

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

(Preliminary and Incomplete)

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February 15, 2009

Abstract

We characterize the effects of openness on job turnover patterns, unemployment rates, and wage distributions in the presence of ongoing productivity shocks. We do so by introducing Mortensen-Pissarides-type labor market rigidities into a general equilibrium trade model with heterogeneous firms, adding firm-level productivity shocks and allowing for endogenous entry and exit. The resulting model endogenizes separation rates among differentiated goods producers, and highlights some effects of openness on labor markets that have not been previously studied. Specifically, reductions in trade barriers makes profits more sensitive to productivity, as in Melitz (2003). This increases firms' incentives to hire or fire workers as idiosyncratic productivity shocks occur, thereby increasing job turnover and, because of the search frictions, spreading the wage distribution. Preliminary simulations at plausible parameter values suggest that these effects can be important. Estimation of the model is in progress.

1 Introduction

In developing countries, globalization is often blamed for exacerbating wage inequality, reducing job security, and increasing the size of the informal sector. Reduced-form empirical studies have suggested that a link is present—in particular, greater exposure to international markets appears to be associated with increased wage inequality.¹ However, labor market outcomes reflect many factors besides foreign competition, and reduced-form regressions have not convincingly isolated causal relationships. To better isolate and measure the effects of openness on developing countries' workers, we formulate and estimate a dynamic structural model of trade with labor market frictions.

Our formulation shares some features with a number of recent trade models that describe the effects of openness on labor market outcomes (Felbermayr et al, 2007; Helpman and Itskhoki, 2007; Helpman, et al, 2008; Egger and Kreickemeier, 2007; Davis and Harrigan, 2008; Amiti and Davis, 2008).² In particular, it embodies Melitz's (2003) basic insight that openness

¹Goldberg and Pavcnik (2007) provide an excellent survey of the literature. They argue: "First, the exposure of developing countries to international markets . . . has increased substantially in recent years. Second, . . . all existing measures for inequality in developing countries seem to point to an increase in inequality, which in some cases (e.g., pre-NAFTA Mexico, Argentina in the 1990's) is severe. And finally, "Many globalization opponents have argued that globalization may have adverse effects on inequality in the broader sense, by . . . increasing the proportion of workers in the informal sector of the economy." Menezes-Filho and Muendler (2007) find that increased openness in Brazil was associated with an increase in self-employment and the size of the informal sector.

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

compounds the advantage of relatively efficient firms by creating new exporting opportunities for them, while compounding the problems of relatively inefficient firms by intensifying the competitive pressures they face. However we depart from the existing literature in two ways. First, we assume that firms experience ongoing, idiosyncratic productivity shocks (as in Hopenhayn, 1992, and Hopenhayn and Rogerson, 1993), inducing them to adjust their vacancy postings, lay-offs and exit decisions. (as in Bertola and Caballero, 1994, and Bertola and Garibaldi, 2001). Second, we use Colombian micro data to estimate many of the parameters in our model, thus providing a basis for numerical experiments that quantify the effects of openness under alternative assumptions.

Idiosyncratic productivity shocks and endogenous exit by firms induce a little-studied mechanism through which openness affects labor markets. Specifically, reductions in trade barriers makes firms' profits more sensitive to their productivity, as in Melitz (2003). This increases their incentives to hire or fire workers as productivity shocks occur, thereby increasing job turnover and, because of the search frictions, spreading the wage distribution.³ Simulations at plausible parameter values show that these effects can be important.

While we do not pretend to capture all of the channels through which openness can affect labor market outcomes, our focus on idiosyncratic firm-level productivity shocks is supported by existing empirical evidence on the sources of job insecurity and wage heterogeneity. Studying Colombia, Chile and Morocco, Roberts (1996) documents that more than 80 percent of the job creation and destruction during his sample years was due to intra-industry plant-specific shocks. 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." In particular, Haltiwanger et al (2004) find that, in six Latin American countries, tariff reductions were associated with increased within-sector job turnover and lower sectoral employment. Finally, while cross-worker differences in wages are

³This mechanism is related to some arguments put forward by Rodrik (1997) a decade ago. He reasoned that as firms improve their capacity to move production facilities across borders, the elasticity of demand for domestically-based workers increases, reducing their bargaining power and job security. Although we are not concerned with the international mobility of capital, openness effectively increases the elasticity of labor demand in our model through product market effects, and similarly reduces job security.

obviously partly due to differences in worker characteristics, much is attributable to labor market frictions and firm heterogeneity.⁴

2 Environment: The Closed Economy

For expositional clarity, we first develop our model for the case of a closed economy.⁵ This formulation extends Bertola and Cabellero (1994) and Bertola and Garibaldi (2001) to a general equilibrium setting with fully articulated product markets, arbitrary (stationary) Markov processes for productivity shocks, endogenous firm entry and exit, and risk of exogenous worker separation. Once we have characterized the interactions between the labor markets, product markets, and productivity shocks in this setting, it is straightforward to generalize the analysis to an open economy and allow for intra-sectoral trade.

There are two types of output in our economy—services and industrial goods. The former are non-traded while the latter are tradable, subject to transport costs. Services are supplied by 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 who supply services use a common constant returns technology, and face no hiring or firing costs.

Industrial goods cannot be home-produced. They must be supplied by 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 a monopolistically competitive product market. Unlike service sector firms, suppliers of industrial goods are subject to ongoing idiosyncratic productivity shocks, and they must create costly vacancies in order to attract new workers. The shocks can equally well be thought of as affecting firms’ relative product appeal.

Producer dynamics in the industrial sector resemble those in Hopenhayn and Rogerson

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

⁵Hobijn and Sahin (2007) and Lentz and Mortensen (2008) study labor market frictions and firm heterogeneity in closed economy contexts.

(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, we assume hiring in the industrial sector is subject to search frictions captured by a standard matching function. Further, workers make forward-looking decisions concerning which sector to work in and what job offers to accept.

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 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 yet employed in the industrial sector 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 using a relatively inefficient technology to home-produce services.

2.1 Production Technologies

All service-sector firms exploit a common constant-returns technology to produce the homogeneous good. So with an appropriate choice of output inputs, we may write the total supply of services as

$$S = L_S,$$

where L_S is labor hired in services.

In the industrial sector, output of producers with productivity level z is given by

$$q(z, l) = zl^\alpha, \tag{1}$$

where l is the labor input and $\alpha < 1$. 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.

⁶The 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.

2.2 Preferences

Worker-consumers in the economy are homogenous and their measure is normalized to unity. Each has lifetime utility given by

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

where r is the rate of time preference, s_t^c is consumption of services, and q_t^c is an index of differentiated good consumption. The momentary utility function u takes the form:

$$u(s^c, q^c) = \frac{(s^c)^{1-\gamma} (q^c)^\gamma}{(1-\gamma)^{1-\gamma} \gamma^\gamma},$$

and our index of industrial goods consumption is

$$q^c = \left(\int_0^N q^c(n)^{\frac{\sigma-1}{\sigma}} f(n) dn \right)^{\frac{\sigma}{\sigma-1}}.$$

Here N is our measure of differentiated varieties, $q_t^c(n)$ is consumption of variety n , and $\sigma > 1$ is the elasticity of substitution between varieties.

The price of services is our numeraire, and given our representation of preferences above, the exact price index for the composite good q^c is

$$P = \left(\int_0^N p(n)^{1-\sigma} f(n) dn \right)^{\frac{1}{1-\sigma}},$$

where $p(n)$ is the price of variety n .

Letting I_i be the income of worker i and disallowing savings, the period-by-period budget constraint is

$$I_i = s_i^c + P q_i^c.$$

Welfare maximization implies that consumer i spends a fraction γ of her income on the composite industrial good and her demand for variety n is

$$q_i^c(n) = \frac{\gamma I_i}{P} \left(\frac{p(n)}{P} \right)^{-\sigma} = D_i p(n)^{-\sigma}, \quad (2)$$

where $D_i = \gamma I_i P^{\sigma-1}$. Finally, since worker-consumers are risk neutral, consumer i enjoys momentary indirect utility

$$\mathcal{W}_i = I_i P^{-\gamma}. \quad (3)$$

2.3 Labor Markets and the Matching Technology

The service sector labor market is frictionless so, given that the price of services 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

$$M(V, U) = \frac{VU}{(V^m + U^m)^{1/m}},$$

where U is the measure of unemployed workers searching in industrial sector and V is the measure of vacancies in industry.⁷ Consequently, industrial firms fill each vacancy they post with probability

$$\phi^f(V, U) = \frac{M(V, U)}{V} = \frac{U}{(V^m + U^m)^{1/m}},$$

while unemployed workers searching for industrial jobs find matches with probability

$$\phi^w(V, U) = \frac{M(V, U)}{U} = \frac{V}{(V^m + U^m)^{1/m}}.$$

At the beginning of each period, all workers choose whether to work in industry or services. Workers who choose services are employed with certainty at the wage w_s , but workers who choose industry may or may not find employment. Those who already hold industrial sector jobs can continue with them so long as they neither experience an exogenous separation nor lose their jobs because their employers contract or shut down. Those who are not already employed in the industrial sector can begin working there if they successfully match with a vacancy-posting producer. The probabilities of these different events shape workers' sectorial choices, as well as firms' employment policies. We start by describing the latter.

2.4 Incumbent Firm's Problem

The demand function (2) and the production function (1) imply that any producer with productivity z who chooses employment level l will earn revenue

$$r(z, l) = D^{\frac{1}{\sigma}}(z l^\alpha)^{\left(\frac{\sigma-1}{\sigma}\right)}, \quad (4)$$

⁷The functional form of the matching function follows den Haan et al. (2000). It is constant returns to scale, and increasing in both arguments. The advantage relative to the standard Cobb-Douglas form is that it has no scale parameter and is naturally bounded between zero and one.

where $D = \int_0^1 D_i di$ is aggregate demand for differentiated goods.

When choosing employment levels, firms weigh this payoff against wage costs, the effects of changes in l on the their continuation value, and hiring costs. To characterize the latter, let the cost of posting v vacancies for a firm of size l be

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

where $c_h > 0$ and $\lambda > 1$.⁸ Also assume that firms are large in the sense that cross-firm variation in realized arrival rates is ignorable. (That is, all firms fill the same fraction ϕ^f of their posted vacancies.) It follows that expansion from l to l' simply requires the posting of $v(l, l') = \frac{l' - l}{\phi^f}$ vacancies, and the cost of expanding from l to l' workers is

$$C_h(l, l') = \frac{c_h}{\lambda} \frac{1}{(\phi^f)^\lambda} \left(\frac{l' - l}{l} \right)^\lambda.$$

Finally, assume that each firm bargains with its workers individually and continuously, ensuring, as in Stole and Zwiebel (1996) and Cahuc and Wasner (2000), that all workers at a given firm are paid the same wage.

To derive firms' optimal employment policies, we first specify the sequencing events within each period (see Figure 1). An incumbent firm enters the current period with the productivity z_{-1} and work force l_{-1} , which were determined at the end of 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 , and exogenous separations shrink its labor force to $l = (1 - \delta)l_{-1}$. Then, taking stock of its updated state, (z, l) , the relevant wage schedule, and the economy-wide worker arrival rate, ϕ^f , it chooses its current period work force, l' . The firm can decide to hire ($l' > l$) or fire ($l' \leq l$) workers. If it hires workers, they are immediately available to produce output in the current period. 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 as we will detail shortly, these are bargained over to determine wages. However, since firms can shed

⁸As 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."

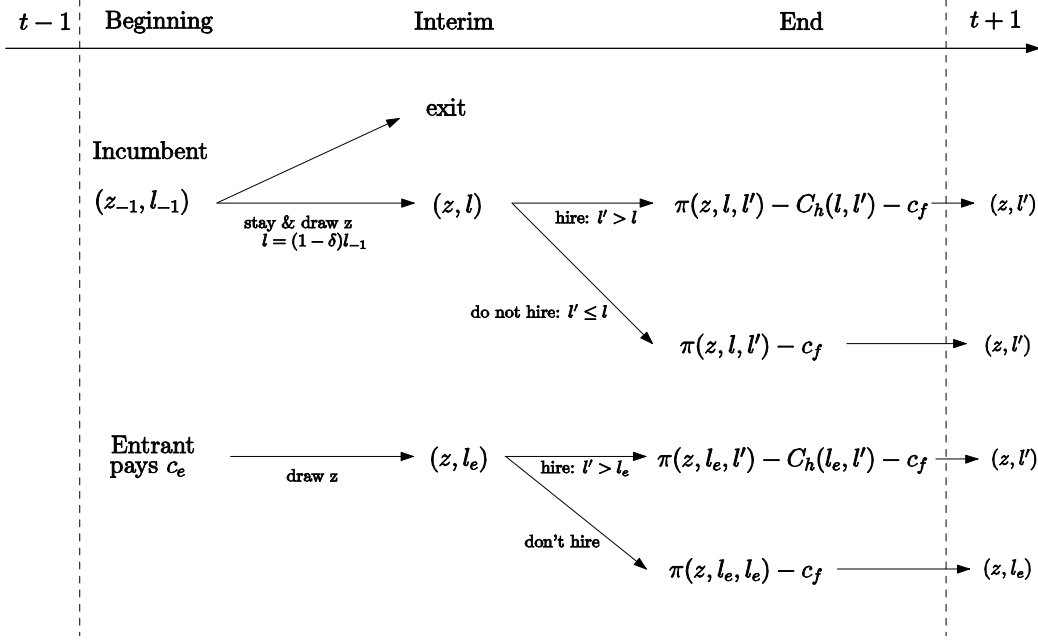


Figure 1: Within-period Sequencing of Events for Firms

workers costlessly, the marginal worker at a firing firm creates no rents and has no bargaining power. Hence expanding and contracting firms face different wage schedules, 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 firing firm, profits are

$$\pi(z, l, l') = \begin{cases} r(z, l') - w_h(z, l')l' - c_f & \text{if } l' > l \\ r(z, l') - w_f(z, l')l' - c_f & \text{otherwise.} \end{cases} \quad (5)$$

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

Using (5), the value of a firm in state (z, l) at the interim stage is given by

$$\mathcal{V}(z, l) = \max_{l'} \frac{1}{1 + r} \{ \pi(z, l, l') - C(l, l') + \max (E_{z'}[\mathcal{V}(z', (1 - \delta)l') | z], 0) \}, \quad (6)$$

where

$$C(l, l') = \begin{cases} C_h(l, l'), & \text{if } l' > l, \\ 0, & \text{otherwise.} \end{cases}$$

In turn, the solution to (6) implies an employment policy function, hereafter denoted $l' = L(z, l)$. It also implies an indicator function that distinguishes hiring firms from others,

$$\mathcal{I}^h(z, l) = \begin{cases} 1, & \text{if } L(z, l) > l, \\ 0, & \text{otherwise.} \end{cases}, \quad (7)$$

and an indicator function that summarizes firm's beginning-of-period continuation/exit policy

$$\mathcal{I}^c(z_{-1}, l_{-1}) = \begin{cases} 1, & \text{if } E_z[\mathcal{V}(z, l)|z_{-1}] > 0, \\ 0, & \text{otherwise.} \end{cases}, \quad (8)$$

where $l = (1 - \delta)l_{-1}$.

2.5 Entry

In the steady state, a constant (endogenous) fraction μ_{exit} of firms exits the industry. There is an infinite pool of potential entrants and actual entrants replace this mass of exiting firms by paying a sunk entry cost of c_e in terms of the service sector good.⁹ Entrants draw their initial productivity from the density function denoted by $f_e(z)$ with support $[\underline{z}, \bar{z}]$, and immediately hire $l_e > 0$ workers at no additional cost. After observing z , entrants behave exactly like the incumbent firms in the interim stage, with their interim state given by (z, l_e) – see Figure 1. Free entry implies that

$$\mathcal{V}_e = \int_{\underline{z}}^{\bar{z}} \mathcal{V}(z, l_e) f_e(z) dz \leq c_e, \quad (9)$$

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 at the beginning of the current period is employed by an industrial sector firm in state (z_{-1}, l_{-1}) . This worker learns immediately whether her firm will exit and, if not, whether she will be separated from her job for exogenous reasons. If either event occurs she joins the pool of industrial job seekers (enters state u) in the interim stage. If neither event occurs, 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 interim state (z, l) , with its labor force from the previous period depleted by exogenous separations: $l = l_{-1}(1 - \delta)$. At this point her firm decides whether to hire or fire workers. In the former

⁹We assume that entrants do not pay the fixed cost f_c in the period that they enter.

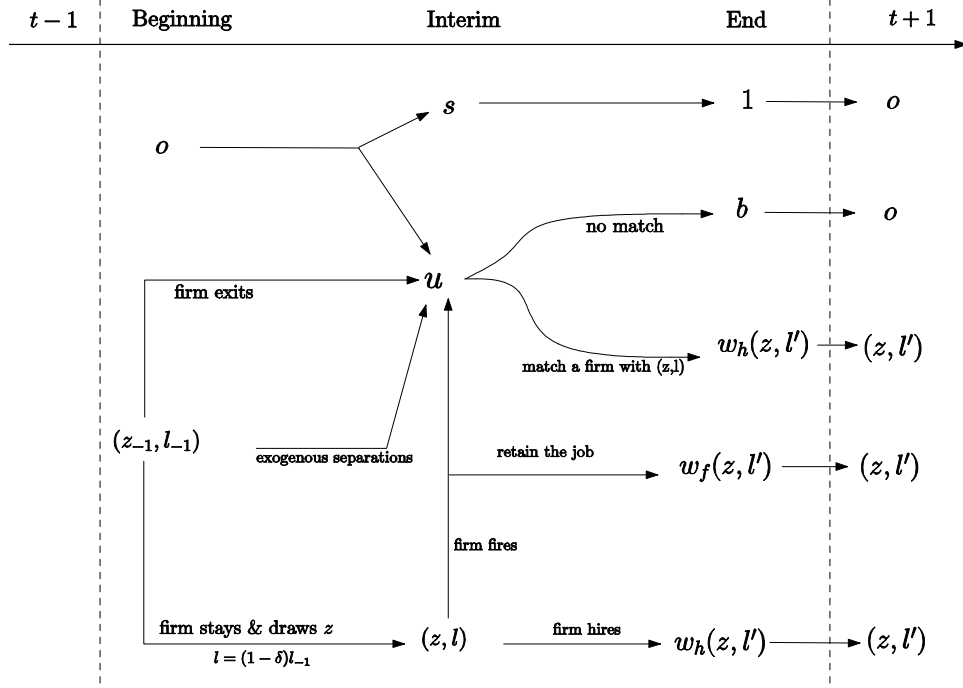


Figure 2: Within-period Sequencing of Events for Workers

case it expands its workforce to $l' > l$, and she earns $w_h(z, l')$. She is then positioned to start the next period in state (z, l') . In the latter case, she loses her job and reverts to state u with probability $p_f = (l - l')/l$. Finally, with probability $1 - p_f$ she retains her job, earns $w_f(z, l')$ during the current period, and starts next period in state (z, l') .

Workers in state u search for an industrial job. 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 remain unemployed in the current period, and support themselves by 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

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

$$J^s = \frac{1}{1+r} (1 + J^o), \quad (10)$$

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 on a high-value job. Given the probability of finding a match is ϕ^w , the interim value of searching for an industrial job is given by

$$J^u = \frac{1}{1+r} [(1 - \phi^w)(b + J^o) + \phi^w E J_h^e], \quad (11)$$

where $E J_h^e$ is the expected value of being employed in a hiring firm. Given these two values, the value of the sectorial choice is $J^o = \max\{J^s, J^u\}$. Since both sectors must exist in equilibrium (given consumer preferences),

$$J^o = J^s = J^u. \quad (12)$$

The expected value of matching to an industrial job, $E J_h^e$, depends only on the distribution of hiring firms and the value of the jobs they offer. For workers who match with a firm that is in state (z, l) before hiring, the interim period value is given by

$$J_h^e(z, l) = \frac{1}{1+r} [w_h(z, l') + J^e(z, l')], \quad (13)$$

where $l' = L(z, l)$ and $J^e(z, l')$ is the value of being employed at an industrial firm in state (z, l') , which may or may not be hiring, at the start of the next period.

The expected value of being employed in a hiring firm depends on the density of vacancies across firm. This density is given by

$$g(z, l) = \frac{v[l, l'(z)] \tilde{f}(z, l) \mathcal{I}^h(z, l)}{\int_z \int_l \tilde{f}(z, l) \mathcal{I}^h(z, l) v(z, l) dl dz}, \quad (14)$$

where $v[l, l'(z)] = [l'(z) - l] / \phi^f$, $\tilde{f}(z, l)$ is the unconditional density of firms over (z, l) in the interim. Accordingly, the expected value of a match for a worker, as perceived at the interim stage, is

$$E J_h^e = \int_z \int_l J_h^e(z, l) g(z, l) dl dz. \quad (15)$$

It remains to specify the unconditional value of starting the period matched with an industrial firm, $J^e(z_{-1}, l_{-1})$, which appears in (13). This object can be written as a weighted

average of the value of exogenous separation (which occurs with probability δ) and the value of continuing with the firm, and is given by

$$J^e(z_{-1}, l_{-1}) = \delta J^u + (1 - \delta) \int_z \tilde{J}^e[z, (1 - \delta)l_{-1}] h(z|z_{-1}) dz, \quad (16)$$

where, since firing firms pay workers their reservation wage, the continuation value is

$$\tilde{J}^e(z, l) = \begin{cases} \frac{1}{1+r} [w_h(z, l') + J^e(z, l')], & \text{if } l' \geq l, \\ J^u, & \text{otherwise.} \end{cases}$$

Given the wage schedules, firms employment policies, and the distribution of firms, the system of equations described in this section determines workers' payoffs and their associated behavior.

2.7 Wage Schedules

All firms that decide to hire—either to replace workers who were lost due to exogenous separations or to expand their workforce—post vacancies. After the matching takes place, the firm bargains with its workers simultaneously and on a one-to-one basis, treating each worker as the marginal one. Hiring firms cannot begin bargaining with their workers until they have finished posting their current-period vacancies and matching has taken place. As a result, vacancy posting costs are already sunk and workers who walk away from the bargaining table cannot be replaced 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 expanding/replenishing firms is given by

$$w_h(z, l) = (1 - \beta)U + \Gamma(\alpha, \beta, \sigma) D^{\frac{1}{\sigma}} z^{\frac{\sigma-1}{\sigma}} l^{-[\frac{\alpha}{\sigma} + (1-\alpha)]},$$

where $\Gamma(\alpha, \beta, \sigma) = \frac{\alpha\beta(\sigma-1)}{\sigma(1-\beta) + \alpha\beta(\sigma-1)}$. Note that if $\beta = 0$, i.e. all the bargaining power is with the firm, the firm pays reservation wages equal to the flow value of the outside option, U .

The marginal worker at a contracting firm generates no rents, so the firing wage just matches their reservation wage. It is given by (see Appendix 1):

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

Note that, unlike $b + J^o$, $w_f(z, l')$ varies across firms, reflecting their different future prospects. It can be less than the value of home production, as firing firms may draw a better z values in the future and raise their wages.

3 Closed Economy 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 firms receive upon entry. Second, supply matches demand for services and for each differentiated good, where supplies are determined by employment 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. And finally, workers optimally choose the sector in which they are working or seeking work. Appendix 2 provides the algebraic details of these conditions, and appendix 5 summarizes the numerical solution algorithm we use to find the associated equilibrium.

4 Open Economy Equilibrium

4.1 Symmetric Countries

Now consider an open economy version of our model in which two symmetric countries trade industrial goods with one another, subject to iceberg transportation costs and fixed exporting costs. Transport costs are parameterized by τ , which denotes the amount of each good that must be shipped in order for one unit to arrive at its foreign destination. Fixed costs are denoted by c_x , and must be paid once per period by each exporting firm, regardless of its total shipments. These fixed costs keep firms with high labor costs and/or low productivity levels out of foreign markets.

Demand for an exporting firm comes from domestic and foreign consumers. By symmetry, product-specific demand functions have the same intercept D in both markets. However trade costs induce cross-country asymmetries in sales. If a firm in state (z, l) exports some fraction η of its output, its export revenues are:

$$r_x(z, l, \eta) = D^{\frac{1}{\sigma}} \left[\frac{\eta}{\tau} z l^\alpha \right]^a,$$

and its domestic revenues are

$$r_d(z, l, \eta) = D^{\frac{1}{\sigma}} [(1 - \eta) z l^\alpha]^a.$$

where $a = \frac{\sigma-1}{\sigma}$. Accordingly, if the firm chooses η optimally, its total revenue (net of fixed exporting costs) is:

$$\begin{aligned} r(z, l) &= \max_{\eta \in [0,1]} (r_d(z, l, \eta) + r_x(z, l, \eta) - c_x \mathcal{I}^x) \\ &= \max \left\{ \frac{D^{\frac{1}{\sigma}} (z l^\alpha)^a [(\eta^*/\tau)^a + (1 - \eta^*)^a] - c_x \mathcal{I}^x}{D^{\frac{1}{\sigma}} (z l^\alpha)^a} \right\}; \end{aligned} \quad (17)$$

where $\eta^* = \frac{1}{1+\tau^{\sigma-1}}$ and $\mathcal{I}^x = 1_{\eta>0}$ is an indicator function that equals one if the firm exports a non-zero quantity of its output. Clearly, since $\eta^* > 0$, firms can always increase their revenues by exporting and there is a threshold value of $z l^\alpha$ above which firms do best to export. Once the closed economy revenue function (4) has been replaced with (17), and we have redefined our price and quantity indices in the usual way for intra-industry trade (see appendix 3), the analysis proceeds exactly as before.

Embedded in our general equilibrium model, this standard revenue function delivers a number of desirable features. First, for any given (z, l) , it implies that 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.¹⁰ Finally, re-interpreting z shocks to be product appeal indices rather than productivity indices, it explains why exporters manage to be larger than non-exporters, even though they charge higher prices and pay higher wages.¹¹

¹⁰Hallak and Sividasan (2008) explain this fact 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.

¹¹Kugler and Verhoogen (2008) interpret this pattern to be due to complementarities in production between worker ability and product quality, arguing that it is difficult to otherwise reconcile the data with optimizing behavior.

4.2 The Small Country Case

The model can be modified to represent a small open economy such that domestic conditions do not affect the foreign price index, the extensive margin of imports and foreign income level. We normalize the price of the composite import good to 1. Since we have a domestic and a foreign numeraire now, there is an exchange rate ε_x which determines their parity. Iceberg trade costs are still denoted by τ for exports, and there is an ad-valorem import tariff τ_m . The domestic price of imports is thus $(1 + \tau_m)\varepsilon_x$.

Let $D_F^\$$ and $D_F = \varepsilon_x D_F^\$$ be foreign income in foreign and domestic currencies respectively. Then export revenues for a firm in state (z, l) are given by:

$$r_x(z, l, \eta) = D_F^{\frac{1}{\sigma}} \left[\frac{\eta}{\tau} z l^\alpha \right]^a.$$

As above, the firm solves a static problem of exporting or not, and what fraction of output to be exported:

$$\begin{aligned} r(z, l) &= \max_{\eta \in [0, 1]} (r_d(z, l, \eta) + r_x(z, l, \eta) - c_x \mathcal{I}^x) \\ &= \max \left\{ \begin{aligned} &\left[D_H^{\frac{1}{\sigma}} (1 - \eta)^a + D_F^{\frac{1}{\sigma}} \left(\frac{\eta}{\tau} \right)^a \right] - c_x \mathcal{I}^x, \\ &D_H^{\frac{1}{\sigma}} (z l^\alpha)^a. \end{aligned} \right. \end{aligned} \quad (18)$$

Conditional on exporting, firms choose the fraction of output exported optimally:

$$\eta^* = \frac{1}{1 + \frac{D_H}{D_F} \tau^{\sigma-1}}.$$

The domestic price index can be written as

$$P = \left[((1 + \tau_m)\varepsilon_x)^{1-\sigma} + \tilde{p}_d^{1-\sigma} \right]^{\frac{1}{1-\sigma}},$$

where $\tilde{p}_d^{1-\sigma} = N \int \int p_d(z, l)^{1-\sigma} f(z, l) dz dl$ is the price index of domestic sales of domestic varieties. In turn, import demand is

$$q_m = \left[\frac{\gamma I}{P} \right] \left(\frac{(1 + \tau_m)\varepsilon_x}{P} \right)^{-\sigma} = D_H [(1 + \tau_m)\varepsilon_x]^{-\sigma},$$

where $D_H = \gamma I P^{\sigma-1}$ is the domestic demand intercept as before. Domestic expenditure on imports is $E_m = q_m (1 + \tau_m)\varepsilon_x$. Because of the tariff wedge, this figure is higher than what is actually paid to foreigners (in domestic currency). Denoting the latter by R_m ,

$$R_m = \frac{E_m}{1 + \tau_m} = \frac{D_H [(1 + \tau_m)\varepsilon_x]^{1-\sigma}}{1 + \tau_m} = D_H (1 + \tau_m)^{-\sigma} \varepsilon_x^{1-\sigma}.$$

Total tariff revenues, $T_m = R_m \tau_m$, are rebated back to consumers.

Total export revenue of the country is given by

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

Trade balance holds when

$$R_m = R_x.$$

In appendix 3, we show that if all other market clear, trade balance holds by Walras' Law. Next we turn to the empirical implementation of the model which is based on the small open economy environment.

5 Empirical Implementation

5.1 The Revenue Function and Productivity Process

As detailed in appendix 4, the revenue function (18) 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, $d_H = \ln[D_H^{\frac{1}{\sigma}}(1 - \eta^*)^a]$, an index of the *percentage increase* in total demand associated with exporting, $d_F = \ln[D_F^{\frac{1}{\sigma}}(\eta^*/\tau)^a \cdot e^{-d_H} + 1]$, and an indicator for whether firm i is an exporter, $\mathcal{I}_{it}^x$:

$$\ln r_{it} = d_H + \mathcal{I}_{it}^x d_F + \frac{\sigma - 1}{\sigma} \ln z_{it} + \alpha \frac{\sigma - 1}{\sigma} \ln l_{it} \quad (19)$$

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

$$\ln z_{it} = \rho \ln z_{it-1} + \epsilon_{it}, \quad (20)$$

equation (19) can be restated as:

$$\begin{aligned} \ln r_{it} &= (d_H + \mathcal{I}_{it}^x \cdot d_F) - \rho (d_H + \mathcal{I}_{it-1}^x d_F) + \rho \ln r_{it-1} \\ &\quad - \alpha \rho \left(\frac{\sigma - 1}{\sigma} \right) \ln l_{it-1} + \alpha \left(\frac{\sigma - 1}{\sigma} \right) \ln l_{it} + \frac{\sigma - 1}{\sigma} \epsilon_{it}, \end{aligned} \quad (21)$$

If one could obtain consistent estimates of the coefficients that appear on the right-hand-side observable variables, these would allow one to infer consistent estimates of ρ , α , and σ , and the variance of the error term would allow one to infer $var(\epsilon)$. However, selection bias

and simultaneity bias prevent us from consistently estimating (21) with ordinary least squares. The former problem occurs because firms choose whether exit the market partly on the basis of their ϵ_{it} realizations, so the ϵ_{it} realizations observed for active producers are not random draws from the unconditional distribution of ϵ 's. The latter problem occurs because firms' current exporting decisions and employment levels are chosen after the current realization on ϵ is observed, so ϵ_{it} is correlated with both $\mathcal{I}_{it}^x$ and $\ln l_{it}$. Appendix 4 develops a generalized method of moments (GMM) estimator related to Olley and Pakes' (1996) that deals with both problems.

Application of this estimator to the set of all Colombian producers observed for at least a three year period between 1982 and 1991 yields the results summarized in Table 1 below¹². Since σ proved to be poorly identified, we tried fixing this parameter at several values typical of the literature: $\sigma = 5$ and $\sigma = 8$. The results are reported in Table 1 below. All parameters are estimated with considerable precision and fall in plausible ranges. The results are not very sensitive to σ , although the lower σ value is associated with somewhat smaller estimates for α and ρ , and a modestly larger estimate for $\sqrt{\text{var}(\epsilon)}$. We will use the $\sigma = 8$ estimates for our baseline calibration.

Table 1: Revenue function and productivity process

<i>parameter</i>	$\sigma = 8$			$\sigma = 5$		
	<i>estimate</i>	<i>std. error</i>	<i>z-ratio</i>	<i>estimate</i>	<i>std. error</i>	<i>z-ratio</i>
α	0.677	0.027	24.793	0.486	0.022	21.84
ρ	0.812	0.004	188.92	0.744	0.004	194.71
$\sqrt{\text{var}(\epsilon)}$	0.549	0.008	72.377	0.594	0.008	77.65
d_H	0.020	0.012	1.521	0.007	0.013	0.569
d_F	0.215	0.004	51.616	0.214	0.004	51.46

6 Simulations

[To Be Completed]

¹²The 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.

7 Conclusions

[To Be Completed]

Appendix 1: The Wage Functions

7.1 Hiring Wages

In order to characterize wages in hiring firms, we first determine the total surplus for a the firm and a worker that are matched in state (z, l) . The surplus that the marginal worker generates for a firm is given by

$$\Pi^{firm} = \frac{1}{1+r} \left[\frac{\partial \pi(z, l)}{\partial l} + \mathcal{I}^c(z, l) \int \mathcal{I}^h(z', l') \frac{\partial \mathcal{V}(z', l')}{\partial l'} \frac{\partial l'}{\partial l} h(z'|z) dz' \right],$$

where $l' = (1 - \delta)l$. 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 being in state (z, l') at the start of the next period. If the firm does not exit next period, i.e. if $\mathcal{I}^c(z, l) = 1$, the marginal worker will have a positive value for the firm only if the firm decides to hire, i.e. $\mathcal{I}^h(z', l') = 1$. As exit and firing are costless, if the firm exists or fires workers, his expected marginal value from its current marginal hire is zero.

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

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

where the worker enjoys $w_h(z, l)$ in the current period, and starts next period in a firm with beginning of the period state (z, l) .

The worker and firm split the total surplus by Nash bargaining where the bargaining power of the worker is given by β . Wages are thus determined by

$$\beta \left[\frac{\partial \pi(z, l)}{\partial l} + (1 - \delta) \mathcal{I}^c(z, l) \int \mathcal{I}^h(z', l') \frac{\partial \mathcal{V}(z', l')}{\partial l'} h(z'|z) dz' \right] = (1 - \beta) [w_h(z, l) + J^e(z, l) - (b + J^o)]. \quad (22)$$

Extending (16) to account for the exit decision of firms,

$$J^e(z, l) = \mathcal{I}^c(z, l) \left[\delta J^u + (1 - \delta) \int_z \tilde{J}^e[z', l'] h(z'|z) dz \right] + [1 - \mathcal{I}^c(z, l)] J^u,$$

and noting that $J^u = J^o$ in equilibrium, the right-hand side of (22) can be written as

$$(1 - \beta) w_h(z, l) - (1 - \beta) U + (1 - \beta) (1 - \delta) \mathcal{I}^c(z, l) \int \left(\tilde{J}^e[z', l'] - \frac{b + J^o}{1+r} \right) h(z'|z) dz' \quad (23)$$

where

$$U = \mathcal{I}^c(z, l) (1 - \delta) \left[b + r \left(\frac{b + J^o}{1+r} \right) \right] - b$$

is the value of unemployment taking into account the exit decision of the firm and the probability of exogenous separation.¹³ The last term in (23), $(1-\delta)\mathcal{I}^c(z, l) \int \left(\tilde{J}^e[z', l'] - \frac{b+J^o}{1+r} \right) h(z'|z) dz'$, is the expected capital gain or loss next period for a worker employed in this firm. Correspondingly, the expected capital gain of employing the marginal worker to the firm is given by the term $(1-\delta)\mathcal{I}^c(z, l) \int \mathcal{I}^h(z', l') \frac{\partial \mathcal{V}(z', l')}{\partial l'} h(z'|z) dz'$. We assume that the firm and the worker split the expected surplus according to the same rule.¹⁴

$$\begin{aligned} (1-\beta)(1-\delta)\mathcal{I}^c(z, l) \int \left(\tilde{J}^e[z', l'] - \frac{b+J^o}{1+r} \right) h(z'|z) dz' \\ = \beta(1-\delta)\mathcal{I}^c(z, l) \int \mathcal{I}^h(z', l') \frac{\partial \mathcal{V}(z', l')}{\partial l'} h(z'|z) dz'. \end{aligned}$$

So the forward-looking terms cancel in (22), leaving

$$\frac{\partial w_h(z, l)}{\partial l} \beta l + w_h(z, l) - \beta \frac{\partial r(z, l)}{\partial l} - (1-\beta)U = 0,$$

which is the same as Bertola and Garibaldi (2001)'s equation (10). Using

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

the wage schedule for expanding/replenishing firms is given by

$$w_h(z, l) = (1-\beta)U + \Gamma(\alpha, \beta, \sigma) D^{\frac{1}{\sigma}} z^{\frac{\sigma-1}{\sigma}} l^{-[\frac{\alpha}{\sigma} + (1-\alpha)]},$$

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

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

Firing Wages

To derive the firing wage schedule, we begin by writing the value of employment at a firing firm as

¹³Since hiring is effective within the same period, we cannot rule out the case where a firm hires and exits in the following period. For $\delta = 0$ and $\mathcal{I}^c(z, l) = 1$, this is equal to $r \left(\frac{b+J^o}{1+r} \right)$, flow value of the outside option in a continuing firms.

¹⁴Since the parties bargain every period, this ex-ante surplus sharing being renegotiation-proof is not an issue.

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

where $l' = L(z, l)$. This expression reflects the possibility of losing one's job, $p_f(z, l)$, which we assume occurs at firing firms with probability

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

It also 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, which gives us

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

and defines the wage schedule faced by firing firms as

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

Appendix 2: Steady State Equilibrium

In steady state equilibrium, the aggregate variables $\{N, M, P, Q, I, L_S, u, \phi^f, \phi^w, \mu_{exit}\}$, the value functions and associated policy functions $\{\mathcal{V}(z, l), L(z, l), \mathcal{I}^h(z, l), \mathcal{I}^c(z, l), J^o, J^u, J^s, J^e\}$, the wage schedules $\{w_h(z, l), w_f(z, l)\}$, and end-of-the period and interim distributions $\{f(z, l), \tilde{f}(z, l)\}$ satisfy the following conditions:

1. **Steady State Distributions:** Because of the transitions that occur within the period, we have to distinguish the distributions at relevant points in time. Let $f(z, l)$ and $\tilde{f}(z, l)$ be the stationary probability distributions over (z, l) at the end and interim respectively. In equilibrium, these distributions reproduce themselves through the Markov processes on z , the policy functions and the productivity draws upon entry. The interim distribution is defined as

$$\tilde{f}(z, l) = \begin{cases} h(z|z_{-1})f(z_{-1}, l_{-1}) & \text{if } l = (1 - \delta)l_{-1} \text{ and } \mathcal{I}^c(z_{-1}, l_{-1}) = 1, \\ 0, & \text{otherwise.} \end{cases}$$

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

$$f(z, l') = \begin{cases} \tilde{f}(z, l) & \text{if } \mathcal{I}^h(z, l)L(z, l) + [1 - \mathcal{I}^h(z, l)]L(z, l) = l', \\ 0, & \text{otherwise.} \end{cases}$$

2. **Market Clearance in Sector S :** Demand for the S -sector comes from two sources: consumers spend a $(1 - \gamma)$ fraction of aggregate income I on it, and firms demand it to pay their fixed operation costs, labor adjustment and entry costs. Define the fraction of hiring firms as $\mu_h = \int_z \int_l \mathcal{I}^h(z, l) \tilde{f}(z, l) dl dz$. Average labor adjustment cost is given by

$$\tilde{c} = \int_z \int_l C[(l, L(z, l))] \mathcal{I}^h(z, l) \frac{\tilde{f}(z, l)}{\mu_h} dl dz.$$

Market clearance condition in this sector is

$$L_S + b \cdot (uL_Q) = (1 - \gamma)I + N\tilde{c} + Nc_f + Mc_e,$$

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

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

$$E_Q = N \int_z \int_l l \cdot f(z, l) dl dz = (1 - u)L_Q.$$

The measure of unemployed workers is then

$$U = L_Q - E_Q = uL_Q.$$

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

$$uL_Q\phi^w = (1 - u)L_Qk,$$

which yields the usual Beveridge curve

$$u = \frac{k}{k + \phi^w}.$$

Aggregate number of vacancies in this economy is

$$V = N \int_z \int_l v(z, l) \mathcal{I}^h(z, l) \frac{\tilde{f}(z, l)}{\mu_h} dldz.$$

which, together with U , determines matching probabilities $\phi^f(V, U)$ and $\phi^w(V, U)$ 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 (9) holds with equality. The fraction of firms exiting is implied by the steady state distribution and the exit policy function,

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

and measure of exits equals that of entrants,

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

5. **Income and Market Clearance for the Q -sector:** The composite good Q and its price are given by:

$$P = \left(N \int_z \int_l p(z, l)^{1-\sigma} f(z, l) dldz \right)^{\frac{1}{1-\sigma}},$$

and

$$Q = \left(N \int_z \int_l q(z, l)^{\frac{\sigma-1}{\sigma}} f(z, l) dldz \right)^{\frac{\sigma}{\sigma-1}}.$$

Aggregating over the revenue functions (4) across producers, total revenues earned by the differentiated good sector is a fraction γ of total income in the economy:

$$\gamma I = PQ = R.$$

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

$$I = L_S + b \cdot (uL_Q) + W_Q + \Pi, \quad (24)$$

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

$$\begin{aligned} \Pi = & N \int_z \int_l [\tilde{\mathcal{I}}^h(z, l) \{r(z, l) - w_h(z, l) \cdot l\} \\ & + [1 - \tilde{\mathcal{I}}^h(z, l)] \{r(z, l) - w_f(z, l) \cdot l\}] f(z, l) dldz \\ & - N\tilde{c} - Nc_f - Mc_e \end{aligned} \quad (25)$$

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

$$W_Q = N \int_z \int_l \left\{ \tilde{\mathcal{I}}^h(z, l) w_h(z, l) \cdot l + [1 - \tilde{\mathcal{I}}^h(z, l)] w_f(z, l) \cdot l \right\} f(z, l) dldz. \quad (26)$$

Using (24), (25) and (26),

$$\gamma I = N \int_z \int_l \left[\tilde{\mathcal{I}}^h(z, l) r(z, l) + [1 - \tilde{\mathcal{I}}^h(z, l)] r(z, l) \right] f(z, l) dldz.$$

Right-hand of that equation is total revenue R earned by the differentiated good sector.

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

$$J^o = J^s = J^u. \quad (27)$$

Appendix 3: Open Economy Equilibrium

7.2 Equilibrium conditions

The equilibrium definition in an open economy is similar to that in a closed economy with the addition export policy function $\mathcal{I}_{\eta>0}^x(z, l)$, exchange rate ε_x , fraction of firms exporting μ_x and the trade balance condition. Here we show that when all markets clear, trade balance condition follows from Walras' Law.

By definition of income as before,

$$\begin{aligned} I &= L_s + b \cdot (uL_Q) + W_Q + \Pi + T_m \\ I &= L_s + b \cdot (uL_Q) + W_Q + R_x + R_d - W_Q - N\tilde{c} - Nc_f - Mc_e + T_m \end{aligned}$$

where $N\tilde{c}$, Nc_f and Mc_e are aggregate hiring costs, overhead and entry costs respectively. Market clearance for S sector is

$$L_S + b \cdot (uL_Q) = (1 - \gamma)I + N\tilde{c} + Nc_f + Mc_e$$

which implies

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

On the expenditure side, a fraction γ of income is spent on differentiated goods, foreign and domestic.

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

By domestic market clearance, $E_d = E_m$ which implies

$$R_x + T_m = E_m.$$

Payment to foreigners is given by $R_m = E_m / (1 + \tau_m)$. Substituting E_m and cancelling tariff revenues $T_m = R_m \tau_m$ leaves us with the trade balance condition:

$$R_m = R_x.$$

7.3 Price and quantity indices

To re-state the price and quantity indices for the open economy case, let N now denote total varieties sold in each country, let N_D denote the number of varieties that each country produces

domestically, and let μ_x be the equilibrium fraction of firms in each country that export. (By symmetry, $N = (1 + \mu_x)N_D$.) Then, the composite good Q is the following weighted average of foreign and domestic quantities:

$$Q = N^{\frac{\sigma}{\sigma-1}} \left(\frac{\mu_x}{1 + \mu_x} Q_F^{\frac{\sigma-1}{\sigma}} + \frac{1}{1 + \mu_x} Q_D^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}},$$

where

$$Q_F = \left(\int_z \int_{l_e}^{\infty} \left[\frac{\eta^*}{\tau} z l^\alpha \right]^{\frac{\sigma-1}{\sigma}} \mathcal{I}_{\eta>0}^x(z, l) \frac{f(z, l)}{\mu_x} dl dz \right)^{\frac{\sigma}{\sigma-1}},$$

and

$$Q_D = \left(\mu_x Q_{D,x}^{\frac{\sigma-1}{\sigma}} + (1 - \mu_x) Q_{D,nx}^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}}.$$

Also the domestic index Q_D is itself an aggregate across domestic sales of exporters given by $Q_{D,x}$ and sales of domestic only producers represented by $Q_{D,nx}$:

$$Q_{D,x} = \left(\int_z \int_{l_e}^{\infty} [(1 - \eta^*) z l^\alpha]^{\frac{\sigma-1}{\sigma}} \mathcal{I}^x(z, l) \frac{f(z, l)}{\mu_x} dl dz \right)^{\frac{\sigma}{\sigma-1}},$$

and

$$Q_{D,nx} = \left(\int_z \int_{l_e}^{\infty} (z l^\alpha)^{\frac{\sigma-1}{\sigma}} [1 - \mathcal{I}^x(z, l)] \frac{f(z, l)}{1 - \mu_x} dl dz \right)^{\frac{\sigma}{\sigma-1}}$$

The price index for Q follows from a similar aggregation. The export indicator function $\mathcal{I}^x(z, l)$ and the fraction of exporting firms μ_x are additions to the equilibrium definition in the open economy case. All conditions in the closed economy equilibrium are valid with the additional demand for the homogenous good resulting from fixed exporting costs $\mu_x N_D f_x$ and the modified aggregate profit function to account for export revenues and costs.

Appendix 4: Estimating the Revenue Function and the Productivity Process

The Revenue Function

From (21), the equation we wish to estimate is:

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

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 exit the market partly on the basis of their ϵ_{it} realizations, and the latter problem occurs because firms' current exporting decisions ($\mathcal{I}_{it}^x$) and employment levels (l_{it}) depend upon their current productivity levels.

Selection Bias and Identification

To deal with these problems, let χ_{it} 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 $\xi_{it} = \epsilon_{it} - E[\epsilon_{it} | \chi_{it} = 1, \ln r_{it-1}, \ln \ell_{it-1}, \mathcal{I}_{it-1}^x]$, the revenue function can be re-formulated as:

$$\begin{aligned} \ln r_{it} = & \rho \ln r_{it-1} + d_H(1 - \rho) + d_F(I_{it}^X - \rho \cdot I_{it-1}^X) + \alpha \frac{\sigma - 1}{\sigma} \ln \ell_{it} \\ & - \alpha \rho \frac{\sigma - 1}{\sigma} \ln \ell_{it-1} + \frac{\sigma - 1}{\sigma} E[\epsilon_{it} | \chi_{it} = 1, \dots] + \frac{\sigma - 1}{\sigma} \xi_{it} \end{aligned} \quad (\text{A3.2})$$

The error term ξ_{it} has zero mean and is orthogonal to $\ln r_{it-1}$, $\ln \ell_{it-1}$, $\mathcal{I}_{it-1}^x$, and $E[\epsilon_{it} | \chi_{it} = 1, \dots]$. Further, although it is correlated with current exporting decisions ($\mathcal{I}_{it}^x$), it is orthogonal to $E[\mathcal{I}_{it}^x | \chi_{it} = 1, \ln r_{it-1}, \ln \ell_{it-1}, \mathcal{I}_{it-1}^x]$. Hence, if $E[\epsilon_{it} | \chi_{it} = 1, \dots]$ and $E[\mathcal{I}_{it}^x | \chi_{it} = 1, \dots]$ can be calculated, the orthogonality conditions $E(\xi_{it} \cdot r_{it-1}) = 0$, $E(\xi_{it} \cdot \ln \ell_{it-1}) = 0$, $E(\xi_{it} \cdot \mathcal{I}_{it-1}^x) = 0$, $E(\xi_{it} \cdot E[\epsilon_{it} | \chi_{it} = 1, \dots]) = 0$, and $E(\xi_{it} \cdot E[\mathcal{I}_{it}^x | \chi_{it} = 1, \dots]) = 0$ provide the basis for a generalized method of moments (GMM) estimator that identifies the parameters of equation

(A3.1).¹⁵ Further, the efficiency of this estimator can be improved by exploiting information on the ratio of exports to total sales—hereafter, x_{it} . Our model implies that this variable is related to the foreign demand shifter d_F by $\mathcal{I}_{it}^x(1 - e^{-dx}) = x_{it}$, so treating x_{it} as a noisy measure of true export intensity, the moment condition $E(\mathcal{I}_{it}^x(1 - e^{-dx}) - x_{it}) = 0$ can be incorporated into the analysis.

To implement this estimation strategy we need a way to calculate $E[\epsilon_{it}|\chi_{it} = 1, \ln r_{it-1}, \ln \ell_{it-1}, \mathcal{I}_{it-1}^x]$ and $E[\mathcal{I}_{it}^x|\chi_{it} = 1, \ln r_{it-1}, \ln \ell_{it-1}, \mathcal{I}_{it-1}^x]$. Consider the former expression first. There is a threshold productivity level above which all firms with beginning-of-period employment level ℓ_{it-1} will continue operating. Denote this productivity level $g^*(\ell_{it-1})$, so that the continuation condition is $z_{it} = \rho z_{it-1} + \epsilon_{it} > g^*(\ell_{it-1})$. By (19), $z_{it-1} = \frac{\sigma}{\sigma-1} [\ln r_{it-1} - (d_H + \mathcal{I}_{it-1}^x d_F)] - \alpha \ln \ell_{it-1}$, so continuation occurs when $\frac{\epsilon_{it}}{\sigma_\epsilon} > g(r_{it-1}, \ell_{it-1}, \mathcal{I}_{it-1}^x)$, where

$$\begin{aligned} & g(\ln r_{it-1}, \ln \ell_{it-1}, \mathcal{I}_{it-1}^x) \\ &= \left(g^*(\ell_{it-1}) - \frac{\sigma}{\sigma-1} [\ln r_{it-1} - (d_H + \mathcal{I}_{it-1}^x d_F)] - \alpha \ln \ell_{it-1} \right) / \sigma_\epsilon. \end{aligned}$$

Accordingly, letting $\epsilon_{it} \sim N(0, \sigma_\epsilon^2)$, it follows that the probability of continuation can be calculated as

$$p_{it} = 1 - \Phi[g(\ln r_{it-1}, \ln \ell_{it-1}, \mathcal{I}_{it-1}^x)], \quad (\text{A3.3})$$

where $\Phi()$ is the standard normal cumulative distribution. And once p_{it} has been estimated with the probit function (A3.3), the object of interest can be calculated using well-known properties of the normal distribution (e.g., Maddala, 1983):¹⁶

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

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

It remains to discuss the endogeneity of exporting status, $\mathcal{I}_{it}^x$. Since the probability of exporting in the current period depends upon (z_{it-1}, ℓ_{it-1}) , we can calculate:

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

¹⁵Note that the dependence of $\ln \ell_{it}$ on ϵ_{it} does not prevent us from obtaining consistent estimates of these parameters because the coefficient on $\ln \ell_{it}$ can be inferred from the coefficients on $\ln \ell_{it-1}$ and $\ln r_{it-1}$.

¹⁶When estimating this probit, we use a flexible (translog) functional form for $g(r_{it-1}, \ell_{it-1}, \mathcal{I}_{it-1}^x)$.

where $h(r_{it-1}, l_{it-1}, \mathcal{I}_{it-1}^x)$, like $g(\cdot)$, is a flexible function of its arguments.¹⁷ Thus to deal with the simultaneity between I_{it}^X and ϵ_{it} , we can use p_{it}^X as an instrument for I_{it}^X .

Although $g(\ln r_{it-1}, \ln l_{it-1}, \mathcal{I}_{it-1}^x)$ and $h(\ln r_{it-1}, \ln l_{it-1}, \mathcal{I}_{it-1}^x)$ could, in principle, be estimated at the same time as the structural parameters that appear in (A1.1), doing so makes for a poorly-behaved objective function. We therefore obtain estimates of these probabilities by fitting the profit functions (A3.3) and (A3.4) in a preliminary stage; then we use the resulting (p_{it}, p_{it}^X) as input to the GMM estimator described below.¹⁸

The Moment Conditions

We are now prepared to summarize our estimation strategy. Define the following three error terms:

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

where x_{it} is the share of total revenues that firm i generated through exports in period t . Letting ι be a vector ones, Our GMM estimator is based on the moment conditions:

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

In principle, these conditions identify ρ , α , σ_ϵ^2 , d_X , d_H , $\frac{\sigma-1}{\sigma}$. In practice, while ρ , α , σ_ϵ^2 , d_X , and d_H can be estimated with some precision using this estimator, $\frac{\sigma-1}{\sigma}$ is poorly identified. We therefore fix $\frac{\sigma-1}{\sigma}$ at several alternative values taken from the existing literature, and generate corresponding sets of estimates for the remaining parameters. (Refer to Table 1 in the text.) Our results proved not to be sensitive to the inclusion of time dummies in A1.1. Accordingly, since our theoretical model presumes that the macro environment is stable, we focus our attention on the case in which they are omitted.

¹⁷It is interesting that lagged exports help predict current exports here, even though we have assumed away sunk entry costs. The reason is that, (19), lagged exports help to explain lagged productivity.

¹⁸Olley and Pakes (1996) pursue a similar strategy.

Appendix 5: Numerical Solution Algorithm

[To Be Completed]

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