about \$139,000, and the fixed costs of exporting are about \$76,000. Note also that those who end up working 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 ($\lambda_2 = 0.30$).[21]

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[21] Our of $\lambda_1$ is consistent with the available evidence on hiring cost convexities (e.g. Merz and Yashiv (2007), and Yashiv (2006)). We also come close to satisfying the relationship $\lambda_2 = 1 - 1/\lambda_1$ implied by Nilsena et al's (2007) specification.

## 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 puts downward pressure on the domestic sales of Q-sector firms. But it also induces a real currency devaluation through the balanced trade condition and thereby increases the optimal export share $\eta$ (by equation 10) and the fraction of firms that export. As in Melitz's (2003) model, this export expansion is concentrated among large firms, so the right-hand tail of the firm size distribution becomes more skewed (Table 6).

Three forces link tariff rates to labor market outcomes. First, as tariff reductions shift the size distribution in favor of large firms, they concentrate employment at firms that can exploit scale economies in vacancy posting. Second, this same shift in the size distribution concentrates production at firms that experience relatively small productivity shocks, since the estimated productivity process is mean-reverting.[22] Finally, tariff reductions move the threshold output level for exporting, and thus change the number and type of firms that adjust their exporting status in response to productivity shocks. This matters because firms that cross this threshold make larger percentage-wise employment adjustments than they would have if exporting had never been an attractive option.

Tables 6 and 7 show that the second effect is dominant. Tariff reductions shift jobs toward larger firms, and as this happens job turnover declines by several points. Further, because this means less worker displacement, the rate of unemployment/informality falls. Finally, because fewer jobs are located at firms that wish to rapidly expand after the tariff reduction, 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 in isolation tend to reduce job turnover and wage inequality.[23] The results

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[22]Since $z' - z = (\rho - 1)z + \epsilon$, $E(z' - z|z)$ is a negative monotonic function of $z$ for $0 < \rho < 1$.

[23]Our results on wage inequality also contrast with those of other recent models of trade with heterogeneous

Table 6: **Size Distribution Effects of Trade Costs and Firing Costs**

| | Base Case | Reductions in | | | |
| --- | --- | --- | --- | --- | --- |
| | | Tariffs | Firing Costs | Tariffs and Firing Costs | Tariffs and Iceberg Costs |
| Tariffs $(\tau_m)$ | 1.21 | 1.11 | 1.21 | 1.11 | 1.11 |
| Iceberg costs $(\tau_c)$ | 2.50 | 2.50 | 2.50 | 2.50 | 2.19 |
| Firing costs $(c_f)$ | 1.60 | 1.60 | 1.20 | 1.20 | 1.60 |
| 20th percentile | 14.9 | 15.5 | 11.2 | 14.4 | 16.4 |
| 40th percentile | 31.4 | 32.3 | 22.5 | 29.6 | 32.2 |
| 60th percentile | 62.8 | 63.0 | 48.6 | 49.8 | 69.5 |
| 80th percentile | 105.0 | 131.1 | 90.9 | 90.1 | 104.0 |

Table 7: **The Labor Market Effects of Trade Costs and Firing Costs**

| | Base Case | Reductions in | | | |
| --- | --- | --- | --- | --- | --- |
| | | Tariffs | Firing costs | Tariffs and Firing Costs | Tariffs and Iceberg Costs |
| Tariffs $(\tau_m)$ | 1.21 | 1.11 | 1.21 | 1.11 | 1.11 |
| Iceberg costs $(\tau_c)$ | 2.50 | 2.50 | 2.50 | 2.50 | 2.19 |
| Firing costs $(c_f)$ | 1.60 | 1.60 | 1.20 | 1.20 | 1.60 |
| Share of firms exporting | 0.145 | 0.176 | 0.143 | 0.164 | 0.237 |
| Job turnover | 0.222 | 0.199 | 0.231 | 0.239 | 0.196 |
| Unemployment/informality | 0.284 | 0.262 | 0.311 | 0.319 | 0.263 |
| Log 90-10 wage ratio | 2.033 | 1.789 | 2.055 | 2.066 | 1.902 |
| Share labor in Q sector | 0.429 | 0.425 | 0.444 | 0.452 | 0.419 |
| Wage dispersion, Q sector | 0.800 | 0.755 | 0.854 | 0.812 | 0.796 |
| Average wage, Q sector | 1.829 | 1.753 | 1.928 | 1.940 | 1.780 |

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.

### 4.4.2 Firing Costs

We next investigate the effects of firing reductions on job turnover and wage inequality. To begin, consider the effects of reducing these costs by 25 percent, per Table 1, holding the tariff rate at its pre-reform level. Relative to the pre-reform equilibrium, firms with low employment and high current productivity react by hiring more workers, while large, inefficient firms shed labor. This is shown in Figure 3, which reports the absolute changes in employment levels, $L(z', l)$, associated with lower firing costs.

These adjustments concentrate employment among smaller firms which, as discussed above,

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 (2010), Helpman et al, (2010), Egger and Kreickemeier (2007), Amiti and Davis (2008), Davis and Harrigan (2008), Felbermayr et al (2008).

are relatively volatile (Table 6, column 3 versus column 1). Further, as is standard in many search and matching models (e.g., Ljungqvist (2002) and Mortensen and Pissarides (1999)), lower firing costs increase the value of reallocating labor. Combined, the size distribution effect and the reduction in market frictions drive up the turnover rate by about one percentage point (Table 7, column 3).

Finally, the higher turnover rate also leads to more rents among expanding firms, increasing the average wage. This 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 of informality/unemployment by 3 percentage points. So Colombia's firing cost reduction, taken by itself, goes part way toward explaining the changes in labor market conditions Colombia experienced during the 1990s.

### 4.4.3   The Reform Package

Now consider the combined effects of reduced tariffs and reduced firing costs, i.e., the reform package that Colombia implemented circa 1990s. Interestingly, although tariff reductions in isolation reduce turnover, tariff reductions in combination with firing cost reductions *amplify* turnover (Table 7, column 4). The reason is that reductions in firing costs make employment and output more responsive to productivity shocks, and thereby increase the set of firms that cross the threshold between exporting and non-exporting in a typical period. That is, reductions in firing costs make the third linkage between tariffs and labor market outcomes (discussed above) more important. The same interaction effects between tariff reductions and firing costs lead to a larger informal sector than Colombia would have experienced if it had implemented a reduction in firing costs alone. However, reductions in tariffs do little to dampen the effects of reduced firing costs on average wages and wage dispersion.

Overall, our simulations of the Colombian reform package account for much of the observed transformation in labor market conditions during the 1990s (Table 7, column 4). The model predicts an increase in turnover rates by 1.8 percentage points relative to the base case,

while the data show an increase of 1.9 percentage points. The model predicts an increase in unemployment and informality by 3.5 percentage points, while the data show an increase of 2.8 percentage points. Finally, the model predicts an increase in the 90-10 wage ratio by 3.3 percentage points, while the data predict an increase of 8 percentage points. Thus, while other factors surely mattered, the linkages captured by our model by themselves provide a fairly comprehensive explanation for the labor market adjustments of interest.

Colombia's firing cost reductions were partly motivated by a desire to help domestic firms become competitive in global markets, so it is interesting to ask whether they encouraged exporting. According to our model the answer is: yes and no. Small to mid-size firms drawing positive productivity shocks were more likely to take on the extra labor needed to become exporters after firing costs fell. This is reflected in Figure 4, which shows the changes in the export indicator function $\mathcal{I}^x(z, l)$ induced by the reform package. (Recall that this function takes a value of 1 for firms that starts exporting and 0 for others.) On the other hand, large firms with mediocre productivity carried excessive labor when firing costs were high, and they used this labor to generate export revenue. Once firing costs were reduced, these large unproductive firms shed some of their excess workers and cut back or eliminated their foreign sales (Those that did the latter show a change in $\mathcal{I}^x(z, l)$ of -1 in Figure 4.)

### 4.4.4 Iceberg Costs

Our simulations imply that Colombia's reform package increased the share of firms that export by about 2 percentage points. But this share actually rose 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 that tariffs and firing costs were falling, it is likely that other forces were encouraging trade, including reductions in transport costs and protection rates among trading partners.

To approximate the effects of these other trade-inducing forces, our final exercise is to consider reductions in iceberg costs by an amount sufficient to induce a 9 pecentage point increase in the share of firms who export. The rightmost column in Tables 6 and 7 reports the

associated changes in the plant size distributions and labor market aggregates, respectively. As expected, reductions in iceberg costs make imported varieties cheaper, causing firms to contract their domestic sales and induce more firms to export. However, unlike in the $\tau_m$ 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 firms with few workers 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 $\tau_m$ alone—do not entice small efficient firms into exporting because the associated increment to their profits falls short of fixed exporting costs.)

### 4.4.5 Welfare Effects of the Reforms

Overall, our simulations imply that the reforms increased average welfare by only 0.3 percent. However, some $Q$-sector workers were affected much more dramatically, and their fates depended upon their employer's characteristics. To summarize these welfare effects we present three figures, each depicting the change in $J^e(z,l)$ associated with a particular reform. (Recall that $J^e(z,l)$ is the value of starting a period matched with a firm in state $z,l$.) Figure 5 depicts the change associated with the tariff reduction from $\tau_m = 1.21$ to $\tau_m = 1.11$, Figure 6 depicts the change associated with the reduction in firing costs from $c_f = 1.6$ to $c_f = 1.2$, and Figure 7 depicts the change associated with both reductions at once. When interpreting the magnitudes of the changes, it is useful to keep in mind that the value of being in the unemployed state is $1/r = 6.67$ for all workers.

For reductions in $\tau_m$ alone, workers at small firms do worse (as reflected in negative numbers in Figure 5), workers at large, high productivity firms do better, and all others are unaffected. This is essentially because most small employers face new import competition but don't have sufficiently high productivity to benefit from export markets. For reductions in $c_f$

alone, 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 $c_f$. Finally, the actual reform package created a mixture of these forces, with workers at small, low productivity firms losing the most and workers at large, high productivity firms gaining the most.

# 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 the policy reforms, idiosyncratic productivity shocks, exporting incentives, and scale economies in hiring workers. Simulations of our model imply that by themselves, tariff reductions are unlikely to have caused the deterioration in labor market conditions that Colombia experienced during the 1990s. However, reductions in firing costs and tariffs interact with one another, and together go some way toward explaining observed increases in job turnover, wage dispersion and informality.

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, it generalizes the representation of labor markets with multi-worker firms 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, it demonstrates 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 $\beta$, 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

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

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

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

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 $\beta$. In event of a contraction, the firm cannot enforce contracts that stipulate laid-off workers must 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

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

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

Using

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

where

$$\Delta(z', l') = D_H^{\frac{1}{\sigma}}[1 - \eta^o\mathcal{I}^x(z', l')]^{\frac{\sigma-1}{\sigma}} + D_F^{\frac{1}{\sigma}}k\tau_c^{-\frac{\sigma-1}{\sigma}}[\eta^o\mathcal{I}^x(z', l')]^{\frac{\sigma-1}{\sigma}},$$

the wage schedule for expanding firms is given by

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

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

**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 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 $\mu_u$, job finding rate $\phi_w$, vacancy filling rate $\phi_f$, the exit rate $\mu_{exit}$, the fraction of firms exporting $\mu_x$, 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. In order to define the interim distribution, $\widetilde{f}(z,l)$, let $\widetilde{\widetilde{f}}(z',l)$ be the interim frequency measure of firms defined as

$$\widetilde{\widetilde{f}}(z',l) = \left\{ \begin{array}{l} \int_z h(z'|z)f(z,l)\mathcal{I}^c(z,l)dz \text{ if } l \neq l_e \\ f_e(z') + \int_z h(z'|z)f(z,l)\mathcal{I}^c(z,l)dz \text{ if } l = l_e \end{array} \right. .$$

Then, $\widetilde{f}(z',l)$ is given by

$$\widetilde{f}(z',l) = \frac{\widetilde{\widetilde{f}}(z',l)}{\int_{z'}\int_l \widetilde{\widetilde{f}}(z',l)dz'dl},$$

while the end-of-the period distribution is

$$f(z',l') = \frac{\int_l \widetilde{f}(z',l)\mathcal{I}_{(L(z',l),l')}dl}{\int_{z'}\int_l \widetilde{f}(z',l)\mathcal{I}_{(L(z',l),l')}dz'dl},$$

where $\mathcal{I}_{(L(z',l),l')}$ is an indicator function with $\mathcal{I}_{(L(z',l),l')} = 1$ if $L(z',l) = l'$.

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, fixed exporting costs, labor adjustment

and entry costs. The average labor adjustment cost is given by

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

Market clearance condition in this sector is then given by

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

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

3. **Labor Market Clearing:** 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

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

where

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

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 $\mu_l$ of workers in that sector are laid off due to exits and downsizing

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

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 $\mu_h$ 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. **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

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

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

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

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

$$S_F = N_H \int_z \int_l s_F(z, l, \eta^o) \mathcal{I}^x(z, l) f(z, l) dl dz,$$

and since service goods are non-traded, balanced trade obtains when $\frac{E_F}{\tau_m} = S_F$. The exchange rate $k$ moves to ensure that this condition holds. Balanced trade ensures that national income matches national expenditure.

6. Workers are indifferent between taking a certain job in the undifferentiated sector and searching a job in industrial sector: $J^o = J^s = J^u$.

# Appendix 3: Estimating the Revenue Function and Productivity Process

**The Revenue Function**  The equation we wish to estimate is:

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

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 $\epsilon_{it}$ 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 $\xi_{it} = \epsilon_{it} - E\left[\epsilon_{it}|\mathcal{I}_{it}^c = 1, \ln s_{it-1}, \ln \ell_{it-1}, \mathcal{I}_{it-1}^x\right]$, the revenue function can be reformulated as:

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

where the error term $\xi_{it}$ has zero mean and is orthogonal to $\ln s_{it-1}$, $\ln \ell_{it-1}$, $\mathcal{I}_{it-1}^x$, and $E\left[\epsilon_{it}|\mathcal{I}_{it}^c = 1, ...\right]$. Also, although it is correlated with current exporting decisions $(I_{it}^x)$, $\xi_{it}$ is orthogonal to $E\left[\mathcal{I}_{it}^x|\mathcal{I}_{it}^c = 1, \ln s_{it-1}, \ln \ell_{it-1}, \mathcal{I}_{it-1}^x\right]$. 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).[24] 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 $E\left[\epsilon_{it}|\mathcal{I}_{it}^c = 1, \ln s_{it-1}, \ln \ell_{it-1}, \mathcal{I}_{it-1}^x\right]$. To this end, recall that there is a threshold productivity level above which all firms with beginning-of-period employment level $\ell_{it-1}$ 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 $\ln z_{it-1} = \frac{\sigma}{\sigma-1}\left[\ln s_{it-1} - (d_H + \mathcal{I}_{it-1}^x d_F)\right] - \alpha \ln l_{it-1}$ (by equation 28), continuation occurs when $\frac{\epsilon_{it}}{\sigma_\epsilon} > \frac{g^*(\ell_{it-1}) - \rho \ln z_{it-1}}{\sigma_\epsilon} \overset{def}{=} g(s_{it-1}, l_{it-1}, \mathcal{I}_{it-1}^x)$, and the probability of continuation can be calculated as

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

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):[25]

$$E\left[\epsilon_{it}|\mathcal{I}_{it}^c = 1, \ln s_{it-1}, \ln \ell_{it-1}, \mathcal{I}_{it-1}^x\right] = \sigma_\epsilon \cdot M_{it},$$

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

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 $E\left[\mathcal{I}_{it}^x|\mathcal{I}_{it}^c = 1, \ln s_{it-1}, \ln \ell_{it-1}, \mathcal{I}_{it-1}^x\right]$. For this, note that firms above some threshold productivity level will choose to export, given

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[24]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 $\epsilon_{it}$ 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 $\ln r_{it-1}$.

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

$(l_{it-1}, z_{it-1})$. Thus, once again exploiting the normality of $\epsilon_{it}$, we can write

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

where $p_{it}^X$ is the probability that firm $i$ exports in period $t$ and $h(s_{it-1}, l_{it-1}, \mathcal{I}_{it-1}^x)$ is a flexible function of its arguments.[26] 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.[27]

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

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

where:

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

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

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[26] 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.

[27] 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.

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

We begin our solution algorithm with exogenous values for $\tau, \tau^m$, $D_F$, and $r$, thereby immediately determining $J^o = 1/r$. To compute the value functions, we discretize the state space on a log scale using 500 grid points for employment and 50 grid points for productivity. We set the maximum firm size as 7,500 workers and numerically check that this is not restrictive. In steady state, a negligible fraction of firms reach this size. We then:

1. Formulate guesses for $c_f, D_H$, $w_f(z,l), \eta$ and $\phi_f$. Calculate $w_h(z,l)$ using equation (24).

2. Given $D_H$, $w_f(z,l), \eta$, $\phi_f$ 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 $w_f(z,l), \eta$, $\phi_f$ 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 $\phi_f$, the converged value of $D_H$ from 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 $\bar{v}$, calculate the mass of unemployed $L_u$ in differentiated goods sector from

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

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

$$\underbrace{L_S + b\mu_u L_Q}_{\text{supply}} = \underbrace{(1 - \gamma) I + N_H(\bar{c} + c_p + \mu_x c_x) + M c_e}_{\text{demand}},$$

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 $\eta$ and if exports are less than imports, increase $\eta$. Go back to Step 1 with the updated value of $\eta$, and repeat until convergence.

5. Given the converged value of $D_H$ from Step 2, the converged value of $w_f(z, l)$ from Step 3, and the converged value of $\eta$ from Step 4, update $\phi_f$. In order to do that, first

calculate $EJ_h^e$ using (20). Then find $\phi_w$ from

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

Given $EJ_h^e$ and $\phi_w$, calculate $J^u$ using (18). If $J^o > J^u$, increase $\phi_f$ (to attract workers to differentiated goods sector) and if $J^o < J^u$, we lower $\phi_f$ (to make the differentiated goods sector less attractive). Go back to Step 2, and repeat until $\phi_f$ converges.

6. Calculate average wages in equilibrium. Check if $c_f$ is the right multiple of average wages. If not, update $c_f$ and go back to Step 1.

**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, we: i) use the empirical value of $\eta$, 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 Step 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 $\eta$ change endogenously, so we use the complete algorithm to solve the model.

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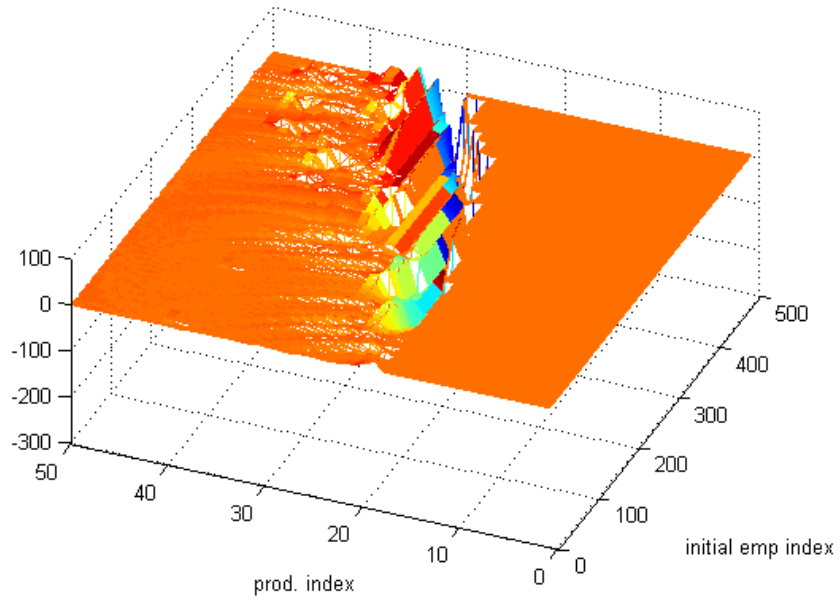Figure 3: Change in Employment Policy with Reduced Firing Costs



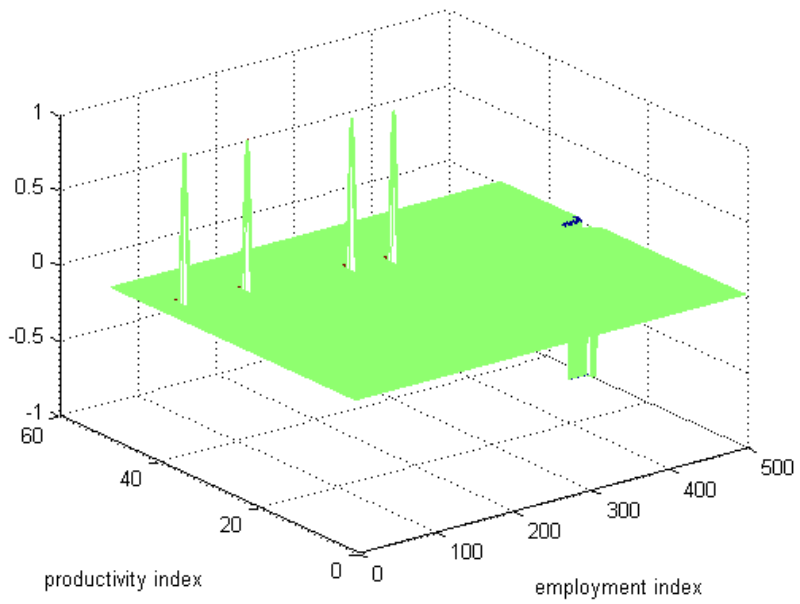Figure 4: Change in Export Indicator with Reduction in Firing Costs

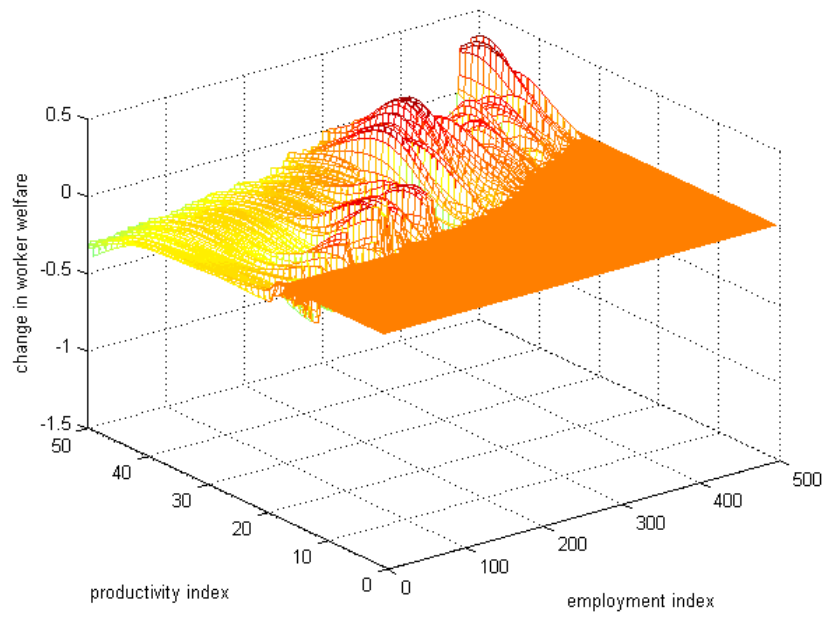Figure 5: Tariff reduction and change in worker welfare



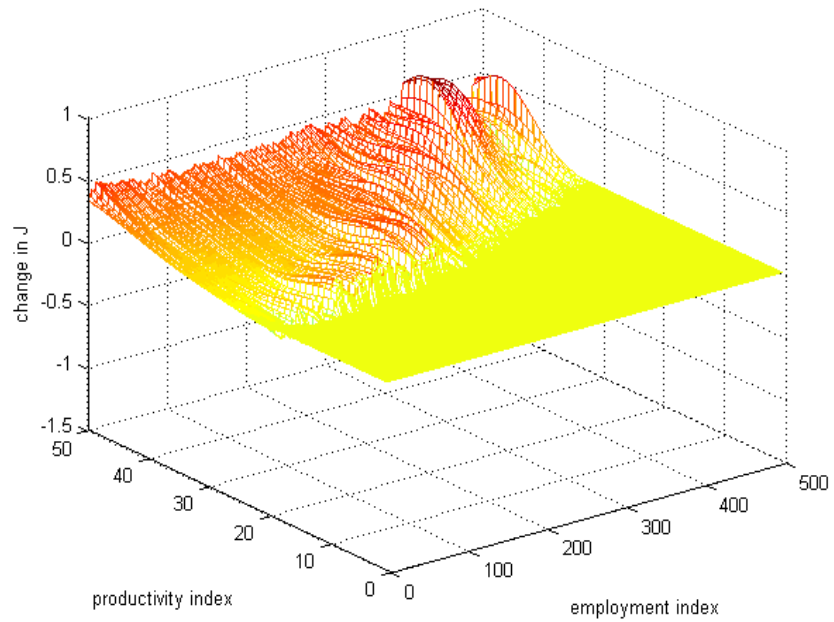Figure 7: Change in Employed Worker Welfare with Reform Package

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Figure 7: Change in Worker Welfare with Reform Package