Trade Liberalization and the Geographic Location of Industries *

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Abstract

In most countries, the uneven geographical distribution of population, capital, natural resources and institutions is associated with disparities in economic outcomes. For instance, it is common to observe factor price differences across geographical areas within a country. However, studies assessing the consequences of trade liberalization on the reallocation of factors between or within industries usually do not consider such geographical disparities, and thus they do not shed light on how regions with dissimilar economic conditions respond differently to external trade. This study investigates one aspect of the link between international trade and the economic geography of a country. It extends the Melitz (2003) model of monopolistic competition with heterogeneous firms by considering a country consisting of an urban region and a rural region which exhibit different cost structures for manufacturing production. In this context, firms make choices between two geographic locations and whether to export. This model allows us to examine the impact of trade liberalization on the distribution of firms across the two locations. Using data on Colombian manufacturing industries for the period 1981-1991, we document the existence of productivity differences between metropolitan and non-metropolitan plants. Furthermore, we obtain empirical evidence of the impact of tariff liberalization on the pattern of industry location. We find that a decline in tariffs entails a reallocation of industrial production from metro- to non-metropolitan areas.

Key words: Colombia, firm heterogeneity, industry location, trade liberalization, urban and rural

JEL classification: F12, F14, O18, R12

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1 Introduction

In most countries, the uneven spatial distribution of productive factors and infrastructure, natural resources, institutions, and economic opportunities, is associated with territorial disparities in the outcomes of the economic functions of production, exchange, and consumption. For instance, it is common to observe absolute and relative factor price differences across geographical areas within countries.[1] Some authors have studied the impact of trade on the spatial distribution of economic activity within countries. They argue that since international trade, whether it is explained by relative factor endowment differences or scale economies, entails a reallocation of resources across sectors and firms and a shift in market opportunities, then, it might also alter the geographical allocation of economic activities. The consideration of geographical disparities in the assessment of trade policy is important because an increase in exposure to trade might have different implications, in terms of adjustment and economic opportunities, for different regions. This paper treats an aspect of the relationship between international trade openness and industry geographical location. We address the question of whether trade liberalization leads to a relocation of industrial production from urbanized areas to less densely populated regions where wages are supposedly lower. For that purpose, we develop a dynamic model of monopolistic competition with heterogeneous firms that links a country's trade policy to the pattern of industry location. Then, we test for the consistency of our model's implications using data on Colombian manufacturing industries for the period 1981-1991.

Some empirical studies have examined the impact of trade and trade liberalization on the pattern of industry location within a country. Tomiura (2003) finds that the Japanese industries that experienced a high import penetration growth in the 1990's became less geographically concentrated. His empirical investigation validates the claim that international trade weakens domestic regional input-output linkages and reinforces the influence that non-tradable inputs (such as specialized human capital) have on industry location. In the case of Argentina, which implemented trade policy reforms in the late 1980's and entered the *Mercado Común del Sur* (MERCOSUR) in 1991,

[1] Bernard, Robertson, and Schott (2005b) provides recent evidence of relative factor endowment and price differences across regions in Mexico. For evidence about the United States, see Bernard, Redding, and Schott (2005a).

Sanguinetti and Martincus (2005) document a trend towards lesser geographical concentration of manufacturing employment between 1985 and 1994. They also show that the industries more protected from imports are also the ones that were more localized around the densely populated areas of Argentina, in particular Buenos Aires. These papers along with others[2] provide some anecdotal evidence that a greater exposure to trade in emerging countries led to less concentration in the pattern of industrial location.

From a theoretical standpoint, Krugman and Livas-Elizondo (1996) argue that the import-substituting industrialization policies promoted by many developing countries after World War II bolstered the geographical concentration of population and manufacturing production into a few large cities, and most often into a single large urban center (Mexico is a prime example of such a phenomenon). They also suggest that the trade policy reforms adopted a few decades later by the same countries induced manufacturing firms to locate away from large cities. The intuition of their argument goes as follows: manufacturing firms characterized by economies of scale tend to agglomerate near the most densely populated areas of the country to reduce the transaction costs associated with their relationships to the consumer market (backward linkages), and the labor market and their suppliers of intermediate inputs (forward linkages). The centripetal forces caused by backward and forward linkages are counterbalanced by the centrifugal forces originating from the negative externalities of agglomeration, such as high land rents, high wages, congestion, and so forth. In a relatively closed economy, these centripetal forces are strong. But as the economy opens up to trade, the share of production sold to distant foreign markets rises and the reliance of firms on imported intermediates increases as well, and thus, the incentives to locate near a large urban area are smaller. The location of firms may also become more dependent on the presence of location-specific factor inputs such as natural resources, local economic policies and

[2]Hanson (1998) investigates the growth of manufacturing employment in Mexico before and after the country joined the North American Free Trade Area (NAFTA) in 1994. He distinguishes between two opposing forces affecting regional labor demand: transport costs and agglomeration economies. Hanson argues that transport costs matter since "...employment growth is higher in state-industries relatively close to the United States". In addition, he finds that the related-industry agglomeration (concentration of firms in upstream or downstream industries) has a positive and significant impact on employment growth, whereas within-industry agglomeration has a negative impact on employment growth. Rodríguez-Pose and Sánchez-Reaza (2003) also find evidence that trade liberalization and economic integration have changed the regional geography of industries in Mexico. Regions with access to high-skilled labor grew faster than the other regions in the country. The regional integration of the country into NAFTA led to regional divergence and formation of specialized industrial centers close to the border with the United States.

location-specific knowledge. Consequently, trade liberalization favors the dispersion of manufacturing production across space. Fujita, Krugman, and Anthony (1999) describe a similar model involving input-output linkages between firms. They also find that trade induces a dispersion of the manufacturing sector as a whole, while it stimulates the concentration of related industries.

This paper explores a different kind of link between trade and the pattern of industry location within a country using the assumptions of the Melitz (2003) model. In this model, firms in an industry exhibit different levels of labor productivity. The presence of fixed costs of production and exporting leads to a sorting of firms into two types: less productive firms are non-exporters and more productive ones are exporters. As the economy's exposure to trade increases, the least productive non-exporting firms are driven out of the industry while market shares and profits are reallocated from the less productive firms remaining in the industry to the more productive ones. Our model extends the Melitz model by assuming that the economy is comprised of two locations with different factor prices and fixed costs of production. Therefore, there is also a sorting of firms across locations, according to which the most productive firms locate in the rural region, where the fixed cost is higher and the factor price (that is, the marginal cost) lower than in the urban region. As the cost of trading with the foreign country falls, the least productive firms are driven out of the industry. The shift in domestic and export market opportunities also create incentives for firms to relocate to another region. Under some conditions, the firms initially located in the high-factor-price region that have a sufficiently high productivity level become able to bear the extra fixed cost of producing in the low-factor-price region, because the enhancement of export opportunities allows them to generate more revenue. In general, both the reallocation of firms between regions and the reallocation of market shares between non-exporters and exporters, due to trade liberalization, contribute to a decline in the share of urban production. Using data on Colombian manufacturing industries for the period 1981-1991, we document the existence of productivity differences between metropolitan and non-metropolitan plants. Furthermore, we obtain empirical evidence of the impact of tariff liberalization on the pattern of industry location. We find that a decline in tariffs entails a reallocation of industrial production from metro- to non-metropolitan areas.

The remainder of the paper is organized as follows. Section 2 presents the theoretical setup and describes the equilibrium in a closed economy. Section 3 reports some empirical evidence on the differences in the characteristics of urban and rural manufacturing firms in Colombia prior to the trade policy reforms of the 1985-1991 period. Section 4 depicts theand characterizes its equilibrium. Then, section 5 shows how a change in the variable trade cost leads to a geographical relocation of firms and intra-industry reallocations of market shares. Section 6 estimates the impact of tariffs change on the distribution of plants and production across metropolitan and non-metropolitan regions in Colombia. Section 7 summarizes our findings and outlines direction for future research.

2 The Closed Economy Model

We assume a standard Melitz (2003) type framework, with the addition that the economy is spatially heterogeneous in the sense that it is made up of two distinct and homogeneous locations, or regions, in which firms may be situated. These regions are characterized by a vector of parameters: the price of a composite factor used as an input in production, the fixed cost of production, and the endowment of the composite factor. We assume that input prices and fixed costs of production differ in the two regions. The assumption of different costs will result in different firm types self-selecting into different regions in our model.

2.1 Demand

We also assume that goods are sold in a single domestic market. The delivery of output by urban and rural firms to the domestic market involves an iceberg trade cost. This trade cost is assumed to be identical for both types of firms, and thus it can be normalized to zero without loss of generality. The mass of consumers in the domestic market is normalized to one. This representative consumer is endowed with income R, which is considered exogenous. We assume that urban and rural workers earn the same wage rate and thus receive the same income they spend on consumption. The preferences of the representative consumer are described by a Dixit-Stiglitz, constant-elasticity-of-substitution utility function defined over a continuum of varieties of a good:

$$u = \left[\int_{j \in J} x(j)^{\rho} dj \right]^{1/\rho} \tag{1}$$

where J denotes the set of available varieties of the good and j indexes these varieties; $x(j)$ is the quantity of variety j consumed; ρ is a parameter such that $\rho = (\sigma - 1)/\sigma$, where σ is the elasticity of substitution between any pair of varieties. It is assumed that $\sigma > 1$ (the varieties are substitutes) or, equivalently, that $0 < \rho < 1$. When the number of varieties is large enough, which is guaranteed when there is a continuum of varieties available for consumption, the elasticity of substitution and the elasticity of the residual demand for a particular variety are equal.

The representative consumer maximizes utility (1) subject to the budget constraint

$$\int_{j \in J} p(j) x(j) dj = R$$

where $p(j)$ is the price of variety j and R denotes the aggregate expenditure. The resulting demand for variety j is given by

$$x(j) = \frac{R}{P} \left(\frac{p(j)}{P} \right)^{-\sigma} \tag{2}$$

where P is the price index defined as

$$P \equiv \left[\int_{j \in J} p(j)^{1-\sigma} dj \right]^{1/(1-\sigma)} \tag{3}$$

2.2 Production

We consider an industry characterized by monopolistic competition. There is a continuum of firms producing varieties of the good with a common technology. Each firm j produces a single variety j of the good. Production employs a composite factor input, which is denoted by z. It includes labor, capital, energy, materials, and so forth. The proportion of each input in the composite input z is fixed. The cost function of each firm consists of a fixed operating cost and a variable cost of production with constant marginal cost. There is sufficient evidence showing that factor prices are not equalized across regions in both developing and developed countries. Thus, we assume that the nominal prices of that composite input in the two regions are different. The region with the higher nominal price is called the urban region, and the region with the lower nominal price is called the rural region. The urban and rural regions will be designated by the superscripts u and r, respectively. Their respective input prices are denoted by w^u and w^r. In addition, we assume that the fixed operating cost of production is higher for firms producing in the rural region than for those situated in the urban region; that is, we assume that f^r is sufficiently large relative to f^u so that $w^r f^r > w^u f^u$. The cost function of firm j in region m, where $m \in \{u, r\}$ denotes the region in which the firm is located, is assumed to be a linear function of the output:

$$z(j) = f^m + \frac{y(j)}{\theta(j)}$$

where f^m is the fixed cost of production, which is identical across firms in region m; $y(j)$ is the output of firm j; and $\theta(j)$ is a parameter representing the firm-specific level of factor productivity. Since every firm faces a residual demand with constant elasticity σ, independently of its productivity level, it maximizes its profit by imposing a mark-up of price over marginal cost identical to that imposed by all other firms. The price charged by firm j located in region m is given by

$$p^m(j) = \frac{1}{\rho} \frac{w^m}{\theta(j)} \tag{4}$$

The operating profit of a firm with productivity $\theta(j)$ is given by

$$\pi^m(\theta(j)) = \left(p(j) - \frac{w^m}{\theta(j)} \right) x(j) - w^m f^m \tag{5}$$

By substituting the demand function (2) and the mark-up pricing formula (4) into (5), one obtains the maximal value of operating profits:

$$\pi^m(\theta(j)) = \frac{r^m(\theta(j))}{\sigma} - w^m f^m \tag{6}$$

where $r^m(\theta(j))$, the revenue of the firm, is given by

$$r^m(\theta(j)) = \frac{R\,(P\rho)^{\sigma-1}\,\theta(j)^{\sigma-1}}{(w^m)^{\sigma-1}} \tag{7}$$

Thus, a firm with a higher productivity level will charge a lower price (see (4)), and generate more revenue (see (7)) and profit (see (6)) compared with a less productive firm.

2.3 Firm entry, location, and exit

We assume a dynamic economy with an infinite time horizon. Production and consumption take place in every time period, while consumer preferences, technology, and regional factor prices are constant over time. In each period, some firms enter into a given industry and some exit. Entrants into the industry originate from a continuum of identical "entrepreneurs". These entrepreneurs have to incur a fixed sunk cost of entry[3] of nominal value f_e. The determination of the firm-specific productivity parameter follows the Melitz-Hopenhayn modeling of heterogeneous firms (see Melitz (2003)). Upon incurring the entry fee, an entrepreneur randomly draws a productivity parameter $\theta(j)$ from a distribution given by a continuous p.d.f. g, with support $(0, \infty)$, and a c.d.f. G. Once the entrepreneur—now firm j—learned its productivity level, it decides whether to produce the good and where to locate (in the urban region or the rural region) in the current and future periods, or to opt out of the industry without producing if its productivity level is too low. At any time, firms actually entering in the industry are, a priori, infinitely lived. However, all incumbent firms may be forced to exit with probability δ in every period.[4]

A firm that has just entered the industry with productivity θ (we now omit the index j for convenience) chooses from the three available strategies the one that maximizes the expected value of its stream of present and future per-period profits. The maximal value of expected profits is given by the expected value function of the firm expressed as follows:

$$(8) \quad v(\theta) = \max\left\{0, \sum_{t=0}^{\infty} (1-\delta)^t \, \pi^u(\theta), \sum_{t=0}^{\infty} (1-\delta)^t \, \pi^r(\theta)\right\} = \max\left\{0, \frac{\pi^u(\theta)}{\delta}, \frac{\pi^r(\theta)}{\delta}\right\}$$

where π^u and π^r are given in (6). The firm actually selects the strategy yielding the maximal per-period profit level since its productivity is constant over time. The lowest productivity level, or zero cutoff productivity level, of producing firms is given by $\theta^* = \inf\{\theta : \theta > 0 \text{ and } v(\theta) \geq 0\}$. Since $\pi^m(0) = -w^m f^m$ is negative for any region $m \in \{u, r\}$ and the profit functions (6) are monotonically increasing in θ, then it must be

[3]This entry cost may be interpreted as an investment in R&D to learn a production process for a particular differentiated product, or (and) the cost of setting up a basic organizational structure allowing the firm to function.

[4]One may interpret such an exit as the result of an adverse shock due to, for instance, unforeseen changes in market conditions depressing the profits of some firms.

the case that $\max\{\pi^u(\theta^*), \pi^r(\theta^*)\} = 0$. Thus, any firm entering the industry with a productivity level strictly smaller than θ^* will exit without producing. Given that the rural region exhibits a higher fixed cost but a lower marginal cost than the urban region, two cases arise regarding the distribution of firms between the urban and rural regions along the productivity spectrum. In the first case, $\pi^u(\theta^*) = 0$, $\pi^r(\theta^*) < 0$, and there exists a productivity level $\theta_{u,r}$, which we call the urban-rural cutoff productivity level, such that $\theta_{u,r} = \inf\{\theta : \theta > \theta^* \text{ and } \pi^r(\theta) \geq \pi^u(\theta)\}$. Since π^u and π^r are monotonically increasing, this implies $\pi^u(\theta_{u,r}) = \pi^r(\theta_{u,r})$. Thus, any firm entering the industry with a productivity level between θ^* and $\theta_{u,r}$ will maximize its profits by locating in the urban region. Any firm receiving a productivity level above $\theta_{u,r}$ will obtain maximal profits by producing in the rural region. This situation is illustrated in figure 1, in which the lines labeled π^u and π^r depict the per-period operating profits associated with the urban and rural locations, respectively, as a function of Θ, where $\Theta \equiv \theta^{\sigma-1}$ is a transformed measure of productivity. The π^r line is steeper than the π^u line because, at a given

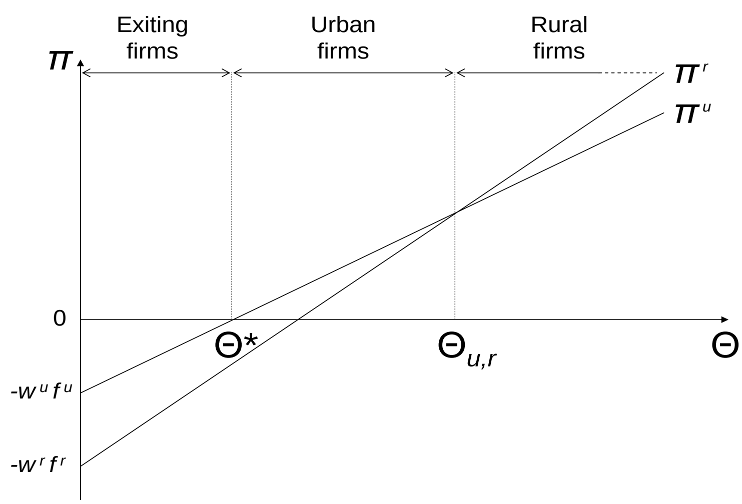

Figure 1: Operating profits for the urban and rural location strategies

productivity level, the variable cost of producing one unit of output is lower for firms operating in the rural region. The value of the intercept of the π^r line, however, is below that of the π^u line because the fixed operating cost of rural firms is larger. Figure 1 shows that firms with productivity higher than Θ^* but less than $\Theta_{u,r}$ make greater profits by producing in the urban region. At the productivity level $\Theta_{u,r}$, the urban and rural strategies yield equal profits. Firms with productivity exceeding $\Theta_{u,r}$ obtain greater profits by producing in the rural region. In the second case, $\pi^u(\theta^*) \leq 0$ and $\pi^r(\theta^*) = 0$, so when firms are productive enough to stay in the industry, they always find it more profitable to operate in the rural region no matter what their productivity level is. We will not analyze the second case further as it boils down to the Melitz (2003) model.

Figure 1 points at an implicit relationship between θ^* and $\theta_{u,r}$ that hinges on the parameters of the model, that is, σ, w^u, w^r, f^u, and f^r. We derive the expression of this relationship by substituting the zero cutoff profit condition, $\pi^u(\theta^*) = 0$, into the urban-rural cutoff profit condition, $\pi^u(\theta_{u,r}) = \pi^r(\theta_{u,r})$, and solving for $\theta_{u,r}$ as a function of θ^* and the parameters. We obtain[5]

$$(9) \qquad \theta_{u,r} = \alpha\theta^*, \text{ where } \alpha \equiv \left[\frac{w^r f^r - w^u f^u}{w^u f^u}\left(\frac{(w^u)^{\sigma-1} - (w^r)^{\sigma-1}}{(w^r)^{\sigma-1}}\right)^{-1}\right]^{1/\sigma-1}$$

Note that the condition $\alpha > 1$ guarantees the existence of urban firms. This condition will be satisfied when the additional fixed cost of operating in the rural region is large enough relative to the difference in factor prices between the urban and rural regions.

The equilibrium distribution of all the firms' productivity levels is shaped by the exogenous distribution, g, and the probability of actual entry in the industry, $1-G(\theta^*)$. The exit of incumbents from the industry does not shift the equilibrium distribution of productivity levels because the probability that a firm be forced to exit, δ, is independent of its productivity level and location by assumption. Thus, the equilibrium productivity distribution is given by the p.d.f. g conditional on entry, with support $[\theta^*, \infty)$:

$$(10) \qquad \mu(\theta) = \begin{cases} \frac{g(\theta)}{1-G(\theta^*)} & \text{if} \quad \theta \geq \theta^*, \\ 0 & \text{otherwise.} \end{cases}$$

[5]On one hand, $\pi^u(\theta^*) = 0 \Leftrightarrow R(\rho P)^{\sigma-1}/\sigma = (w^u)^{\sigma-1} w^u f^u/(\theta^*)^{\sigma-1}$ (using the revenue and profit expressions (7) and (6)). On the other hand, $\pi^u(\theta_{u,r}) = \pi^r(\theta_{u,r}) \Leftrightarrow (\theta_{u,r})^{\sigma-1} = (w^r f^r - w^u f^u)\big[(R(\rho P)^{\sigma-1}/\sigma)[(1/w^r)^{\sigma-1} - (1/w^u)^{\sigma-1}]\big]^{-1}$. Substituting the expression of $R(\rho P)^{\sigma-1}/\sigma$ into that of $(\theta_{u,r})^{\sigma-1}$ and solving for $\theta_{u,r}$ yields the expression in (9).

In addition, we can specify the equilibrium productivity distributions of urban and rural firms separately. For urban firms, the p.d.f. is $g(\theta)/[G(\theta_{u,r}) - G(\theta^*)]$ for $\theta* < \theta < \theta_{u,r}$ and 0 otherwise, where $\theta_{u,r}$ is implicitly a function of θ^* as in (9). $q^u = [G(\theta_{u,r}) - G(\theta^*)]/[1 - G(\theta^*)]$ is the probability that an actual entrant choose the urban location, and it also equals the share of urban firms. Likewise, the p.d.f. of rural firms is given by $g(\theta)/[1 - G(\theta_{u,r})]$ for $\theta > \theta_{u,r}$ and 0 otherwise. $q^r = [1 - G(\theta_{u,r})]/[1 - G(\theta^*)]$ is the probability that an actual entrant become a rural firm, and it also equals the share of rural firms. The equilibrium distribution of productivity levels depends on the zero cutoff productivity level, θ^*, which is itself endogenous to the decisions of firms about whether to remain in the industry upon entry and where to locate. Firms are not urban or rural by assumption. They select themselves into being urban or rural depending on where they achieve the highest operating profits, given their exogenous productivity levels. The sorting of firms across locations determines, in turn, the average productivity levels of the urban and rural locations. Like in Melitz (2003), we analyze a steady-state equilibrium in which the aggregate variables are constant over time and the location decision of every firm is optimal given these aggregate variables.

2.4 Equilibrium conditions

2.4.1 Price index and average productivities

In the steady-state equilibrium, the mass of firms is $M = M^u + M^r$, where M^u and M^r are the masses of urban and rural firms, respectively. The distribution of these firms' productivity levels is given by the function μ defined over (θ^*, ∞). In accordance with (3), the price index is given by

$$P = \left[\int_0^{\theta_{u,r}} p^u(\theta)^{1-\sigma} M\mu(\theta)d\theta + \int_{\theta_{u,r}}^{\infty} p^r(\theta)^{1-\sigma} M\mu(\theta)d\theta \right]^{1/(1-\sigma)}$$

After substituting in the above expression the mark-up pricing formula (4) and the right-hand side of each of the following equalities,

$$\int_0^{\theta_{u,r}} \theta^{\sigma-1}\mu(\theta)d\theta = q^u \frac{1}{G(\theta_{u,r}) - G(\theta^*)} \int_{\theta^*}^{\theta_{u,r}} \theta^{\sigma-1}g(\theta)d\theta$$
$$\int_{\theta_{u,r}}^{\infty} \theta^{\sigma-1}\mu(\theta)d\theta = q^r \frac{1}{1 - G(\theta_{u,r})} \int_{\theta_{u,r}}^{\infty} \theta^{\sigma-1}g(\theta)d\theta$$

and recognizing that q^m equals the share of firms in location m, $s^m \equiv M^m/M$, one can rewrite the price index as

$$P = M^{1/(1-\sigma)} \left[s^u p^u(\tilde{\theta^u}(\theta^*, \theta_{u,r}))^{1-\sigma} + s^r p^r(\tilde{\theta^r}(\theta_{u,r}))^{1-\sigma} \right]^{1/(1-\sigma)} \tag{11}$$

where $\tilde{\theta^u}$ and $\tilde{\theta^r}$ are weighted averages of urban and rural firms' productivity levels, respectively. They are functions of θ^* defined as[6]

$$\tilde{\theta^u}(\theta^*, \theta_{u,r}) = \left[\frac{1}{G(\theta_{u,r}) - G(\theta^*)} \int_{\theta^*}^{\theta_{u,r}} \theta^{\sigma-1} g(\theta) d\theta \right]^{1/(\sigma-1)} \tag{12}$$

$$\tilde{\theta^r}(\theta_{u,r}) = \left[\frac{1}{1 - G(\theta_{u,r})} \int_{\theta_{u,r}}^{\infty} \theta^{\sigma-1} g(\theta) d\theta \right]^{1/(\sigma-1)} \tag{13}$$

Since more productive firms can sell goods at lower prices, they capture greater shares of the market than less productive firms. Thus, the former exert a greater weight on the price index. The weights in the expressions of the average productivities account for the disproportionate influence of more productive firms.

The aggregate profit of urban firms can be written as a function of their average productivity:

$$\Pi^u = \int_{\theta^*}^{\theta_{u,r}} \pi^u(\theta) M \mu(\theta) d\theta = M \left[\frac{R(\rho P)^{\sigma-1}}{\sigma (w^u)^{\sigma-1}} \int_{\theta^*}^{\theta_{u,r}} \theta^{\sigma-1} \mu(\theta) d\theta - w^u f^u \int_{\theta^*}^{\theta_{u,r}} \mu(\theta) d\theta \right]$$

Since $\int_{\theta^*}^{\theta_{u,r}} \theta^{\sigma-1}\mu(\theta)d\theta = q^u(\tilde{\theta^u}(\theta^*, \theta_{u,r}))^{\sigma-1}$ and $\int_{\theta^*}^{\theta_{u,r}} \mu(\theta)d\theta = q^u$, we obtain $\Pi^u = M^u \pi^u(\tilde{\theta^u}(\theta^*, \theta_{u,r}))$, which entails $\pi^u(\tilde{\theta^u}(\theta^*, \theta_{u,r})) = \bar{\pi}^u \equiv \Pi^u/M^u$. Hence, the profit of the firm with the average urban productivity equals the average profit of urban firms. Similarly, we can express the aggregate profit of rural firms as a function of their average productivity:

$$\Pi^r = \int_{\theta_{u,r}}^{\infty} \pi^r(\theta) M \mu(\theta) d\theta = M \left[\frac{R(\rho P)^{\sigma-1}}{\sigma (w^r)^{\sigma-1}} \int_{\theta_{u,r}}^{\infty} \theta^{\sigma-1} \mu(\theta) d\theta - w^r f^r \int_{\theta_{u,r}}^{\infty} \mu(\theta) d\theta \right]$$

Since $\int_{\theta_{u,r}}^{\infty} \theta^{\sigma-1}\mu(\theta)d\theta = q^r(\tilde{\theta^r}(\theta_{u,r}))^{\sigma-1}$ and $\int_{\theta_{u,r}}^{\infty} \mu(\theta)d\theta = q^r$, we have $\Pi^r = M^r \pi^r(\tilde{\theta^r}(\theta_{u,r}))$, which implies $\pi^r(\tilde{\theta^r}(\theta_{u,r})) = \bar{\pi}^r \equiv \Pi^r/M^r$. Hence, the profit of the firm with the average rural productivity equals the average profit of rural firms.

[6] The condition for $\tilde{\theta^r}(\theta_{u,r})$ to be finite requires that the $(\sigma-1)$-th uncentered moment of g be finite.

2.4.2 Cutoff profit conditions

According to (7), the ratio of any two urban firms' revenues depends only on the ratio of their productivity levels; in particular, for two firms with productivities $\tilde{\theta^u}(\theta^*, \theta_{u,r})$ and θ^*, we have

$$r^u(\tilde{\theta^u}(\theta^*, \theta_{u,r})) / r^u(\theta^*) = \left(\frac{\tilde{\theta^u}(\theta^*, \theta_{u,r})}{\theta^*}\right)^{\sigma-1} \tag{14}$$

It follows that $r^u(\tilde{\theta^u}(\theta^*, \theta_{u,r})) = r^u(\theta^*)(\tilde{\theta^u}(\theta^*, \theta_{u,r})/\theta^*)^{\sigma-1}$. Substituting the expression for $r^u(\tilde{\theta^u}(\theta^*, \theta_{u,r}))$ into (6) yields an expression for the profit of the firm with the average urban productivity, or, equivalently, the average profit level of urban firms:

$$\bar{\pi}^u(\theta^*, \theta_{u,r}) = \frac{r^u(\theta^*)}{\sigma}\left(\frac{\tilde{\theta^u}(\theta^*, \theta_{u,r})}{\theta^*}\right)^{\sigma-1} - w^u f^u$$

Furthermore, since $\pi^u(\theta^*) = 0$ entails $r^u(\theta^*) = \sigma w^u f^u$ (see (6)), the average urban profit can be expressed as

$$\bar{\pi}^u(\theta^*, \theta_{u,r}) = w^u f^u \left[\left(\frac{\tilde{\theta^u}(\theta^*, \theta_{u,r})}{\theta^*}\right)^{\sigma-1} - 1\right] \tag{15}$$

where $\theta_{u,r}$ is a function of θ^* as in (9). Thus, like the average productivity level $\tilde{\theta^u}$, the average urban profit level depends only on the zero cutoff productivity level θ^*.

The average profit level of rural firms, derived in similar way as the average urban profit, is given by

(16)

$$\bar{\pi}^r(\theta^*, \theta_{u,r}) = w^u f^u \left[\left(\frac{\tilde{\theta^r}(\theta_{u,r})}{\theta^*}\right)^{\sigma-1} - \left(\frac{\tilde{\theta^r}(\theta_{u,r})}{\theta_{u,r}}\right)^{\sigma-1}\right] + w^r f^r \left[\left(\frac{\tilde{\theta^r}(\theta_{u,r})}{\theta_{u,r}}\right)^{\sigma-1} - 1\right]$$

and, likewise, it is entirely determined by θ^*.

2.4.3 Free entry condition

The present values of the average profit flows for urban and rural firms are, respectively, $\sum_{t=0}^{\infty}(1-\delta)^t\bar{\pi}^u = \bar{\pi}^u/\delta$ and $\sum_{t=0}^{\infty}(1-\delta)^t\bar{\pi}^r = \bar{\pi}^r/\delta$. Thus, the *ex ante* net expected value of entry into the industry, v_e, is expressed as

$$v_e(\theta^*, \theta_{u,r}) = [G(\theta_{u,r}) - G(\theta^*)]\,\frac{\bar{\pi}^u}{\delta} + [1 - G(\theta_{u,r})]\,\frac{\bar{\pi}^r}{\delta} - f_e$$

In equilibrium, under the assumption of free entry, the value of entry will be driven to zero since there is an infinite number of potential firms. Hence, we have the following relationship between the average profits and cutoff productivity levels:

$$\frac{G(\theta_{u,r}) - G(\theta^*)}{1 - G(\theta^*)}\bar{\pi}^u + \frac{1 - G(\theta_{u,r})}{1 - G(\theta^*)}\bar{\pi}^r = \frac{\delta f_e}{1 - G(\theta^*)} \tag{17}$$

where $\theta_{u,r}$ is a function of θ^* as in (9). The left-hand side of (17) is the *ex post* (that is, conditional upon entry) per-period average profit in the industry.

2.5 The closed economy equilibrium

The cutoff profit conditions for urban and rural firms and the free entry condition imply three relationships, first, between θ^* and the average urban profit (see (15)); second, between θ^* and the average rural profit (see (16)); and third, between θ^*, the average urban profit, and the average rural profit (see (17)). As it is shown in appendix A.2, there exists one, and only one combination of productivity and profit values (θ^*,$\bar{\pi}^u$,$\bar{\pi}^r$) that satisfies these three conditions. In addition, the equilibrium zero cutoff productivity level determines, according to (9), a unique urban-rural cutoff productivity level, $\theta_{u,r}$.

The masses of urban and rural firms must be constant over time in the steady-state equilibrium. Thus, in each period, there must be a mass M_e of firms paying the sunk cost of entry and drawing a productivity level, such that the mass of actual entrants in region m, $m \in \{u, r\}$, matches the mass δM^m of incumbent firms forced to exit from region m:

$$q^u M_e = \delta M^u \quad \text{and} \quad q^r M_e = \delta M^r$$

where $q^u = G(\theta_{u,r}) - G(\theta^*)$ and $q^r = 1 - G(\theta_{u,r})$ are the probabilities of successful entry in the urban and rural regions, respectively. The movement of firms in and out of the industry will not shift the equilibrium distribution of productivity levels because actual entrants' and exiting incumbents' productivities are identically distributed.

We denote the exogenous stocks of the composite input available for production in the urban and the rural regions by Z^u and Z^r, respectively. The aggregate stock of inputs is given by $Z = Z^u + Z^r$. We assume that households own the factors of production. Households in region m receive an aggregate payment of $w^m Z^m = R^m - \Pi^m$. This expression is the market clearing condition for the composite factor of production in region m. Then, the mass of producing firms in region m can be expressed as a function of the average revenue in the region.

$$M^m = \frac{R^m}{\bar{r}^m} = \frac{w^m L^m + \Pi^m}{\sigma\left(\bar{\pi}^m + w^m f^m\right)}$$

The equilibrium price index is determined by the masses of firms in the two regions derived above as in (11).

3 Firm-Level Evidence on Regional Productivity Differences in Colombia

In the closed-economy model of the previous section, firms select themselves into two different geographical locations depending on their productivity level. As a consequence of this selection process, rural firm are more productive and sell more output than urban firms. According to our model, one would expect that firms located in predominantly rural regions of a country tend to be more productive than firms situated in metropolitan areas. In this section, we estimate the production function of Colombian manufacturing plants during the period 1981-1984 while controlling for firms' choices of location. The econometric results show that the metropolitan nature of location contributes in explaining the variation in productivity across plants in a significant way.

Colombian trade policy varied substantially during the period 1977-1991 (see **?**) and Fernandes (2007)). A first wave of trade reforms occurred between 1977 and 1981. The Colombian government lowered tariffs and expanded the list of products allowed to be imported without a license. This period of trade liberalization was followed by a period of return to protectionist policies, between 1982 and 1984, during which the government raised tariffs, removed many products from the list of license-free imports, and prohibited some imports. In 1984 the average tariff reached a peak of 45 percent. The most protected industries were textiles, apparel, footwear, furniture, beverages, and plastics. Trade reforms were again implemented between 1985 and 1991, a period during which the administrative barriers to imports were reduced, tariffs declined gradually and significantly, and the number of freely imported products increased.

To test the implications of our model, we use a plant-level unbalanced panel dataset for the Colombian manufacturing sector covering the years from 1981 to 1984. The data was originally collected by the *Departamento Administrativo Nacional de Estadística* through the annual Colombian census of the manufacturing sector.[7] Plants are classified according to a 4-digit ISIC code similar to the one in the United States. This dataset contains information about various plants characteristics such as employment, labor costs, the stock of capital, energy consumption, raw materials and intermediates used, production and sales, exports, and so forth.[8] (See appendix E for a detailed description of the variables we use in the following analysis.)

Prior studies (Olley and Pakes (1996), Pavcnik (2002), Levinsohn and Petrin (2003), and Fernandes (2007)) estimated total factor productivity (TFP) using a Cobb-Douglas production function. The general form of this production function, after taking the logarithm, is given by:

$$y^i_{j,t} = \beta_0 + \beta_1 l^i_{j,t} + \beta_2 m^i_{j,t} + \beta_3 k^i_{j,t} + \beta_4 e^i_{j,t} + \omega^i_{j,t} + \epsilon^i_{j,t}$$

where i, j and t denote the particular industry, firm and time period, respectively. Firm j in industry i produces output $y^i_{j,t}$ at time t by employing several factors of production: labor $l^i_{j,t}$, materials $m^i_{j,t}$, capital $k^i_{j,t}$, and energy $e^i_{j,t}$. The quantity of output produced also depends on a firm-specific parameter, $\omega^i_{j,t}$, which shifts the production function. $\omega^i_{j,t}$ is known to the plant's decision-maker, varies over time, and is correlated with the choice of factor inputs. This correlation leads to a simultaneity bias, which needs to be addressed when estimating the production function. The random productivity shocks, occurring after the choice of inputs is made, are captured by the error term $\epsilon^i_{j,t}$.

In our model the prices of factor inputs differ in the two regions. Thus, different firms self-select into different regions and that will cause the coefficient estimates to vary across regions. A firm's choice of location is not exogenous and urban firms cannot be treated in the same way as rural firms. Therefore, we include controls for location (metropolitan versus non-metropolitan) and estimate the following production function:

$$\begin{aligned} y^i_{j,t} = {} & \beta_0 + \beta_1 l^i_{j,t} + \beta_2 m^i_{j,t} + \beta_3 k^i_{j,t} + \beta_4 e^i_{j,t} + \beta_5 metro + \beta_6 l^i_{j,t} metro + \beta_7 m^i_{j,t} metro \\ & + \beta_8 k^i_{j,t} metro + \beta_9 e^i_{j,t} metro + \omega^i_{j,t} + \epsilon^i_{j,t} \end{aligned} \tag{18}$$

[7]The dataset we utilized is provided by Mark Roberts (see Roberts (1996) for a comprehensive description of the data).

[8] The plants with less than ten employees were excluded from the census in 1983 and 1984. For consistency, we dropped the plants with less than ten employees despite the fact that data is available in the years 1981 and 1982.

We use plant-level fixed effects to control for the simultaneity bias, thus $\omega_{j,t}^i = \omega_j^i$.[9] We have an unbalanced panel since not all plants appear in the survey for each year. This mostly reflects the net change in the number of firms due to new entry and exits in and out from an industry, which helps to partly address the possibility of self-selection. Our dependent variable is the real value of production of plant j in industry i at time t.[10] The productivity differences between metropolitan and non-metropolitan plants are estimated by a dummy varible *metro*, which is equal to one if the plant is located in a metropolitan area and zero otherwise. We also use interaction terms between the metro variable and the different factors of production (labor, capital, energy, and materials) to measure the differences in factor productivities between plants located in metropolitan and nonmetroplitan areas.

3.1 Regression results

We estimate three different specifications of the production function (18) including controls for the industry differences at the 4-digit SIC level. The first specification is the one typically used in the literature to estimate TFP. In the second specification we add controls for location to capture the differences between metropolitan and non-metropolitan plants in terms of different factor productivities. The third specification is estimated with additional dummy variables for each 4-digit SIC industry and for each year. Our regression results are summarized in table 1. As expected, the factor inputs are positively correlated with output. Specifications 2 and 3 suggest that urban or metropolitan plants have higher capital and raw materials productivity than rural or non-metropolitan plants. In contrast, labor and energy productivities are lower for manufacturers located in metropolitan (metro) areas as compared with those in the rest of the country. The coefficient on the metro variable is negative and statistically significant at the ten percent level. This sign is consistent with the predictions of our model. The inclusion of the year dummies does not significantly alter our findings. Our results provide evidence that metro and non-metro plants have different productivities.

[9]Note that the fixed effect approach ignores the possibility of changes in productivity over time but this is not an issue if the time span is short, that is, it is very unlikely that within 3-4 years firms' productivity in a given industry can change dramatically. Hence, this model is suitable for our goal of investigating the impact of geographic location on productivity.

[10]As explained in Fernandes (2003), it is better to use an output rather than a value added specification for this dataset.

It is important, however, to take into account the possibility that the productivity differences between metro and non-metro plants can reflect the different geographical preferences of the different industries. In particular, some industries, by their nature, would choose to locate in rural regions (for instance, labor intensive industries), whereas other industries would rather locate in urban regions (such as high-technology industries or industries with high value-added). Thus, for a robustness check we estimate the same fixed effect models for the three biggest industries in Colombia at the four-digit level: grain mill products, clothing, and motor vehicles.[11] The regression results are provided in table 2. The coefficient estimates on the metro dummy variable are still negative but statistically insignificant. However, the estimates on the interaction terms turn to have different signs and magnitudes across the three industries. For example, labor productivity is higher in the non-metro plants compared with the metro establishments, whereas materials productivity is lower for the non-metro establishments when looking at the grain mill products industry. These differences are statistically significant. In contrast, the productivity of the material factor input is higher for the metro plants but all other factor productivity differences are insignificant for the Colombian clothing industry. Furthermore, metro plants producing motor vehicles seem to be more productive in terms of materials and less productive in terms of energy compared with their rivals in the less densely populated areas. These regression results suggest that even within a particular industry, the producers located in metro areas have different factor productivities than the producers in non-metro areas.

4 The Open Economy Model

In this section, our goal is to characterize the equilibrium when the country described in the closed economy section has the opportunity to trade with another country. Henceforth, the former is referred to as the domestic country (d) and the latter is called the foreign country (f). The two countries are symmetric. In particular, the urban and rural prices of the factor input in the foreign country are identical to those in the domestic country. In both countries, firms set the price of output sold domestically according to the same rule as in the closed economy model. A firm with productivity θ and located in

[11] These industries have the biggest share in terms of real production in 1981.

region $m \in \{u, r\}$ sets its domestic price at $p_d^m(\theta) = w^m/\rho\theta$, and the revenue it garners from domestic sales is

$$r_d^m(\theta) = \frac{R\left(\rho P\right)^{\sigma-1}\theta^{\sigma-1}}{\left(w^m\right)^{\sigma-1}} \tag{19}$$

Domestic firms incur both a variable trade cost and a fixed cost[12] to sell their output abroad. The variable trade cost is assumed to take the form of an iceberg trade cost, so that $\tau > 1$ units of domestic output must be shipped in order for one unit to be delivered to the foreign market. Since the per-unit variable cost of serving the foreign market includes this iceberg trade cost, then, the mark-up pricing rule applied by a domestic firm for output sold in the foreign market is given by $p_f^m(\theta) = \tau w^m/\rho\theta = \tau p_d^m(\theta)$. The firm's revenue from export sales is

$$r_f^m(\theta) = \frac{R\left(\rho P\right)^{\sigma-1}\theta^{\sigma-1}}{\left(\tau w^m\right)^{\sigma-1}} = \tau^{1-\sigma} r_d^m(\theta) \tag{20}$$

where R and P, the aggregate expenditure and price index in the foreign country, respectively, are equal to R and P in the domestic country as both countries are identical and trade must be balanced. Hence, the total revenue of an exporting firm located in region m is $r^m(\theta) = r_d^m(\theta) + r_f^m(\theta) = (1 + \tau^{1-\sigma})r_d^m(\theta)$. The total revenue of a firm serving only the domestic market is just the revenue from domestic sales, $r_d^m(\theta)$.

4.1 Firm entry, location, and export status

The conditions of entry and exit are the same as in the closed economy model. In particular, firms entering the industry draw their productivity level at random from the distribution g. Upon learning their productivity level, firms decide whether they will export goods to the foreign country (firms can accurately foresee their future foreign sales),and simultaneously select their location. In order to export, firms must pay a periodic fixed cost whose nominal value is f_{ex}.[13] This per-period fixed cost of exports is

[12] To enter a foreign market, a firm must incur search and information costs associated with seeking foreign partners and customers, marketing costs such as the cost of establishing a distribution network, costs of meeting local regulatory constraints, and other possible costs associated with doing business abroad. Previous studies (see for example Roberts and Tybout (1997), Clerides, Lach, and Tybout (1998)) have shown that manufacturing firms entering export markets have to make significant outlays that do not depend on the volume of their exports.

[13] As explained in Melitz (2003), it is equivalent for a firm, in terms of resource expenditure, to incur a one-time fixed cost in the initial period that enables the firm to export in all periods, and to spread the fixed cost of exporting evenly over time in such a way that the discounted value of the sum of the periodic payments is equal to the one-time payment.

the same for urban and rural producers. Firms supplying goods to the foreign market are not exempt from the fixed production cost. Any exporting firm maximizes its profits by also serving the domestic market (since the domestic revenue r_d^m is positive for any firm remaining in the industry). The profit of a firm producing in region m with productivity θ, denoted $\pi^m(\theta)$, will be equal to $[r_d^m(\theta) + r_f^m(\theta)]/\sigma - w^m f^m - f_{ex}$. However, it will be convenient for the subsequent analysis to write it as $\pi_d^m(\theta) + \pi_f^m(\theta)$, where

$$\pi_d^m(\theta) = \frac{r_d^m(\theta)}{\sigma} - w^m f^m \quad \text{and} \quad \pi_f^m(\theta) = \frac{r_f^m(\theta)}{\sigma} - f_{ex} = \frac{\tau^{1-\sigma} r_d^m(\theta)}{\sigma} - f_{ex} \tag{21}$$

$\pi_d^m(\theta)$ will be referred to as the domestic profit because it accounts for domestic sales earnings, and $\pi_f^m(\theta)$ as the export profit since it reflects foreign sales revenues.

In the open economy there are four strategies available to a firm, that is, being an urban firm supplying goods for the domestic market only, being an urban exporter, producing in the rural region and selling goods exclusively to domestic consumers, and being a rural exporter. A firm will choose the strategy that yields the greatest expected value of future profits flow. The value function of a firm with productivity θ is defined by the expression $v(\theta) = \max\left\{\pi_d^u(\theta)/\delta, [\pi_d^u(\theta) + \pi_f^u(\theta)]/\delta, \pi_d^r(\theta)/\delta, [\pi_d^r(\theta) + \pi_f^r(\theta)]/\delta\right\}$. The zero cutoff productivity level for profitable entry is determined by $\theta^* = \inf\{\theta : \theta > 0 \text{ and } v(\theta) \geq 0\}$. As in the closed economy model, we assume in the following discussion that the advantage to the urban region based on the lower fixed cost is sufficiently large relative to the disadvantage due to the higher factor price to allow low-productivity firms to locate there. In particular, it warrants that $\pi^u(\theta^*) = 0$ and $\pi^r(\theta^*) < 0$. Moreover, we suppose that the fixed and variable trade costs, f_{ex} and τ, are sufficiently high so that some firms, at relatively low productivity levels, find it profitable not to export. However, it remains ambiguous whether the first exporting firms (along the productivity line) will be urban or rural. Accordingly, the lowest productivity level at which it is profitable to export, or the export cutoff productivity level, is defined as

(22)

$$\theta_{ex} = \inf\left\{\theta : \theta \geq \theta^* \text{ and } \max\left\{\pi_d^u(\theta) + \pi_f^u(\theta), \pi_d^r(\theta) + \pi_f^r(\theta)\right\} \geq \max\left\{\pi_d^u(\theta), \pi_d^r(\theta)\right\}\right\}$$

In addition, the urban-rural cutoff productivity is defined as

(23)

$$\theta_{u,r} = \inf\left\{\theta : \theta \geq \theta^* \text{ and } \max\left\{\pi_d^r(\theta), \pi_d^r(\theta) + \pi_f^r(\theta)\right\} \geq \max\left\{\pi_d^u(\theta), \pi_d^u(\theta) + \pi_f^u(\theta)\right\}\right\}$$

We can distinguish two cases to begin with: (a) $\theta_{ex} < \theta_{u,r}$; and (b) $\theta_{ex} < \theta_{u,r}$. In case (a), when moving along the productivity line to the right, one first encounters urban exporters before coming across rural firms of any kind (non-exporters or exporters). Firms with productivity levels superior to, and in the vicinity of $\theta_{u,r}$, could, a priori, either be rural non-exporters or rural exporters. The following lemma rules out the possibility to observe the former type of firms in this case.

Lemma 1 *If urban exporters operate below a given level of productivity $\theta_{u,r}$, where $\theta_{u,r} > \theta_{ex}$, then rural non-exporters cannot operate above $\theta_{u,r}$; only rural exporters can.*

Proof If rural non-exporters directly follow urban exporters, then, according to (23), it implies that $\pi_f^u(\theta_{u,r}) > 0$, $\pi_f^r(\theta_{u,r}) < 0$, and $\pi_d^r(\theta_{u,r}) \geq \pi_d^u(\theta_{u,r}) + \pi_f^u(\theta_{u,r})$. However, we know from (20) that $\pi_f^r(\theta) > \pi_f^u(\theta)\ \forall\ \theta \in \Re^+$ since $w^r < w^u$. It is true in particular for $\theta = \theta_{u,r}$. Hence, it must the case that $\pi_f^r(\theta_{u,r}) > 0$, which contradicts the premise and implies that firms with productivities greater than $\theta_{u,r}$ are rural exporters. Q.E.D.
Thus, case (a) is characterized by the succession along the productivity line of urban non-exporters, urban exporters, and rural exporters.

In case (b), when moving along the productivity line to the right, we observe rural non-exporters before coming across exporting firms of any sort (urban or rural). Firms with productivity levels superior to, and in the vicinity of θ_{ex}, could, a priori, either be urban exporters or rural exporters. The following lemma shows that rural non-exporters cannot be superseded by urban exporters.

Lemma 2 *If rural non-exporters operate under a given level of productivity θ_{ex}, where $\theta_{ex} > \theta_{u,r}$, then urban exporters cannot operate above θ_{ex}; only rural exporters can.*

Proof If urban exporters directly follow rural non-exporters, then, according to (22), $\pi_d^r(\theta_{ex}) > \pi_d^u(\theta_{ex})$, $\pi_d^u(\theta_{ex}) + \pi_f^u(\theta_{ex}) > \pi_d^r(\theta_{ex}) + \pi_f^r(\theta_{ex})$, and $\pi_d^u(\theta_{ex}) + \pi_f^u(\theta_{ex}) \geq \pi_d^r(\theta_{ex})$. However, we know that $\pi_f^r(\theta) > \pi_f^u(\theta)\ \forall\ \theta \in \Re^+$ since $w^r < w^u$. This is also true for $\theta = \theta_{ex}$. Hence, it must be the case that $\pi_d^r(\theta_{ex}) + \pi_f^r(\theta_{ex}) > \pi_d^u(\theta_{ex}) + \pi_f^u(\theta_{ex})$, which contradicts the premise. Q.E.D.
Thus, case (b) is characterized by the succession along the productivity line of urban non-exporters, rural non-exporters, and rural exporters. Note that, in the special case where $\theta_{ex} = \theta_{u,r}$, firms with productivity levels inferior to the common value of θ_{ex} and

$\theta_{u,r}$ are urban non-exporters, and firms with productivities superior to this level are rural exporters. In what follows, we will analyze cases (a) and (b) formally and provide an intuitive description of this special case, which is not of particular interest.

4.2 Relationships among the cutoff productivity levels

4.2.1 Case (a): urban non-exporters, urban exporters, and rural exporters

To obtain the relationship between θ^* and θ_{ex} we substitute the zero cutoff profit condition, $\pi_d^u(\theta^*) = 0$, into the export cutoff profit condition, $\pi_f^u(\theta_{ex}) = 0$, and then we solve for θ_{ex} as a function of θ^*[14]:

$$\theta_{ex} = \eta\theta^*, \text{ where } \eta \equiv \tau \left(\frac{f_{ex}}{w^u f^u} \right)^{1/\sigma-1} \tag{24}$$

The condition $\eta > 1$ ensure the existence of urban non-exporters. The relationship between θ^* and $\theta_{u,r}$ is derived in a similar way by substituting $\pi_d^u(\theta^*) = 0$ into the urban-rural cutoff profit condition, $\pi^u(\theta_{u,r}) = \pi^r(\theta_{u,r})$. Thus, we obtain

$$\theta_{u,r} = \gamma\theta^*, \text{ where } \gamma \equiv \frac{1}{(1+\tau^{1-\sigma})^{1/(\sigma-1)}} \left[\frac{w^r f^r - w^u f^u}{w^u f^u} \left(\frac{(w^u)^{\sigma-1} - (w^r)^{\sigma-1}}{(w^r)^{\sigma-1}} \right)^{-1} \right]^{1/\sigma-1} \tag{25}$$

Note that the conditions $\eta > 1$ and $\gamma/\eta > 1$ together guarantee the joint existence of urban non-exporters and urban exporters. The former condition means that f_{ex} must be large relative to $w^u f^u$. The second condition imposes that f_{ex} be relatively small with respect to $w^r f^r - w^u f^u$ for given values of τ, w^u, and w^r. Hence, case (a) is likely to arise when the fixed cost of exporting remains relatively small compared with the difference between the fixed operating cost in the rural region and that in the urban region.

[14] Using the domestic revenue and profit expressions (19) and (21) we can rewrite $\pi_d^u(\theta^*) = 0$ as $R(\rho P)^{\sigma-1}/\sigma = w^u f^u (w^u)^{\sigma-1}/(\theta^*)^{\sigma-1}$. In addition, $\pi_f^u(\theta_{ex}) = 0 \Leftrightarrow (\theta_{ex})^{\sigma-1} = f_{ex}(\tau w^u)^{\sigma-1}(R(\rho P)^{\sigma-1}/\sigma)^{-1}$ (utilizing the export revenue and profit expressions (20) and (21)). Substituting the expression for $R(\rho P)^{\sigma-1}/\sigma$ into that of $(\theta_{ex})^{\sigma-1}$ and solving for θ_{ex} yields the expression in (24).

4.2.2 Case (b): urban non-exporters, rural non-exporters, and rural exporters

The relationship between θ^* and $\theta_{u,r}$ is the same as that in the closed economy, that is, $\theta_{u,r} = \alpha\theta^*$, where α is defined in (9). The relationship between θ^* and θ_{ex} is derived by substituting the zero cutoff profit condition, $\pi_d^u(\theta^*) = 0$, into the export cutoff profit condition appropriate for case (b), $\pi_f^r(\theta_{ex}) = 0$, and solving for θ_{ex} as a function of θ^*[15]:

$$\theta_{ex} = \beta\theta^*, \text{ where } \beta \equiv \tau\frac{w^r}{w^u}\left(\frac{f_{ex}}{w^u f^u}\right)^{1/\sigma-1} \tag{26}$$

The conditions $\alpha > 1$ and $\beta/\alpha > 1$ together guarantee the joint existence of urban and rural non-exporters. The latter condition says that, unlike case (a), f_{ex} must be large relative to $w^r f^r - w^u f^u$ for given values of τ, w^u, and w^r. Thus, case (b) is likely to arise when the fixed cost of exporting is relatively large compared with the additional fixed cost of producing in the rural region over that of operating in the urban region. This difference with case (a) is illustrated in figures 2 and 3.

4.3 The open economy equilibrium—case (a): urban non-exporters, urban exporters, and rural exporters

4.3.1 Price index and average productivities

The distribution of incumbent firms' productivity levels in equilibrium, μ, is defined as in (10). The probabilities that firms entering the industry and locating in the urban and rural regions will export are $q_{ex}^u = [G(\theta_{u,r}) - G(\theta_{ex})]/[G(\theta_{u,r}) - G(\theta^*)]$ and $q_{ex}^r = 1$, respectively. The mass of exporting firms in regions u and r amount to $M_f^u = q_{ex}^u M^u$ and $M_f^r = M^r$, respectively.[16] As per (3), the price index is

$$P = \left[\int_0^{\theta_{u,r}} p_d^u(\theta)^{1-\sigma} M\mu(\theta)d\theta + \int_{\theta_{ex}}^{\theta_{u,r}} p_f^u(\theta)^{1-\sigma} M\mu(\theta)d\theta\right.$$

[15] $\pi_f^r(\theta_{ex}) = 0 \Leftrightarrow (\theta_{ex})^{\sigma-1} = f_{ex}(\tau w^r)^{\sigma-1}(R(\rho P)^{\sigma-1}/\sigma)^{-1}$ (using the export revenue and profit expressions (20) and (21)). Substituting the same expression of $R(\rho P)^{\sigma-1}/\sigma$ as in case (a) into that of $(\theta_{ex})^{\sigma-1}$ and solving for θ_{ex} yields the expression in (26).

[16] The mass of varieties sold in any country, originating from its own producers and from abroad, is given by $M' = M + M_f^u + M_f^r$.

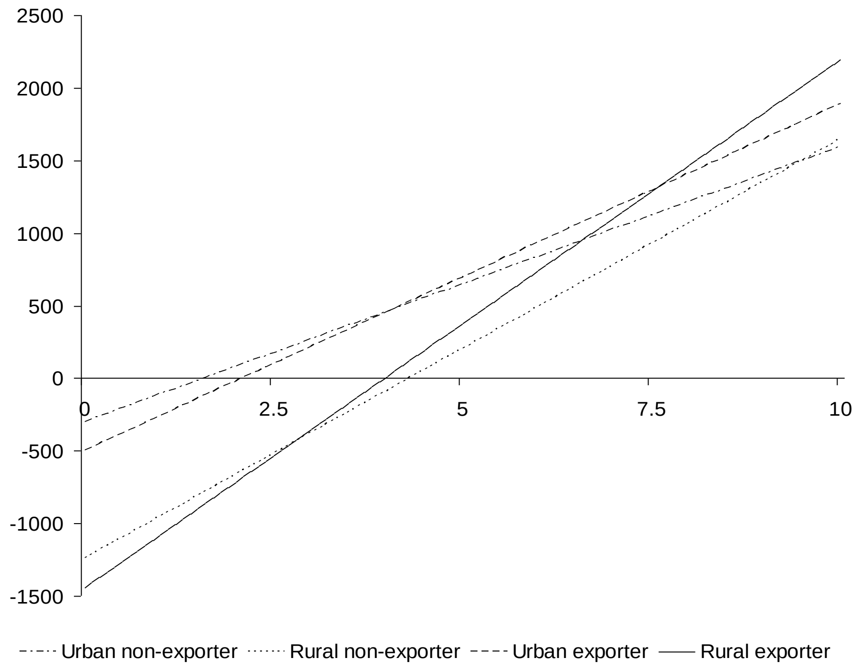

Figure 2: Case (a): Urban Non-Exporters, Urban Exporters, Rural Exporters

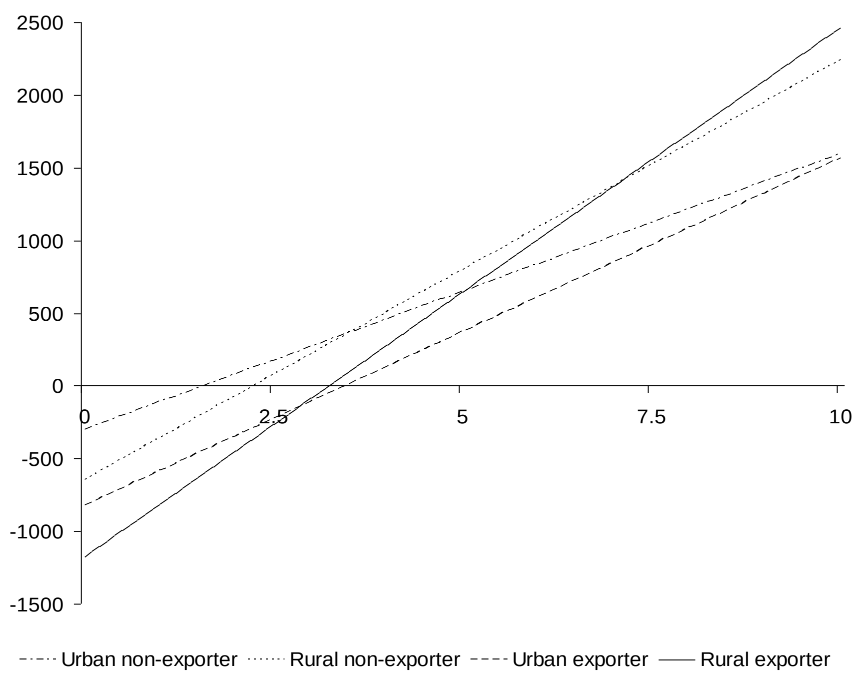

Figure 3: Case (b): Urban Non-Exporters, Rural Non-Exporters, Rural Exporters

$$+\int_{\theta_{u,r}}^{\infty} p_d^r(\theta)^{1-\sigma} M\mu(\theta)d\theta + \int_{\theta_{u,r}}^{\infty} p_f^r(\theta)^{1-\sigma} M\mu(\theta)d\theta\Bigg]^{1/(1-\sigma)}.$$

Like in the closed-economy case, the price index can be rewritten as a function of average productivities:

$$(27)\quad P = M^{1/(1-\sigma)}\Bigg[s^u\left(p_d^u(\tilde{\theta^u}(\theta^*,\theta_{u,r}))^{1-\sigma} + q_{ex}^u p_f^u(\tilde{\theta^u}(\theta_{ex},\theta_{u,r}))^{1-\sigma}\right)$$
$$+ s^r\left(p_d^r(\tilde{\theta^r}(\theta_{u,r}))^{1-\sigma} + p_f^r(\tilde{\theta^r}(\theta_{u,r}))^{1-\sigma}\right)\Bigg]^{1/(1-\sigma)}$$

where $\tilde{\theta^u}$ and $\tilde{\theta^r}$ are defined as in (12) and (13), respectively. Note that, while $\tilde{\theta^u}(\theta^*,\theta_{u,r})$ is the average productivity over the population of domestic urban firms, $\tilde{\theta^u}(\theta_{ex},\theta_{u,r})$ is the average productivity of domestic urban exporters alone.

4.3.2 Equilibrium conditions and determination

The average revenue of urban firms received from domestic sales can be expressed as $r_d^u(\tilde{\theta^u}(\theta^*,\theta_{u,r})) = r_d^u(\theta^*)(\tilde{\theta^u}(\theta^*,\theta_{u,r})/\theta^*)^{\sigma-1}$. Like in the closed economy case, one can substitute the expression for $r_d^u(\tilde{\theta^u}(\theta^*,\theta_{u,r}))$ into the domestic profit function defined in (21) to obtain the average domestic profit level over all urban firms:

$$\bar{\pi}_d^u(\theta^*,\theta_{u,r}) = \frac{r_d^u(\theta^*)}{\sigma}\left(\frac{\tilde{\theta^u}(\theta^*,\theta_{u,r})}{\theta^*}\right)^{\sigma-1} - w^u f^u$$

The zero cutoff profit condition, $\pi_d^u(\theta^*) = 0$, which entails $r_d^u(\theta^*) = \sigma w^u f^u$, is thus equivalent to the following relationship between the average urban domestic profit and θ^*:

$$\bar{\pi}_d^u(\theta^*,\theta_{u,r}) = w^u f^u\left[\left(\frac{\tilde{\theta^u}(\theta^*,\theta_{u,r})}{\theta^*}\right)^{\sigma-1} - 1\right]$$

where $\theta_{u,r}$ is a function of θ^* as in (25). Similarly, the average revenue of urban exporting firms received from foreign sales is given by $r_f^u(\tilde{\theta^u}(\theta_{ex},\theta_{u,r})) = r_f^u(\theta_{ex})(\tilde{\theta^u}(\theta_{ex},\theta_{u,r})/\theta_{ex})^{\sigma-1}$. By substituting the expression for $r_f^u(\tilde{\theta^u}(\theta_{ex},\theta_{u,r}))$ into the export profit function defined in (21), one obtains the average export profit level of all urban exporters:

$$\bar{\pi}_f^u(\theta_{ex},\theta_{u,r}) = \frac{r_f^u(\theta_{ex})}{\sigma}\left(\frac{\tilde{\theta^u}(\theta_{ex},\theta_{u,r})}{\theta_{ex}}\right)^{\sigma-1} - f_{ex}$$

Then, the export cutoff profit condition, $\pi_f^u(\theta_{ex}) = 0$, that is, $r_f^u(\theta_{ex}) = \sigma f_{ex}$, implies the following implicit relationship between the average urban export profit and θ^*:

$$\bar{\pi}_f^u(\theta_{ex}, \theta_{u,r}) = f_{ex}\left[\left(\frac{\tilde{\theta}^u(\theta_{ex}, \theta_{u,r})}{\theta_{ex}}\right)^{\sigma-1} - 1\right]$$

where θ_{ex} is a function of θ^* as in (24). Given that q_{ex}^u is the fraction of exporters among urban firms, the average profit over all urban firms is

(28)

$$\bar{\pi}^u(\theta^*, \theta_{ex}, \theta_{u,r}) = w^u f^u\left[\left(\frac{\tilde{\theta}^u(\theta^*, \theta_{u,r})}{\theta^*}\right)^{\sigma-1} - 1\right] + q_{ex}^u f_{ex}\left[\left(\frac{\tilde{\theta}^u(\theta_{ex}, \theta_{u,r})}{\theta_{ex}}\right)^{\sigma-1} - 1\right]$$

The above equation is the zero cutoff profit condition for urban firms in the open economy.

The cutoff profit condition for rural firms (see appendix B.1 for its derivation) also relates the average profit over all rural firms to θ^*:

$$\begin{aligned}(29)\quad \bar{\pi}^r(\theta^*, \theta_{ex}, \theta_{u,r}) = w^u f^u &\left[\left(\frac{\tilde{\theta}^r(\theta_{u,r})}{\theta^*}\right)^{\sigma-1} - \left(\frac{\tilde{\theta}^r(\theta_{u,r})}{\theta_{u,r}}\right)^{\sigma-1}\right] \\ &+ w^r f^r\left[\left(\frac{\tilde{\theta}^r(\theta_{u,r})}{\theta_{u,r}}\right)^{\sigma-1} - 1\right] + f_{ex}\left[\left(\frac{\tilde{\theta}^r(\theta_{u,r})}{\theta_{ex}}\right)^{\sigma-1} - 1\right]\end{aligned}$$

Again, the net expected value of entry is $v_e(\theta^*, \theta_{u,r}) = [G(\theta_{u,r}) - G(\theta^*)]\bar{\pi}^u/\delta + [1 - G(\theta_{u,r})]\bar{\pi}^r/\delta - f_e$. The free entry condition, that is, $v_e(\theta^*, \theta_{u,r}) = 0$, holds if and only if

$$(30)\qquad [G(\theta_{u,r}) - G(\theta^*)]\,\bar{\pi}^u + [1 - G(\theta_{u,r})]\,\bar{\pi}^r = \delta f_e$$

Equations (28), (29), and (30) define the open-economy equilibrium conditions. We show in appendix B.2 that these three conditions determine a unique equilibrium $(\theta^*, \bar{\pi}^u, \bar{\pi}^r)$. Furthermore, the equilibrium zero cutoff productivity level determines, according to (24) and (25), a unique export cutoff level, θ_{ex}, and a unique urban-rural cutoff level, $\theta_{u,r}$, respectively.

Similarly to the closed economy, the mass of firms in region m is determined by the average revenue in the region:

$$(31)\qquad M^m = \frac{R^m}{\bar{r}^m} = \frac{w^m L^m + \Pi^m}{\sigma\left(\bar{\pi}^m + w^m f^m + q_{ex}^m f_{ex}\right)}$$

where Π^m is the sum of aggregate domestic and foreign profits of firms in region m and q_{ex}^m is the probability of exporting conditional on entry in m, which is equal to one for rural firms.

4.4 The open economy equilibrium—case (b): urban non-exporters, rural non-exporters, and rural exporters

4.4.1 Price index and average productivities

We now consider the case in which we observe urban non-exporters, rural non-exporters, and rural exporters. The probabilities that firms will export, conditional on their entry and location in the urban and rural regions, are $q_{ex}^u = 0$ and $q_{ex}^r = [1 - G(\theta_{ex})]/[1 - G(\theta_{u,r})]$, respectively. The masses of exporting firms are zero in region u and $M_f^r = q_{ex}^r M^r$ in region r.[17] The price index is

$$P = \left[\int_0^{\theta_{u,r}} p_d^u(\theta)^{1-\sigma} M\mu(\theta)d\theta + \int_{\theta_{u,r}}^{\infty} p_d^r(\theta)^{1-\sigma} M\mu(\theta)d\theta + \int_{\theta_{ex}}^{\infty} p_f^r(\theta)^{1-\sigma} M\mu(\theta)d\theta \right]^{1/(1-\sigma)}.$$

Furthermore, we can express the price index as a function of average productivities:

(32)
$$P = M^{1/(1-\sigma)} \left[s^u p_d^u(\tilde{\theta^u}(\theta^*, \theta_{u,r}))^{1-\sigma} + s^r \left(p_d^r(\tilde{\theta^r}(\theta_{u,r}))^{1-\sigma} + q_{ex}^r p_f^r(\tilde{\theta^r}(\theta_{ex}))^{1-\sigma} \right) \right]^{1/(1-\sigma)}$$

where $\tilde{\theta^r}(\theta_{ex})$ is the average productivity of domestic rural exporters alone.

4.4.2 Equilibrium conditions and determination

Since none of the urban firms exports, the zero cutoff profit condition for urban firms is expressed as in (15):

$$\bar{\pi}^u(\theta^*, \theta_{u,r}) = w^u f^u \left[\left(\frac{\tilde{\theta^u}(\theta^*, \theta_{u,r})}{\theta^*} \right)^{\sigma-1} - 1 \right] \quad (33)$$

[17] The mass of varieties sold in any country equals $M' = M + M_f^r$.

where $\theta_{u,r}$ is a function of θ^* as in (9). The cutoff profit condition for rural firms (see appendix C.1) is given by:

$$(34) \quad \bar{\pi}^r(\theta^*, \theta_{u,r}, \theta_{ex}) = w^u f^u \left[\left(\frac{\tilde{\theta^r}(\theta_{u,r})}{\theta^*} \right)^{\sigma-1} - \left(\frac{\tilde{\theta^r}(\theta_{u,r})}{\theta_{u,r}} \right)^{\sigma-1} \right] + w^r f^r \left[\left(\frac{\tilde{\theta^r}(\theta_{u,r})}{\theta_{u,r}} \right)^{\sigma-1} - 1 \right] + q^r_{ex} f_{ex} \left[\left(\frac{\tilde{\theta^r}(\theta_{ex})}{\theta_{ex}} \right)^{\sigma-1} - 1 \right]$$

The expression of the net expected value of entry is the same as in case (a), and thus, the free entry condition is identical to (30). The latter condition together with (33) and (34) characterize the open economy equilibrium in case (b). The existence and uniqueness of the equilibrium $(\theta^*, \bar{\pi}^u, \bar{\pi}^r)$ is established in appendix C.2. The equilibrium zero cutoff productivity level θ^*, in turn, identifies unique urban-rural and export cutoff levels according to (9) and (26).

The expression of the mass of firms in region m is the same as in (31) except that in case (b) $q^u_{ex} = 0$ since no urban firm exports and $0 < q^r_{ex} < 1$.

5 The Impact of Trade Liberalization

In this section, we make use of the model to get a theoretical answer to our initial query: how does an expansion of trade opportunities affect the geographic location of industries within a country? Our analysis considers a decrease in the variable trade cost as the source of growth in trade opportunities. We investigate the impact of a change in the iceberg trade cost on the distribution of firms in a particular industry between the urban and rural locations by performing comparative statics in the open economy with respect to τ, and comparing two steady-state equilibria. We will use the prime symbol to denote the variables in the new equilibrium, after a change in τ.

Case (a)—urban non-exporters, urban exporters, and rural exporters: As shown in appendix D.1, a decrease in the variable trade cost from τ to τ' entails an increase in the zero cutoff productivity level, from θ^* up to $\theta^{*\prime}$. As a result, the least productive urban firms are driven out of the industry. This decrease in τ also results in a downward shift in the export cutoff productivity level, from θ_{ex} down to θ'_{ex}, which induces the most productive urban non-exporters to enter the export market. Moreover, the decrease in the iceberg trade cost causes the urban-rural cutoff productivity level to fall, from $\theta_{u,r}$ to $\theta'_{u,r}$, which gives an incentive to the most productive urban firms to relocate to the rural region.

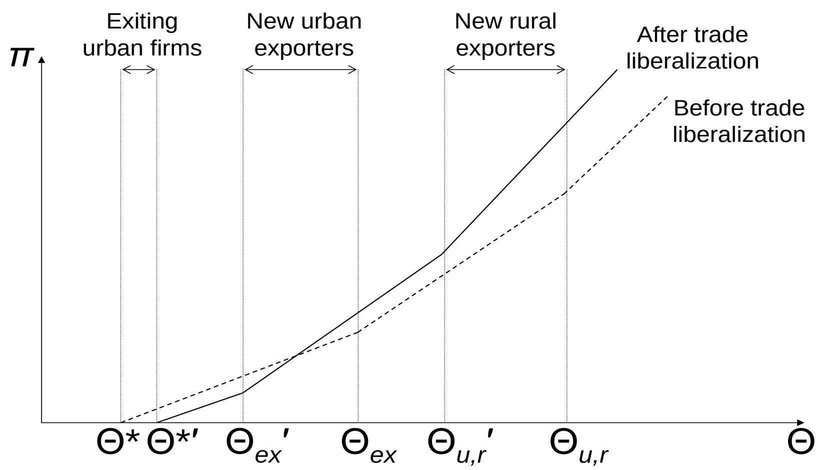

Figure 4: Relocation of Firms and Reallocation of Profits—Case (a)

Case (b)—urban non-exporters, rural non-exporters, and rural exporters: Again, a decrease in τ leads to an increase in θ^*, which compels the least productive urban firms to exit the industry. In contrast to case (a), the upward shift in θ^* results in an increase in the urban-rural cutoff productivity level $\theta_{u,r}$. Consequently, the least productive rural non-exporters are forced to relocate to the urban area. θ_{ex} goes down like in case (a), and that shift induces the most productive rural non-exporters to enter the foreign market. Figures 4 and 5 depict the shifts in the cutoff productivity levels in cases (a) and (b), respectively.

A decrease in the variable trade cost impinges firms' choice of location and export status. Concomitantly, it affects the revenues and profits of firms with different productivity levels in different ways (see appendices D.2 and D.3). In both cases (a) and (b), every firm incurs a loss of revenue from its domestic sales since the varieties sold

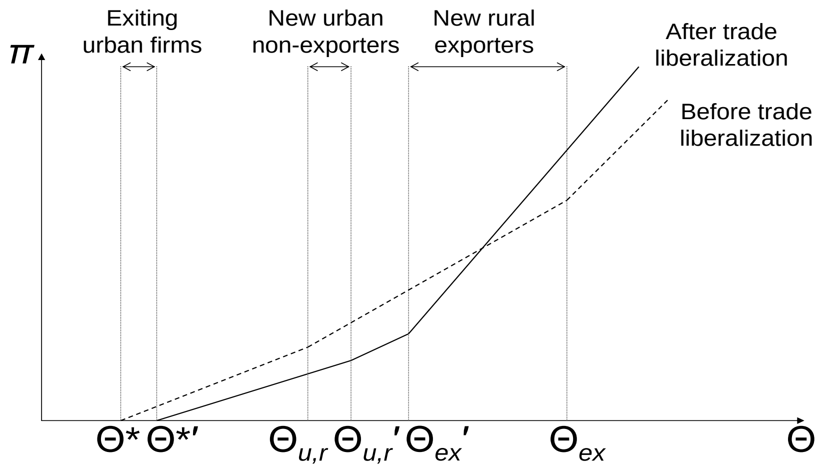

Figure 5: Relocation of Firms and Reallocation of Profits—Case (b)

in the domestic market by foreign exporters capture a share of the market away from domestic firms. Thus, the urban non-exporters remaining in the industry and the rural non-exporters accrue smaller profits in the new equilibrium. In contrast, every exporter, whether it is urban or rural, enjoys an increase in its export and total revenues. In case (a), as trade opportunities grow, the urban firms with lower productivity levels than those urban firms already exporting in the old equilibrium become able to set a sufficiently low price for their varieties. Consequently, they grab a share of the export market and generate enough revenue to finance the fixed cost of exporting. However, not every new urban exporter earns greater profits as in the old equilibrium. Although the revenues (and variable profits) of the least productive firms among the new urban exporters are greater in the new equilibrium, their profits shifted downward in comparison with the old equilibrium because they must now incur the fixed cost of exporting. The urban firms that exported in the initial equilibrium garner additional revenues and profits. The exporters moving from the urban region to the rural region accrue even bigger profits, because they now have a lower marginal cost. The expansion of trade opportunities following a decrease in τ allows the high-productivity urban exporters to sell more units of output into the foreign market. The growth in their output creates an incentive to pay the higher fixed cost of operating in the rural location to reduce the marginal cost of producing more units of output. This mechanism explains how a fall in τ leads to a downward shift in the urban-rural cutoff productivity level in case (a). In the new equilibrium, the rural firms, that were already exporters prior to the change in τ, also receive higher profits.

In case (b), the decline in τ causes the domestic market share of the low-productivity rural non-exporters to shrink, and thus, constrains them to produce smaller quantities. The contraction in their output acts as an incentive to relocate to the urban region and pay the lower fixed cost of operating there since less can be saved on variable costs if producing in the rural region. Hence, $\theta_{u,r}$ shifts up. The least productive firms among the new rural exporters receive greater revenues but earn less profits in comparison with the prior equilibrium. Unlike the latter, the rural firms that exported prior to the decrease in τ receive higher profits in the new equilibrium.

Furthermore, the exit of the least productive urban firms, the entry of some urban firms into the export market and the relocation of some urban exporters from the high-marginal-cost region to the low-marginal-cost region (in case (a)), and the entry of some rural firms into the foreign market and the relocation of rural non-exporters to the urban location (in case (b)), induce reallocations of market shares and profits from less productive firms to the more productive manufacturers.[18]

The above discussion underlines the difference betwen cases (a) and (b) regarding the relationships between the movement of firms and the reallocation of market shares between the urban and rural locations. For a more formal description of this difference, let $\varsigma^u \equiv R^u/R$ be the market share of all urban firms; since $R^u = M^u\bar{r}^u$ and $R = M\bar{r}$, where $\bar{r}$ is the average revenue of all firms, ς^u can be rewritten as $s^u\varrho^u$, where $s^u \equiv M^u/M$ and $\varrho^u \equiv \bar{r}^u/\bar{r}$. Thus, differentiating ς^u with respect to τ yields

$$\frac{\partial\varsigma^u}{\partial\tau} = \frac{\partial s^u}{\partial\tau}\varrho^u + s^u\frac{\partial\varrho^u}{\partial\tau} \tag{35}$$

The above equation shows that two factors contribute to the change in the urban market

[18]The predictions of our model are consistent with the outcome of the Melitz (2003) model that following a decrease in the iceberg trade cost, the least productive firms are forced to exit the industry and market shares are reallocated from less productive to more productive firms. Although we do not provide a formal proof of this proposition, the reallocation of output across firms also generates aggregate productivity gains in both regions and in the industry as a whole.

share following a change in the iceberg trade cost. The first factor is the change in the spatial distribution of firms. The second one reflects the change in the size of the typical urban firm relative to the average firm. Under case (a), both terms of the derivative in (35) are negative. As τ decreases, θ^* goes up and $\theta_{u,r}$ goes down, which implies that the mass of urban firms falls relative to the mass of rural firms, and thus, relative to the mass of all firms: $\partial s^u/\partial\tau < 0$. Since the revenue of urban non-exporters decreases, the average revenue of urban firms declines relative to the average rural revenue, and thus, relative to the average revenue. Hence, $\partial\varrho^u/\partial\tau < 0$. Under case (b), the average urban revenue also falls relative to the average revenue. However, the sign of $\partial s^u/\partial\tau$ is ambiguous since both θ^* and $\theta_{u,r}$ shift up. Whether the share of urban firms increases or decreases ultimately depends on the shape of the productivity distribution, and, therefore, the question can only be answered empirically. In summary, a decrease in τ leads to an unambiguous reallocation of market shares from the urban region to the rural region in case (a). In case (b), the reallocation of market shares occurs in the same direction provided that the increase in the fraction of urban firms is relatively smaller than their decline in relative average size. In conclusion, the theoretical predictions from cases (a) and (b) (depending on the circumstances for the latter case) are consistent with the anecdotal evidence that a greater exposure to international trade was associated with the geographic dispersal of manufacturing firms and production away from urban cores in some emerging countries like Mexico (see Hanson (1998)) and Argentina (see Sanguinetti and Martincus (2005)), or away from industrial clusters as in Japan for instance (Tomiura (2003)).

6 The Impact of Trade Liberalization on the Location of Colombian Industries

In the open-economy model presented above, a decline in the iceberg trade cost shifts the cutoff productivity levels, which induces changes in geographical distribution of firms in a given industry. In particular, one would expect that, *ceteris paribus*, a fall in the variable trade costs leads to within-industry reallocations of firms and production from the metropolitan areas of a country towards the less urbanized regions. In this section, we estimate the impact of trade liberalization, measured by the changes in Colombian tariffs, on the distribution of plants and production across metropolitan and non-metropolitan regions in the country. The econometric results obtained entail that a change in tariffs had a negative impact on within-industry change in the shares of metropolitan plants and production in Colombia between 1984 and 1991.

6.1 Data and empirical approach

Colombia is a country that is large enough to have a significant degree of heterogeneity in the distribution of economic activities across regions, as well as in the price of factors across regions. In addition, this country underwent a trade liberalization episode during a short period of time. Thus, the recent history of Colombia offers a natural experiment to test for the predictions of our model about the effects of trade liberalization on the geographic location of industries within a country. Again, we use plant-level data from the annual census of the Colombian manufacturing sector. Our assessment of the impact of trade liberalization on the location pattern of industries in Colombia is based on the observed changes in the distribution of manufacturing plants and production across metropolitan and non-metropolitan regions. The first outcome variable we use to measure these changes is the change in the fraction (that is, share) of plants located in metropolitan areas between 1984 and 1991, at the 4-digit industry level. The second variable is the change in the share of production originating from plants located in metropolitan areas between 1984 and 1991, at the 4-digit industry level. We perform a cross-industry regression analysis where either of the changes in metro shares is regressed on the change in the 4-digit level industry tariffs over the period 1983-1990. Since the conditional expectation function of the outcome variable may also depend on the factor intensities of manufacturing industries, and because metro and non-metro regions are likely to have different relative factor endowments, we control for the factor shares in the base year. For that purpose, we use the cost shares of labor, capital, energy consumption, and materials. The total cost of production also includes other industrial and general expenditures. The regression equations are specified as follows:

$$\Delta s^{u,i}_{84-91} = \beta_0 + \sum_i \beta^i_1 + \beta_2 \Delta \tau^i_{83-90} + \beta_3 \lambda^i_{l,84} + \beta_4 \lambda^i_{e,84} + \beta_5 \lambda^i_{k,84} + \beta_6 \lambda^i_{m,84} + \epsilon_i$$

where $\Delta s^{u,i}_{84-91}$ denotes the change in the share of metro plants, or, alternatively the change in the share of metro production, from industry i between 1984 and 1991; β_0 is the intercept; the β^i_1's are the two-digit industry level dummy variables; $\Delta\tau^i_{83-90}$ is the change in industry i's tariff between 1983 and 1990[19]; $\lambda^i_{l,84}$, $\lambda^i_{e,84}$, $\lambda^i_{k,84}$ and $\lambda^i_{m,84}$ are the labor, energy, capital and materials cost shares in 1984, respectively; ϵ_i is the error term. We chose 1984 as a base year because the average tariffs were at their highest level and this was also the last year of the temporary surge in trade protection in the 1980's. The year 1991 is retained because it marks the end of the period of trade policy liberalization, and also because it is the last year for which data is available. One limitation of the 1984-1991 time frame is that the 1984 dataset excludes plants with less than ten employees, whereas these plants are included in the 1991 dataset. To address this inconsistency in the data, we also perform the analysis for the period 1985-1991 using the tariffs change between 1984 and 1990.

Our approach differs from that of previous empirical studies such as Hanson (1998), Tomiura (2003), Rodríguez-Pose and Sánchez-Reaza (2003), and Sanguinetti and Martincus (2005) since it conducts an industry-level analysis using first differences in the outcome variable and the policy variable. In addition, unlike these studies, which rely on measures of growth in manufacturing employment or GDP, our dependent variables measure the exact changes in the regional distribution of plants and production.

6.2 Regression results

The regression results are reported in tables 3 and 4. The dependent variable is the change in the share of metro plants in specifications one and two, while it is the change in the share of metro production in specifications three and four. In specification (1), the coefficient estimate of the change in tariffs is positive but not significant. Specification (2) includes the factor share variables as controls. In this regression, only the capital share has significant coefficient estimate (at the 1 percent level). In specification (3), the coefficient on the tariff change is positive and significant at the 10 percent level. According to this regression, a 10 percentage point decline in tariffs is estimated to entail a 1.6 percentage point decline in the share of metropolitan production, on average, over

[19]We follow previous studies such as Fernandes (2007) in using the tariffs lagged one year to correct for endogeneity bias (firms can lobby the government to change a tariff in their own interest).

all industries. Specification (4) leads to a similar conclusion since the tariff coefficient estimate is positive although it is not significant at the conventional levels but it is significant at 12.8 percent. Moreover, the coefficient estimates for the labor, materials and capital shares are positive and statistically significant at least at the five percent level.

We check for the robustness of these results by re-estimating the same regression models for the years 1985 and 1991. The data for 1985 include plants with less than ten employees, which were omitted in the previous analysis because they were not reported in 1984. The regression results are provided in table 4. The estimation of specification (1) yields qualitatively similar results. For specification (2), the magnitude of the coefficient estimates are slightly different but the standard errors are smaller. In addition, the coefficient estimate for the labor share becomes significant at the ten percent level. The estimate for the change-in-tariff variable is positive and statistically significant at the ten percent level in both specifications (3) and (4). The estimation of (3) suggests that a ten percentage point decrease in tariff between 1984 and 1990 induces a 1.2 percentage point increase in the share of non-metro plants production between 1985 and 1991. Similarly, according to specification (4), a ten percentage point decline in tariff between 1984 and 1990 induces a 1.1 percentage point increase in the share of non-metro plants production between 1985 and 1991. The factor shares estimates have similar magnitudes but smaller standard errors. In addition, the energy share estimate is now significant at the five percent level, whereas the materials share estimate is no longer significant at the conventional levels. The empirical evidence confirms the prediction of the model that trade liberalization, that is, a decline in tariffs, induces plants relocation from metropolitan areas to non-metropolitan regions.

7 Conclusion

This paper presented a novel way of thinking about the link between international trade and the pattern of manufacturing firms' location in the absence of factor-price equalization across regions within a country. The model we developed applies well to the context of an emerging country in which wages and other input prices are higher in predominantly urban areas compared with those in rural areas. We extended the Melitz model by adding two locations with different factor prices and fixed costs of production. The urban region had a relatively high factor price compared with the rural region. This hypothesis reflects the fact that, in general, wages are higher in large cities. Unlike the factor price, the fixed operating cost was lower in the urban region. Urbanized areas benefit from agglomeration externalities, thick-market effects, and the strong presence of businesses offering services to industries reducing transactions costs that may not vary with the volume of production. Our model predicted that the more productive firms locate in the rural region where the fixed cost is higher and the factor price (that is, the marginal cost) lower. We investigated empirically whether metropolitan and non-metropolitan plants are different in terms of their total and factor-specific productivities using data on the Colombian manufacturing industries for the period 1981-1984. Our results indicated that metro and non-metro plants have different productivities. In particular, non-metro plants were found to be more productive with respect to labor and energy, whereas metro plants had higher productivities of capital and materials.

In the open economy setup, firms faced an additional choice besides that of location: they had to choose whether to export or not. Like in Melitz (2003), we found that the more productive firms become exporters, capture a larger share of the domestic market, and earn higher profits. A decline in the bilateral variable trade cost gives incentives to exporters to expand their production to serve the foreign market; on the other hand, it induces some firms to enter the export market. It also forces the least productive non-exporting firms located in the region with the higher marginal cost of production to exit the industry. Under some conditions, the enhancement of export opportunities allows the most productive urban firms to generate more revenue, allowing them to bear the extra fixed cost of producing in the low-factor-price rural region. Thus, our model predicts that trade liberalization raises the share of firms located in the low-factor-price region. In general, market shares and profits are reallocated from the less productive firms, predominantly located in the urban region, to the more productive ones, primarily located in the rural region. Thus, our model predicted that trade liberalization induces a reallocation of market shares from the urban region to the rural region. Eventually, we estimated the impact of a change in tariffs on the distribution of plants and production across metropolitan and non-metropolitan regions in Colombia. We obtain significant statistical evidence that the decrease in tariffs had a negative impact on the within-industry shares of metropolitan plants and production in Colombia between 1984 and 1991.

Our findings suggest that trade may benefit less developed regions where labor earnings are lower than in cities. Our methodology could be applied to other countries that underwent episodes of trade liberalization during the late twentieth century. A better assessment of the role trade plays in providing economic opportunities to predominantly rural areas would help policy-makers to determine appropriate rural development policies.

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A Appendix: Closed Economy Equilibrium

A.1 Derivation of the average rural profit

The equality $r^u(\theta_{u,r})/r^u(\theta^*) = (\theta_{u,r}/\theta^*)^{\sigma-1}$ (see (14)) and the zero cutoff profit condition, $\pi^u(\theta^*) = 0$, together entail $r^u(\theta_{u,r}) = \sigma w^u f^u (\theta_{u,r}/\theta^*)^{\sigma-1}$. In addition, the urban-rural cutoff profit condition, $\pi^u(\theta_{u,r}) = \pi^r(\theta_{u,r})$, can be rewritten as $r^r(\theta_{u,r}) = r^u(\theta_{u,r}) + \sigma(w^r f^r - w^u f^u)$. Substituting the expression of $r^u(\theta_{u,r})$ into the latter equation gives

$$r^r(\theta_{u,r}) = \sigma \left[w^u f^u \left[\left(\frac{\theta_{u,r}}{\theta^*} \right)^{\sigma-1} - 1 \right] + w^r f^r \right]$$

By analogy to the derivation of the average urban profit, the average rural profit is given by (using (6) and (14)) $\pi^r(\tilde{\theta^r}(\theta_{u,r})) = [\tilde{\theta^r}(\theta_{u,r})/\theta_{u,r}]^{\sigma-1} r^r(\theta_{u,r})/\sigma - w^r f^r$. Substituting the expression of $r^r(\theta_{u,r})$ into that of $\pi^r(\tilde{\theta^r}(\theta_{u,r}))$ yields

$$\pi^r(\tilde{\theta^r}(\theta_{u,r})) = w^u f^u \left[\left(\frac{\tilde{\theta^r}(\theta_{u,r})}{\theta^*} \right)^{\sigma-1} - \left(\frac{\tilde{\theta^r}(\theta_{u,r})}{\theta_{u,r}} \right)^{\sigma-1} \right] + w^r f^r \left[\left(\frac{\tilde{\theta^r}(\theta_{u,r})}{\theta_{u,r}} \right)^{\sigma-1} - 1 \right]$$

A.2 Existence and uniqueness of the equilibrium zero cutoff productivity level

We show that the zero cutoff profit condition (15), the urban-rural cutoff profit condition (16), and the free entry condition (17) determine a unique cutoff productivity level θ^*. To do so, we prove that there is a unique value of θ, θ^*, that satisfies the equilibrium condition

$$[G(\alpha\theta) - G(\theta)]\, \bar{\pi}^u(\theta, \alpha\theta) + [1 - G(\alpha\theta)]\, \bar{\pi}^r(\theta, \alpha\theta) = \delta f_e \tag{36}$$

where $\bar{\pi}^u(\theta, \alpha\theta) = w^u f^u k^u(\theta, \alpha\theta)$ and $\bar{\pi}^r(\theta, \alpha\theta) = w^u f^u k_1^r(\theta, \alpha\theta) + w^r f^r k_2^r(\alpha\theta)$;
$k^u(\theta, \alpha\theta) = [\tilde{\theta^u}(\theta, \alpha\theta)/\theta]^{\sigma-1} - 1$, $k_1^r(\theta, \alpha\theta) = [\tilde{\theta^r}(\alpha\theta)/\theta]^{\sigma-1} - [\tilde{\theta^r}(\alpha\theta)/\alpha\theta]^{\sigma-1}$, and $k_2^r(\alpha\theta) = [\tilde{\theta^r}(\alpha\theta)/\alpha\theta]^{\sigma-1} - 1$; $\tilde{\theta^u}(\theta, \alpha\theta) = \left[[1/(G(\alpha\theta) - G(\theta))] \int_\theta^{\alpha\theta} \xi^{\sigma-1} g(\xi) d\xi \right]^{1/(\sigma-1)}$ and $\tilde{\theta^r}(\alpha\theta) = \left[[1/(1 - G(\alpha\theta))] \int_{\alpha\theta}^{\infty} \xi^{\sigma-1} g(\xi) d\xi \right]^{1/(\sigma-1)}$. A sufficient condition for the existence and uniqueness of the solution is that the left-hand side of equation (36) be monotonically decreasing on $(0, \infty)$, tending towards infinity for values of θ near zero, and approaching zero for infinitely large values of θ.

The derivatives of k^u, k_1^r, and k_2^r with respect to θ (denoted $(k^u)'$, $(k_1^r)'$, and $(k_2^r)'$, respectively) are given by:

$$\begin{aligned}
(k^u)'(\theta,\alpha\theta) &= \frac{\alpha^\sigma g(\alpha\theta)-g(\theta)}{G(\alpha\theta)-G(\theta)} - [k^u(\theta,\alpha\theta)+1]\left[\frac{\alpha g(\alpha\theta)-g(\theta)}{G(\alpha\theta)-G(\theta)}+\frac{\sigma-1}{\theta}\right]\\
(k_1^r)'(\theta,\alpha\theta) &= -(\alpha^{\sigma-1}-1)\frac{\alpha g(\alpha\theta)}{1-G(\alpha\theta)} + k_1^r(\theta,\alpha\theta)\left[\frac{\alpha g(\alpha\theta)}{1-G(\alpha\theta)}-\frac{\sigma-1}{\theta}\right]\\
(k_2^r)'(\alpha\theta) &= -\frac{\alpha g(\alpha\theta)}{1-G(\alpha\theta)} + [k_2^r(\alpha\theta)+1]\left[\frac{\alpha g(\alpha\theta)}{1-G(\alpha\theta)}-\frac{\sigma-1}{\theta}\right]
\end{aligned}$$

Let j^u and j^r denote functions of θ defined as $j^u(\theta,\alpha\theta)=[G(\alpha\theta)-G(\theta)]\bar{\pi}^u(\theta,\alpha\theta)$ and $j^r(\theta,\alpha\theta)=[1-G(\alpha\theta)]\bar{\pi}^r(\theta,\alpha\theta)$. The derivatives of j^u and j^r with respect to θ (denoted $(j^u)'$ and $(j^r)'$, respectively) are

$$\begin{aligned}
(j^u)'(\theta,\alpha\theta) &= w^u f^u \alpha g(\alpha\theta)(\alpha^{\sigma-1}-1) - [G(\alpha\theta)-G(\theta)]w^u f^u[k^u(\theta,\alpha\theta)+1]\frac{\sigma-1}{\theta}\\
(j^r)'(\theta,\alpha\theta) &= -\, w^u f^u \alpha g(\alpha\theta)(\alpha^{\sigma-1}-1)\\
&\quad - [1-G(\alpha\theta)]\big[w^u f^u k_1^r(\theta,\alpha\theta)+w^r f^r[k_2^r(\alpha\theta)+1]\big]\frac{\sigma-1}{\theta}
\end{aligned}$$

We define j as j^u+j^r. Thus, $j(\theta,\alpha\theta)$ is the left-hand side of (36). The derivative of j with respect to θ (denoted j') is given by $j'(\theta,\alpha\theta)=(j^u)'(\theta,\alpha\theta)+(j^r)'(\theta,\alpha\theta)$, that is,

$$\begin{aligned}
(37)\quad j'(\theta,\alpha\theta) = -\Big[&[G(\alpha\theta)-G(\theta)]w^u f^u[k^u(\theta,\alpha\theta)+1]\\
&+[1-G(\alpha\theta)]\big[w^u f^u k_1^r(\theta,\alpha\theta)+w^r f^r[k_2^r(\alpha\theta)+1]\big]\Big]\frac{\sigma-1}{\theta}<0
\end{aligned}$$

Thus, the elasticity of j with respect to θ is given by

$$\begin{aligned}
&\frac{j'(\theta,\alpha\theta)\theta}{j(\theta,\alpha\theta)} = -(\sigma-1)\\
&\times\frac{[G(\alpha\theta)-G(\theta)]w^u f^u[k^u(\theta,\alpha\theta)+1]+[1-G(\alpha\theta)]\big[w^u f^u k_1^r(\theta,\alpha\theta)+w^r f^r[k_2^r(\alpha\theta)+1]\big]}{[G(\alpha\theta)-G(\theta)]k^u(\theta,\alpha\theta)+[1-G(\alpha\theta)]\big[w^u f^u k_1^r(\theta,\alpha\theta)+w^r f^r k_2^r(\alpha\theta)\big]}\\
&\qquad< -(\sigma-1)
\end{aligned}$$

The elasticity of j with respect to θ is less than $-(\sigma-1)$ since the fraction on the right-hand side is greater than one; thus, it is strictly negative. Moreover, j is nonnegative. Hence, j must be falling to zero as θ goes to infinity. In addition, $\lim_{\theta\to 0}k^u(\theta)=\infty$, $\lim_{\theta\to 0}k_1^r(\theta)=\infty$, and $\lim_{\theta\to 0}k_2^r(\theta)=\infty$. Hence, we have $\lim_{\theta\to 0}j(\theta)=\infty$. Therefore, j is monotonically decreasing from infinity to zero on $(0,\infty)$.

B Appendix: Open Economy Equilibrium—Case (a)

B.1 Derivation of the average rural profit

Using the equality $r_d^u(\theta_{u,r})/r_d^u(\theta^*) = (\theta_{u,r}/\theta^*)^{\sigma-1}$ (see (14)) and the zero cutoff profit condition, $\pi_d^u(\theta^*) = 0$, one obtains $r_d^u(\theta_{u,r}) = \sigma w^u f^u (\theta_{u,r}/\theta^*)^{\sigma-1}$. Similarly, substituting the export cutoff condition, $\pi_f^u(\theta_{ex}) = 0$, into the equality $r_f^u(\theta_{u,r})/r_f^u(\theta_{ex}) = (\theta_{u,r}/\theta_{ex})^{\sigma-1}$ gives $r_f^u(\theta_{u,r}) = \sigma f_{ex}(\theta_{u,r}/\theta_{ex})^{\sigma-1}$. The urban-rural cutoff profit condition, $\pi^u(\theta_{u,r}) = \pi^r(\theta_{u,r})$, now restated as $[r_d^u(\theta_{u,r}) + r_f^u(\theta_{u,r})]/\sigma - w^u f^u = r^r(\theta_{u,r})/\sigma - w^r f^r$, after rearranging the terms entails $r^r(\theta_{u,r}) = r_d^u(\theta_{u,r}) + r_f^u(\theta_{u,r}) + \sigma(w^r f^r - w^u f^u)$. Substituting the expressions for $r_d^u(\theta_{u,r})$ and $r_f^u(\theta_{u,r})$ into the one for $r^r(\theta_{u,r})$ yields

$$r^r(\theta_{u,r}) = \sigma \left[w^u f^u \left[\left(\frac{\theta_{u,r}}{\theta^*} \right)^{\sigma-1} - 1 \right] + f_{ex} \left(\frac{\theta_{u,r}}{\theta_{ex}} \right)^{\sigma-1} + w^r f^r \right]$$

The expression of the average rural profit in the open economy is derived by substituting the expression of $r^r(\theta_{u,r})$ into this one, $\pi^r(\tilde{\theta}^r(\theta_{u,r})) = [\tilde{\theta}^r(\theta_{u,r})/\theta_{u,r}]^{\sigma-1} r^r(\theta_{u,r})/\sigma - w^r f^r - f_{ex}$, which eventually gives

$$\begin{aligned}\bar{\pi}^r(\theta^*, \theta_{ex}, \theta_{u,r}) = w^u f^u & \left[\left(\frac{\tilde{\theta}^r(\theta_{u,r})}{\theta^*} \right)^{\sigma-1} - \left(\frac{\tilde{\theta}^r(\theta_{u,r})}{\theta_{u,r}} \right)^{\sigma-1} \right] \\ & + w^r f^r \left[\left(\frac{\tilde{\theta}^r(\theta_{u,r})}{\theta_{u,r}} \right)^{\sigma-1} - 1 \right] + f_{ex} \left[\left(\frac{\tilde{\theta}^r(\theta_{u,r})}{\theta_{ex}} \right)^{\sigma-1} - 1 \right]\end{aligned}$$

B.2 Existence and uniqueness of the equilibrium cutoff productivity level

We show that the zero cutoff profit condition (28), the urban-rural cutoff profit condition (29), and the free entry condition (30) define a unique cutoff productivity level θ^* by proving that there is a unique value of θ, θ^*, satisfying the equilibrium condition

$$(38) \qquad [G(\gamma\theta) - G(\theta)]\, \bar{\pi}^u(\theta, \eta\theta, \gamma\theta) + [1 - G(\gamma\theta)]\, \bar{\pi}^r(\theta, \eta\theta, \gamma\theta) = \delta f_e$$

$$\text{where } \bar{\pi}^u(\theta, \eta\theta, \gamma\theta) = w^u f^u k^u(\theta, \gamma\theta) + \frac{G(\gamma\theta) - G(\eta\theta)}{G(\gamma\theta) - G(\theta)} f_{ex} k^u(\eta\theta, \gamma\theta)$$

$$\text{and } \bar{\pi}^r(\theta, \eta\theta, \gamma\theta) = w^u f^u k_1^r(\theta, \gamma\theta) + w^r f^r k_2^r(\gamma\theta) + f_{ex} k_3^r(\eta\theta, \gamma\theta)$$

k^u, k_1^r, k_2^r, $\tilde{\theta^u}$, and $\tilde{\theta^r}$ are defined as previously; $k_3^r(\eta\theta,\gamma\theta) = [\tilde{\theta^r}(\gamma\theta)/\eta\theta]^{\sigma-1} - 1$. A sufficient condition for the existence and uniqueness of the solution is that the left-hand side of equation (38) be monotonically decreasing on $(0,\infty)$, tending towards infinity for values of θ close to zero, and approaching zero for infinitely large values of θ.

Let j_f^u and j_f^r be functions of θ defined as $j_f^u(\eta\theta,\gamma\theta) = [G(\gamma\theta) - G(\eta\theta)]f_{ex}k^u(\eta\theta,\gamma\theta)$ and $j_f^r(\eta\theta,\gamma\theta) = [1 - G(\gamma\theta)]f_{ex}k_3^r(\eta\theta,\gamma\theta)$. The derivatives of j_f^u and j_f^r with respect to θ (denoted $(j_f^u)'$ and $(j_f^r)'$, respectively) are

$$(j_f^u)'(\eta\theta,\gamma\theta) = f_{ex}\gamma g(\gamma\theta)\left[\left(\frac{\gamma}{\eta}\right)^{\sigma-1} - 1\right] - [G(\gamma\theta) - G(\eta\theta)]f_{ex}[k^u(\eta\theta,\gamma\theta) + 1]\frac{\sigma-1}{\theta}$$
$$(j_f^r)'(\eta\theta,\gamma\theta) = -f_{ex}\gamma g(\gamma\theta)\left[\left(\frac{\gamma}{\eta}\right)^{\sigma-1} - 1\right] - [1 - G(\gamma\theta)]f_{ex}[k_3^r(\eta\theta,\gamma\theta) + 1]\frac{\sigma-1}{\theta}$$

Define j_f as $j_f^u + j_f^r$; $j(\theta,\gamma\theta) + j_f(\eta\theta,\gamma\theta)$ is the left-hand side of (38). The derivative of j_f with respect to θ (denoted j_f') is given by $j_f'(\eta\theta,\gamma\theta) = (j_f^u)'(\eta\theta,\gamma\theta) + (j_f^r)'(\eta\theta,\gamma\theta)$, that is,

$$(39)\quad j_f'(\eta\theta,\gamma\theta) = -f_{ex}\big[[G(\gamma\theta) - G(\eta\theta)][k^u(\eta\theta,\gamma\theta) + 1] + [1 - G(\gamma\theta)][k_3^r(\eta\theta,\gamma\theta) + 1]\big]\frac{\sigma-1}{\theta} < 0$$

Thus, the elasticity of j_f with respect to θ is given by

$$\frac{j_f'(\eta\theta,\gamma\theta)\theta}{j_f(\eta\theta,\gamma\theta)} = -(\sigma-1) \times \frac{[G(\gamma\theta) - G(\eta\theta)][k^u(\eta\theta,\gamma\theta) + 1] + [1 - G(\gamma\theta)][k_3^r(\eta\theta,\gamma\theta) + 1]}{[G(\gamma\theta) - G(\eta\theta)]k^u(\eta\theta,\gamma\theta) + [1 - G(\gamma\theta)]k_3^r(\eta\theta,\gamma\theta)} < -(\sigma-1)$$

Since the fraction on the right-hand side is greater than one, the elasticity of j_f with respect to θ is less than $-(\sigma-1)$, and thus, strictly negative. Therefore, as θ goes to infinity, j_f must be decreasing towards zero. In addition, $\lim_{\theta\to 0} k^u(\eta\theta,\gamma\theta) = \infty$ and $\lim_{\theta\to 0} k_3^r(\eta\theta,\gamma\theta) = \infty$. Thus, we also have $\lim_{\theta\to 0} j_f(\eta\theta,\gamma\theta) = \infty$. Hence, j_f is monotonically decreasing from infinity to zero on $(0,\infty)$. Since γ does not depend on θ, we know from the appendix A.2 that j is monotonically decreasing from infinity to zero on $(0,\infty)$. Therefore, $j + j_f$ is also monotonically decreasing from infinity to zero on $(0,\infty)$. Thus, equation (38) determines a unique cutoff level θ^*.

C Appendix: Open Economy Equilibrium—Case (b)

C.1 Derivation of the average rural profit

Note that, in this case, the expression of $r_d^r(\theta_{u,r})$ is identical to that derived in (A.1) for $r^r(\theta_{u,r})$ (because before $\theta_{u,r}$, urban firms do not export, and immediately after $\theta_{u,r}$, rural firms do not export either). Thus, $\bar{\pi}_d^r$, the average rural domestic profit, is now defined as $\bar{\pi}^r$ in (16). In addition, the average rural export profit is given by $\pi_f^r(\tilde{\theta^r}(\theta_{ex})) = [\tilde{\theta^r}(\theta_{ex})/\theta_{ex}]^{\sigma-1} r_f^r(\theta_{ex})/\sigma - f_{ex}$. Substituting the export cutoff condition, $\pi_f^r(\theta_{ex}) = 0$ (that is, $r_f^r(\theta_{ex}) = \sigma f_{ex}$), into the last expression yields

$$\bar{\pi}_f^r(\theta_{ex}) = f_{ex}\left[\left(\frac{\tilde{\theta^r}(\theta_{ex})}{\theta_{ex}}\right)^{\sigma-1} - 1\right]$$

Thus, the average profit over all rural firms, $\bar{\pi}^r(\theta^*, \theta_{u,r}, \theta_{ex}) = \bar{\pi}_d^r(\theta^*, \theta_{u,r}) + \bar{\pi}_f^r(\theta_{ex})$, can be expressed as

$$\begin{aligned}\bar{\pi}^r(\theta^*, \theta_{u,r}, \theta_{ex}) = w^u f^u &\left[\left(\frac{\tilde{\theta^r}(\theta_{u,r})}{\theta^*}\right)^{\sigma-1} - \left(\frac{\tilde{\theta^r}(\theta_{u,r})}{\theta_{u,r}}\right)^{\sigma-1}\right] \\ &+ w^r f^r \left[\left(\frac{\tilde{\theta^r}(\theta_{u,r})}{\theta_{u,r}}\right)^{\sigma-1} - 1\right] + q_{ex}^r f_{ex}\left[\left(\frac{\tilde{\theta^r}(\theta_{ex})}{\theta_{ex}}\right)^{\sigma-1} - 1\right]\end{aligned}$$

C.2 Existence and uniqueness of the equilibrium cutoff productivity level

As in case (a) we want to show that the zero cutoff profit condition (33), the urban-rural cutoff profit condition (34), and the free entry condition (30) identify a unique cutoff productivity level θ^*.

$$\begin{aligned}&[G(\alpha\theta) - G(\theta)]\,\bar{\pi}^u(\theta, \alpha\theta) + [1 - G(\alpha\theta)]\,\bar{\pi}^r(\theta, \alpha\theta, \beta\theta) = \delta f_e \\ &\text{where } \bar{\pi}^u(\theta, \alpha\theta) = w^u f^u k^u(\theta, \alpha\theta) \\ &\text{and } \bar{\pi}^r(\theta, \alpha\theta, \beta\theta) = w^u f^u k_1^r(\theta, \alpha\theta) + w^r f^r k_2^r(\alpha\theta) + f_{ex} k_4^r(\beta\theta)\end{aligned} \tag{40}$$

where $k_4^r(\beta\theta) = [\tilde{\theta^r}(\beta\theta)/\beta\theta]^{\sigma-1} - 1$. A sufficient condition for the existence and uniqueness of the equilibrium is that the left-hand side of equation (40) is monotonically decreasing on $(0, \infty)$. In other words, it should be going towards infinity for values of θ close to zero and approaching zero when θ tends towards infinity.

We define j_f^r as $j_f^r(\beta\theta) = [1 - G(\beta\theta)] f_{ex} k_4^r(\beta\theta)$. Recall that $j(\theta, \alpha\theta) + j_f^r(\beta\theta)$ is the left-hand side of (40). The derivative of j_f^r with respect to θ (denoted $(j_f^r)'$) is given by

$$(j_f^r)'(\beta\theta) = -f_{ex}[1 - G(\beta\theta)][k_4^r(\beta\theta) + 1]\frac{\sigma - 1}{\theta}$$

The elasticity of $j_f^r(\beta\theta)$ with respect to θ is

$$\frac{(j_f^r)'(\beta\theta)\theta}{j_f^r(\beta\theta)} = -(\sigma - 1)\frac{k_4^r(\beta\theta) + 1}{k_4^r(\beta\theta)} < -(\sigma - 1)$$

Since the fraction on the right-hand side is greater than one, the elasticity of j_f^r with respect to θ is less than $-(\sigma - 1)$, and thus, strictly negative. Hence, as θ approaches infinity, j_f^r must be going towards zero. We also have that $\lim_{\theta \to 0} k_4^r(\beta\theta) = \infty$ and $\lim_{\theta \to 0} j_f^r(\beta\theta) = \infty$. Therefore, j_f^r is monotonically decreasing from infinity to zero on the interval $(0, \infty)$.

We showed in appendix A.2 that j is monotonically decreasing from infinity to zero on $(0, \infty)$. Thus, $j + j_f^r$ is also monotonically decreasing from infinity to zero on $(0, \infty)$ and hence, equation (40) determines a unique cutoff level θ^*.

D Appendix: The Impact of Trade Liberalization

D.1 Shifts in the cutoff productivity levels

D.1.1 Case (a): urban non-exporters, urban exporters, and rural exporters

We derive comparative statics of the zero cutoff, export cutoff, and urban-rural cutoff productivity levels (θ^*, θ_{ex}, and $\theta_{u,r}$) for a change in the variable trade cost, τ. Recall (from appendix B.2) that θ^*, $\theta^* \in (0, \infty)$, is the equilibrium zero cutoff productivity level if and only if

$$j(\theta^*, \theta_{u,r}) + j_f(\theta_{ex}, \theta_{u,r}) = \delta f_e \tag{41}$$

where θ_{ex} and $\theta_{u,r}$ are implicitly defined as functions of θ^* as in (24) and (25). Differentiate (41) with respect to τ:

$$\frac{\partial j(\cdot)}{\partial \theta^*}\frac{\partial \theta^*}{\partial \tau} + \frac{\partial j(\cdot)}{\partial \theta_{u,r}}\frac{\partial \theta_{u,r}}{\partial \tau} + \frac{\partial j_f(\cdot)}{\partial \theta_{ex}}\frac{\partial \theta_{ex}}{\partial \tau} + \frac{\partial j_f(\cdot)}{\partial \theta_{u,r}}\frac{\partial \theta_{u,r}}{\partial \tau} = 0$$

Then, using the fact that $\partial j(\cdot)/\partial\theta_{u,r} = (1/\gamma)\partial j(\cdot)/\partial\theta^*$, $\partial j_f(\cdot)/\partial\theta_{ex} = (1/\eta)\partial j_f(\cdot)/\partial\theta^*$, and $\partial j_f(\cdot)/\partial\theta_{u,r} = (1/\gamma)\partial j_f(\cdot)/\partial\theta^*$, by substituting in $\partial\theta_{ex}/\partial\tau = (\theta_{ex}/\theta^*)\partial\theta^*/\partial\tau + \theta_{ex}/\tau$ and $\theta_{u,r}/\partial\tau = (\theta_{u,r}/\theta^*)\partial\theta^*/\partial\tau + \theta_{u,r}/(\tau+\tau^\sigma)$ and rearranging the terms, one obtains

$$\text{(42)} \qquad \frac{\partial\theta^*}{\partial\tau} = -\frac{\theta^*}{\tau}\frac{1}{2(1+\tau^{\sigma-1})}\frac{j'(\theta^*,\gamma\theta^*) + (2+\tau^{\sigma-1})(j_f)'(\eta\theta^*,\gamma\theta^*)}{j'(\theta^*,\gamma\theta^*) + (j_f)'(\eta\theta^*,\gamma\theta^*)} < 0$$

since $j'(\theta,\gamma\theta) < 0$ and $(j_f)'(\eta\theta,\gamma\theta) < 0 \;\forall\; \theta \in (0,\infty)$. Substituting (42) into $\partial\theta_{ex}/\partial\tau = (\theta_{ex}/\theta^*)\partial\theta^*/\partial\tau + \theta_{ex}/\tau$ gives

$$\text{(43)} \qquad \frac{\partial\theta_{ex}}{\partial\tau} = \frac{\theta_{ex}}{\tau}\frac{1}{2(1+\tau^{\sigma-1})}\frac{(1+2\tau^{\sigma-1})j'(\theta^*,\gamma\theta^*) + \tau^{\sigma-1}(j_f)'(\eta\theta^*,\gamma\theta^*)}{j'(\theta^*,\gamma\theta^*) + (j_f)'(\eta\theta^*,\gamma\theta^*)} > 0$$

Substituting (42) into $\partial\theta_{u,r}/\partial\tau = (\theta_{u,r}/\theta^*)\partial\theta_{u,r}/\partial\tau + \theta_{u,r}/(\tau+\tau^\sigma)$ yields

$$\text{(44)} \qquad \frac{\partial\theta_{u,r}}{\partial\tau} = \frac{\theta_{u,r}}{\tau}\frac{1}{2(1+\tau^{\sigma-1})}\frac{j'(\theta^*,\gamma\theta^*) - \tau^{\sigma-1}(j_f)'(\eta\theta^*,\gamma\theta^*)}{j'(\theta^*,\gamma\theta^*) + (j_f)'(\eta\theta^*,\gamma\theta^*)}$$

To determine the sign of $\partial\theta_{u,r}/\partial\tau$ we have to know the sign of the $j'(\theta^*,\gamma\theta^*) - \tau^{\sigma-1}j_f'(\eta\theta^*,\gamma\theta^*)$. Using (37), (39), the expressions for k^u, k_1^r, k_2^r, k_3^r, and (24), we obtain

$$\begin{aligned}
&\frac{j'(\theta^*,\gamma\theta^*)}{j_f'(\eta\theta^*,\gamma\theta^*)} \\
&= \frac{w^u f^u}{f_{ex}}\frac{[G(\gamma\theta^*) - G(\theta^*)][k^u(\theta^*,\gamma\theta^*)+1] + [1-G(\gamma\theta^*)](k_1^r(\theta^*,\gamma\theta^*) + \frac{w^r f^r}{w^u f^u}[k_2^r(\gamma\theta^*)+1])}{[G(\gamma\theta^*) - G(\eta\theta^*)][k^u(\eta\theta^*,\gamma\theta^*)+1] + [1-G(\gamma\theta^*)][k_3^r(\eta\theta^*,\gamma\theta^*)+1]} \\
&= \frac{\tau^{\sigma-1}}{\eta^{\sigma-1}}\frac{\frac{\int_{\theta^*}^{\gamma\theta^*}\xi^{\sigma-1}g(\xi)d\xi}{(\theta^*)^{\sigma-1}} + \frac{\int_{\gamma\theta^*}^{\infty}\xi^{\sigma-1}g(\xi)d\xi}{(\theta^*)^{\sigma-1}} - \frac{\int_{\gamma\theta^*}^{\infty}\xi^{\sigma-1}g(\xi)d\xi}{(\gamma\theta^*)^{\sigma-1}} + \frac{w^r f^r}{w^u f^u}\frac{\int_{\gamma\theta^*}^{\infty}\xi^{\sigma-1}g(\xi)d\xi}{(\gamma\theta^*)^{\sigma-1}}}{\frac{\int_{\eta\theta^*}^{\gamma\theta^*}\xi^{\sigma-1}g(\xi)d\xi}{(\eta\theta^*)^{\sigma-1}} + \frac{\int_{\gamma\theta^*}^{\infty}\xi^{\sigma-1}g(\xi)d\xi}{(\eta\theta^*)^{\sigma-1}}} \\
&= \tau^{\sigma-1}\frac{\int_{\theta^*}^{\gamma\theta^*}\xi^{\sigma-1}g(\xi)d\xi + \int_{\gamma\theta^*}^{\infty}\xi^{\sigma-1}g(\xi)d\xi - \gamma^{1-\sigma}\int_{\gamma\theta^*}^{\infty}\xi^{\sigma-1}g(\xi)d\xi + \gamma^{1-\sigma}\frac{w^r f^r}{w^u f^u}\int_{\gamma\theta^*}^{\infty}\xi^{\sigma-1}g(\xi)d\xi}{\int_{\eta\theta^*}^{\gamma\theta^*}\xi^{\sigma-1}g(\xi)d\xi + \int_{\gamma\theta^*}^{\infty}\xi^{\sigma-1}g(\xi)d\xi} \\
&= \tau^{\sigma-1}\frac{\int_{\theta^*}^{\infty}\xi^{\sigma-1}g(\xi)d\xi + \gamma^{1-\sigma}\int_{\gamma\theta^*}^{\infty}\xi^{\sigma-1}g(\xi)d\xi\left(\frac{w^r f^r}{w^u f^u} - 1\right)}{\int_{\eta\theta^*}^{\infty}\xi^{\sigma-1}g(\xi)d\xi} > \tau^{\sigma-1}
\end{aligned}$$

The inequality follows from the fact that $\int_{\theta^*}^{\infty}\xi^{\sigma-1}g(\xi)d\xi > \int_{\eta\theta^*}^{\infty}\xi^{\sigma-1}g(\xi)d\xi$ as $\eta > 1$, $w^r f^r/w^u f^u > 1$, and, therefore, the fraction is greater than one. Hence, $\partial\theta_{u,r}^*/\partial\tau > 0$.

D.1.2 Case (b): urban non-exporters, rural non-exporters, and rural exporters

We now obtain comparative statics of the cutoff productivity levels for a change in τ from the equilibrium condition

$$j(\theta^*, \theta_{u,r}) + j_f^r(\theta_{ex}) = \delta f_e \tag{45}$$

where $\theta_{u,r}$ and θ_{ex} are implicitly defined as functions of θ^* in (**??**) and (26). The derivative of (45) with respect to τ is:

$$\frac{\partial j(\cdot)}{\partial \theta^*}\frac{\partial \theta^*}{\partial \tau} + \frac{\partial j(\cdot)}{\partial \theta_{u,r}}\frac{\partial \theta_{u,r}}{\partial \tau} + \frac{\partial j_f^r(\cdot)}{\partial \theta_{ex}}\frac{\partial \theta_{ex}}{\partial \tau} = 0$$

Substituting in the previous equation $\partial j(\cdot)/\partial\theta_{u,r} = (1/\alpha)\partial j(\cdot)/\partial\theta^*$, $\partial j_f^r(\cdot)/\partial\theta_{ex} = (1/\beta)\partial j_f^r(\cdot)/\partial\theta^*$, $\partial\theta_{u,r}/\partial\tau = (\theta_{u,r}/\theta^*)\partial\theta^*/\partial\tau$, and $\partial\theta_{ex}/\partial\tau = (\theta_{ex}/\theta^*)\partial\theta^*/\partial\tau + \theta_{ex}/\tau$ and rearranging the terms we obtain:

$$\frac{\partial \theta^*}{\partial \tau} = -\frac{\theta^*}{\tau}\frac{(j_f^r)'(\beta\theta^*)}{2j'(\theta^*, \alpha\theta^*) + (j_f^r)'(\beta\theta^*)} < 0 \tag{46}$$

This inequality holds because $j'(\theta, \alpha\theta) < 0$ and $(j_f^r)'(\beta\theta) < 0$, $\forall \theta \in (0, \infty)$. Substituting equation (46) into $\partial\theta_{ex}/\partial\tau = (\theta_{ex}/\theta^*)\partial\theta^*/\partial\tau + \theta_{ex}/\tau$ yields

$$\frac{\partial \theta_{ex}}{\partial \tau} = \frac{\theta_{ex}}{\tau}\frac{2j'(\theta^*, \alpha\theta^*)}{2j'(\theta^*, \alpha\theta^*) + (j_f^r)'(\beta\theta^*)} > 0 \tag{47}$$

Like $\partial\theta^*/\partial\tau$, the derivative of $\theta_{u,r}$ with respect to τ is negative.

D.2 Reallocation of market shares due to a change in τ

D.2.1 Case (a): urban non-exporters, urban exporters, and rural exporters

From (19), for all $\theta \in [\theta^*, \theta_{u,r})$, $r_d^u(\theta)/r_d^u(\theta^*) = (\theta/\theta^*)^{\sigma-1}$. In addition, $\pi_d^u(\theta^*) = 0 \Leftrightarrow r_d^u(\theta^*) = \sigma w^u f^u$. Then, $r_d^u(\theta) = \sigma w^u f^u(\theta/\theta^*)^{\sigma-1}$. Thus, $\partial r_d^u(\theta)/\partial\tau > 0$, since $\partial\theta^*/\partial\tau < 0$. Similarly, for all $\theta \in [\theta_{u,r}, \infty)$, $r_d^r(\theta)/r_d^r(\theta^*) = (\theta/\theta^*)^{\sigma-1}$. Then, given that $r_d^r(\theta^*)/r_d^u(\theta^*) = (w^u/w^r)^{\sigma-1}$, $\pi_d^u(\theta^*) = 0$ implies $r_d^r(\theta) = \sigma w^u f^u (w^u/w^r)^{\sigma-1}(\theta/\theta^*)^{\sigma-1}$. Thus, $\partial r_d^u(\theta)/\partial\tau > 0$, since $\partial\theta^*/\partial\tau < 0$. Therefore, a fall in the variable trade cost entails a decrease in the domestic sales of all urban and rural firms.

Recall that the total revenue, from domestic and foreign sales, of an exporting firm located in region $m \in \{u, r\}$ is $r^m(\theta) = (1+\tau^{1-\sigma})r_d^m(\theta)$. Thus, for an urban exporter it is $(1+\tau^{1-\sigma})\sigma w^u f^u(\theta/\theta^*)^{\sigma-1}$, and for a rural exporter it is $(1+\tau^{1-\sigma})\sigma w^u f^u(w^u/w^r)^{\sigma-1}(\theta/\theta^*)^{\sigma-1}$. Both the derivatives of the total revenues of urban and rural exporters with respect to τ are of the same sign as the derivative of $(1+\tau^{1-\sigma})/(\theta^*)^{\sigma-1}$.

$$\begin{aligned}\frac{\partial(1+\tau^{1-\sigma})/(\theta^*)^{\sigma-1}}{\partial\tau} &= \frac{(1-\sigma)\tau^{-\sigma}}{(\theta^*)^{\sigma-1}} - \frac{(\sigma-1)(1+\tau^{1-\sigma})}{(\theta^*)^{\sigma}}\frac{\partial\theta^*}{\partial\tau} \\ &= \frac{1+\tau^{1-\sigma}}{(\theta^*)^{\sigma-1}\tau}(\sigma-1)\left[-\frac{\partial\theta^*}{\partial\tau}\frac{\tau}{\theta^*} - (1+\tau^{\sigma-1})^{-1}\right]\end{aligned}$$

The first term in the brackets can be rewritten as

$$-\frac{\partial\theta^*}{\partial\tau}\frac{\tau}{\theta^*} = \frac{1}{2}\left(1+\tau^{\sigma-1}\right)^{-1} + \frac{1}{2}\left[1+\frac{j'(\theta^*,\gamma\theta^*)}{j_f'(\eta\theta^*,\gamma\theta^*)}\right]^{-1} < (1+\tau^{\sigma-1})^{-1}$$

The inequality follows from the fact that $j'(\theta^*,\gamma\theta^*)/j_f'(\eta\theta^*,\gamma\theta^*) > \tau^{\sigma-1}$, which is shown in appendix D.1. Hence, $\partial\left[(1+\tau^{1-\sigma})/(\theta^*)^{\sigma-1}\right]/\partial\tau < 0$. Therefore, a fall in the variable trade cost causes an increase in the revenue of exporters.

D.2.2 Case (b): urban non-exporters, rural non-exporters, and rural exporters

The expressions of the urban and rural domestic revenues are identical to those in case (a). Thus, they are also negatively related to τ. Moreover, the derivative of the total revenue rural exporters with respect to τ is of the same sign as the derivative of $(1+\tau^{1-\sigma})/(\theta^*)^{\sigma-1}$. However, the expression of $(\partial\theta^*/\partial\tau)\tau/\theta^*$ is different than in case (a):

$$-\frac{\partial\theta^*}{\partial\tau}\frac{\tau}{\theta^*} = \left[1+2\frac{j'(\theta^*,\alpha\theta^*)}{(j_f^r)'(\beta\theta^*)}\right]^{-1} < (1+\tau^{\sigma-1})^{-1}$$

The above inequality is established in what follows.

$$\begin{aligned}&\frac{j'(\theta^*,\alpha\theta^*)}{(j_f^r)'(\beta\theta^*)} \\ &= \frac{w^u f^u}{f_{ex}}\frac{[G(\alpha\theta^*)-G(\theta^*)][k^u(\theta^*,\alpha\theta^*)+1] + [1-G(\alpha\theta^*)](k_1^r(\theta^*,\alpha\theta^*)+\frac{w^r f^r}{w^u f^u}[k_2^r(\alpha\theta^*)+1])}{[1-G(\beta\theta^*)][k_4^r(\beta\theta^*)+1]}\end{aligned}$$

$$= \frac{\tau^{\sigma-1}}{\beta^{\sigma-1}} \left(\frac{w^r}{w^u}\right)^{\sigma-1} \frac{\frac{\int_{\theta^*}^{\alpha\theta^*} \xi^{\sigma-1} g(\xi) d\xi}{(\theta^*)^{\sigma-1}} + \frac{\int_{\alpha\theta^*}^{\infty} \xi^{\sigma-1} g(\xi) d\xi}{(\theta^*)^{\sigma-1}} - \frac{\int_{\alpha\theta^*}^{\infty} \xi^{\sigma-1} g(\xi) d\xi}{(\alpha\theta^*)^{\sigma-1}} + \frac{w^r f^r}{w^u f^u} \frac{\int_{\alpha\theta^*}^{\infty} \xi^{\sigma-1} g(\xi) d\xi}{(\alpha\theta^*)^{\sigma-1}}}{\frac{\int_{\beta\theta^*}^{\infty} \xi^{\sigma-1} g(\xi) d\xi}{(\beta\theta^*)^{\sigma-1}}}$$

$$= \tau^{\sigma-1} \left(\frac{w^r}{w^u}\right)^{\sigma-1} \frac{\int_{\theta^*}^{\alpha\theta^*} \xi^{\sigma-1} g(\xi) d\xi + \int_{\alpha\theta^*}^{\infty} \xi^{\sigma-1} g(\xi) d\xi - \alpha^{1-\sigma} \int_{\alpha\theta^*}^{\infty} \xi^{\sigma-1} g(\xi) d\xi + \alpha^{1-\sigma} \frac{w^r f^r}{w^u f^u} \int_{\alpha\theta^*}^{\infty} \xi^{\sigma-1} g(\xi) d\xi}{\int_{\beta\theta^*}^{\infty} \xi^{\sigma-1} g(\xi) d\xi}$$

$$= \tau^{\sigma-1} \left(\frac{w^r}{w^u}\right)^{\sigma-1} \frac{\int_{\theta^*}^{\alpha\theta^*} \xi^{\sigma-1} g(\xi) d\xi + \int_{\alpha\theta^*}^{\infty} \xi^{\sigma-1} g(\xi) d\xi + \alpha^{1-\sigma} \int_{\alpha\theta^*}^{\infty} \xi^{\sigma-1} g(\xi) d\xi \left(\frac{w^r f^r}{w^u f^u} - 1\right)}{\int_{\beta\theta^*}^{\infty} \xi^{\sigma-1} g(\xi) d\xi}$$

Substituting the expression of α from (9) into the above equation we obtain

$$\frac{j'(\theta^*, \alpha\theta^*)}{(j_f^r)'(\beta\theta^*)} = \tau^{\sigma-1} \left[\frac{\left(\frac{w^r}{w^u}\right)^{\sigma-1} \int_{\theta^*}^{\alpha\theta^*} \xi^{\sigma-1} g(\xi) d\xi}{\int_{\beta\theta^*}^{\infty} \xi^{\sigma-1} g(\xi) d\xi} + \frac{\int_{\alpha\theta^*}^{\infty} \xi^{\sigma-1} g(\xi) d\xi}{\int_{\beta\theta^*}^{\infty} \xi^{\sigma-1} g(\xi) d\xi} \right] > \tau^{\sigma-1}$$

since $(w^r/w^u)^{\sigma-1} \int_{\theta^*}^{\alpha\theta^*} \xi^{\sigma-1} g(\xi) d\xi / \int_{\beta\theta^*}^{\infty} \xi^{\sigma-1} g(\xi) d\xi > 0$, and $\int_{\alpha\theta^*}^{\infty} \xi^{\sigma-1} g(\xi) d\xi > \int_{\beta\theta^*}^{\infty} \xi^{\sigma-1} g(\xi) d\xi$ as $\alpha < \beta$ by assumption. Hence, a decline in τ leads to an increase in the revenue of rural exporters.

D.3 Reallocation of profits due to changes in τ

D.3.1 Case (a): urban non-exporters, urban exporters, and rural exporters

The urban firms that still do not export after a decrease in the iceberg trade cost from τ to τ', that is, with productivity $\theta < \theta'_{ex}$, are subject to both revenue and profit losses. The firms with productivity levels between θ'_{ex} and θ_{ex} become exporters as a result of the decline in τ. All of the new exporters earn a greater revenue from their export sales; however, only a fraction of them accrue higher profits because they now have to pay the fixed cost of exporting. The firms that were already exporters before the decline in the trade cost see an increase in their profits, and this increase is positively related to their productivity level. The change in profits of these firms is given by:

$$\begin{aligned} \Delta\pi^u(\theta) &= \frac{1}{\sigma}[r^{u\prime}(\theta) - r^u(\theta)] \\ &= \theta^{\sigma-1} w^u f^u \left[\frac{1 + (\tau')^{1-\sigma}}{(\theta^{*\prime})^{1-\sigma}} - \frac{1 + \tau^{1-\sigma}}{(\theta^*)^{1-\sigma}} \right] \end{aligned}$$

Note that the term in the bracket on the first line is positive, thus the term in the brackets on the second line must also be positive. Hence, the change in profits is increasing in θ.

Similarly, for rural firms, the change in profits is given by:

$$\begin{aligned}\Delta\pi^r(\theta) &= \frac{1}{\sigma}\left[r^{r\prime}(\theta) - r^r(\theta)\right] \\ &= \theta^{\sigma-1} w^u f^u \left(\frac{w^u}{w^r}\right)^{\sigma-1}\left[\frac{1+(\tau')^{1-\sigma}}{(\theta^{*\prime})^{1-\sigma}} - \frac{1+\tau^{1-\sigma}}{(\theta^*)^{1-\sigma}}\right]\end{aligned}$$

Since $r^r(\theta) < r^{r\prime}(\theta)$, the term in the bracket must be positive for all $\theta > \theta'_{u,r}$.

D.3.2 Case (b): urban non-exporters, rural non-exporters, and rural exporters

In this case, the urban non-exporters lose market shares and profits due to decline in τ. Firms with productivities between $\theta_{u,r}$ and $\theta'_{u,r}$ are induced to move to the urban region where they pay a lower fixed cost of production and thus minimize their loss of market share. The rural firms with productivity levels between θ'_{ex} and θ_{ex} start to export as a result of the decline in τ. Like in case (a), the new exporters generate higher revenue from their export sales but only some of them accrue greater profits because of the fixed cost of exporting. The firms that used to export *ex ante* earn more profits after the decrease in the variable trade cost. The change in profits of these rural firms is given by the same equation as in case (a).

E Appendix: Data Description

We use plant-level data from the Colombian Manufacturing census collected by DANE (National Statistical Institute of Colombia) for the years 1977 - 1991. The total factor productivity analysis is applied to the period of more protectionist trade regime in Colombia, i.e. 1981-1984. The trade liberalization analysis covers two years - 1984 and 1991. Industry classification varies across years. For the period 1977-1989 the census provides a four-digit SIC code, whereas for the last two years of the dataset (1990 and 1991) they report a five-digit code. We ignore the five-digit classification in 1991 to make it comparable to the coding in 1984. For a detailed information on the data refer to Roberts, 1996.

E.1 Data description for the productivity differences estimation

For this part of the analysis we use a plant-level data. The following variables have been utilized:

Real production: the log of the real value of production.

Materials: constructed by adding the consumption of raw materials (both domestic and foreign) to the net value of inventories. The raw material input variable has been deflated for each year and transformed in logarithm.

Labor: the log of total employment.

Capital: the log of the total book value of fixed assets (deflated)

Energy: measured as energy consumed (energy purchased minus energy sold) plus purchases of fuels consumed by the establishment. This variable is also deflated and is in logarithm.

Metro: a dummy variable equal to one for a plant located in a metropolitan area and zero otherwise. The metropolitan areas in Colombia are: Bogota D.E., Soacha; Cali, Yumbo; Medellin, Valle de Aburra; Manizales, Villamaria; Barranquilla, Soledad; Bucaramanga, Giron, Floridablanca; Pereira, Santa Rosa de Cabal, Dosquebradas; Cartagena.

E.2 Data description for the trade liberalization analysis

The source for the ad-valorem tariffs at the 4-digit SIC level is Jorge Garcia from the World Bank.

Change in tariff: the difference in tariffs between 1990 and 1983

Change in the share of metro firms: the difference between metro firms share in 1991 and 1984.

Change in the share of metro production is simply the difference between 1991 and 1984 real production of metro plants.

Labor cost share: the fraction of total labor cost (salaries and benefits) from the total factor costs (the sum of labor, capital, raw materials, energy, and other industrial costs) in 1984.

Capital share is calculated as the total book value of fixed assets divided by total factor costs in 1984.

Energy share: measured as energy consumed plus purchases of fuels consumed by the establishment divided by total factor costs in 1984.
Materials share is computed as the total raw materials useage (both domestic and foreign plus the net value of inventories) divided by the total factor costs in 1984.

Table 1: Plant-Level Fixed Effects Regressions

	(1)	(2)	(3)
Labor	0.5554***	0.5802***	0.5783***
	(0.0090)	(0.0190)	(0.0191)
Capital	0.0524***	0.0198**	0.0204**
	(0.0043)	(0.0091)	(0.0091)
Materials	0.3626***	0.3443***	0.3440***
	(0.0038)	(0.0068)	(0.0068)
Energy	0.1587***	0.1949***	0.1955***
	(0.0056)	(0.0113)	(0.0113)
Metro		-0.0982*	-0.0942*
		(0.0568)	(0.0568)
Labor*metro		-0.0355*	-0.0358*
		(0.0206)	(0.0206)
Capital*metro		0.0415***	0.0416***
		(0.0103)	(0.0103)
Materials*metro		0.0235***	0.0233***
		(0.0077)	(0.0077)
Energy*metro		-0.0430***	-0.0435***
		(0.0118)	(0.0118)
4-digit SIC dummies	No	No	Yes
Year 82			-0.0190
			(0.0176)
Year 83			-0.0241
			(0.0178)
Year 84			-0.0040
			(0.0177)
Constant	2.4731***	2.5482***	2.7336***
	(0.0233)	(0.0519)	(0.0718)
Observations	8063	8063	8063
Number of sic	94	94	
R^2	0.90	0.90	0.92

Standard errors in parentheses
* significant at 10%; ** significant at 5%; *** significant at 1%
Note: Labor, capital, energy, materials and output are in logs and all variables excluding labor have been deflated.

Table 2: Fixed Effects Regressions for the Three Largest Industries in Colombia

	(1)	(2)	(3)	(4)	(5)	(6)
	Grain Mill Products		**Clothing**		**Motor Vehicles**	
Labor	0.6703***	0.7708***	0.6808***	0.5696***	0.3915***	0.5340***
	(0.0445)	(0.0587)	(0.0253)	(0.0954)	(0.0427)	(0.1983)
Capital	-0.0114	-0.0300	0.0397***	0.0255	0.0608***	0.0720
	(0.0269)	(0.0361)	(0.0136)	(0.0665)	(0.0227)	(0.0763)
Materials	0.2790***	0.2606***	0.2382***	0.3021***	0.5245***	0.3266***
	(0.0112)	(0.0143)	(0.0082)	(0.0381)	(0.0217)	(0.0912)
Energy	0.3104***	0.2369***	0.1618***	0.1261**	0.1192***	0.2893***
	(0.0390)	(0.0597)	(0.0163)	(0.0631)	(0.0250)	(0.1042)
Metro		-0.5410		-0.0210		-0.0558
		(0.3651)		(0.3741)		(0.3340)
Labor*metro		-0.2137**		0.1128		-0.1525
		(0.0866)		(0.0983)		(0.2034)
Capital*metro		0.0382		0.0191		-0.0059
		(0.0542)		(0.0680)		(0.0800)
Materials*metro		0.0439*		-0.0686*		0.2152**
		(0.0224)		(0.0390)		(0.0938)
Energy*metro		0.1199		0.0356		-0.1902*
		(0.0775)		(0.0652)		(0.1079)
Constant	3.0924***	3.4203***	2.9079***	2.9353***	1.9905***	2.0087***
	(0.1905)	(0.2711)	(0.0714)	(0.3673)	(0.0912)	(0.3190)
Observations	355	355	1190	1190	191	191
Number of years	4	4	4	4	4	4
R^2	0.80	0.81	0.83	0.83	0.97	0.98

Standard errors in parentheses
* significant at 10%; ** significant at 5%; *** significant at 1%
Note: Labor, capital, energy, materials and output are in logs and all variables excluding labor have been deflated.

Table 3
The Impact of Tariff Change between 1983 and 1990 on the Change in Metropolitan Share of Plants and Production

	ΔMetro Share of Plants		ΔMetro Share of Production	
	(1)	(2)	(3)	(4)
Δtariff 83-90	0.1515	0.1119	0.1567*	0.1316
	(0.0996)	(0.0923)	(0.0947)	(0.0853)
2-digit SIC dummies	Yes	Yes	Yes	Yes
Labor share		42.3992		85.6993***
		(27.4221)		(25.3481)
Energy share		-43.4121		-108.5446*
		(64.4433)		(59.5692)
Capital share		69.7418***		74.3032***
		(21.1683)		(19.5672)
Materials share		27.2470		41.4725**
		(20.3707)		(18.8299)
Constant	-1.0075	-30.7132*	-0.2155	-42.4660***
	(2.4307)	(17.1854)	(2.3113)	(15.8856)
Observations	80	80	80	80

Standard errors in parentheses
* significant at 10%; ** significant at 5%; *** significant at 1%

Table 4
The Impact of Tariff Change between 1984 and 1990 on the Change in Metropolitan Share of Plants and Production

	ΔMetro Share of Plants		ΔMetro Share of Production	
	(1)	(2)	(3)	(4)
Δtariff 84-90	0.0920	0.0572	0.1223*	0.1060*
	(0.0684)	(0.0612)	(0.0708)	(0.0625)
2-digit SIC dummies	Yes	Yes	Yes	Yes
Labor share		43.7382*		68.3266***
		(22.9302)		(23.4255)
Energy share		-66.1324		-133.9544**
		(55.9239)		(57.1319)
Capital share		61.5706***		57.7203***
		(15.6412)		(15.9791)
Materials share		18.0564		18.5289
		(15.4702)		(15.8044)
Constant	-1.0387	-23.5830*	-0.1441	-23.7864*
	(2.3307)	(13.0132)	(2.4126)	(13.2943)
Observations	80	80	80	80

Standard errors in parentheses
* significant at 10%; ** significant at 5%; *** significant at 1%