Firm-to-Firm Technology Transfers, Aggregate Spillovers and the Gains from Openness

Juan Ignacio Jacoubian

Department of Economics, Boston University*

Abstract

I develop a static model to study the macroeconomic effect of multinational production (MP) and trade in the context of technology diffusion among the best firms in the sector and simultaneous firm-to-firm technology transfers between sectors. I show the importance of separately calibrating aggregate spillovers and firm-to-firm technology transfers in the buyer-supplier linkages. I focus my analysis on non-tradable suppliers and show how different levels of technology transfer affect the gains from openness.

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Trade and the inflow of multinational companies can impact the productivity of domestic firms. Recent literature has empirically demonstrated various mechanisms through which this occurs. On the one hand, part of the literature has focused on aggregate spillovers (Greenstone et. al 2010; Abebe et. al. 2022; Alfaro-Ureña et al. 2021; Setzler and Tintelnot 2021) i.e., domestic firms enhance their productivity because there are better firms around them. On the other hand, another part of the literature has concentrated on buyer-supplier linkages (Javorcik 2004; Alfaro-Ureña et al. 2022; Amiti et al 2023). Moreover, some papers emphasize the role of endogenous technology adoption and how trade changes this decision (Bustos, 2011). In each case, it has been concluded that there are positive effects stemming from all these mechanisms.

While most of the literature has focused on aggregate spillovers to calculate the gains from trade or multinational production (MP), this paper develops a model incorporating aggregate spillovers at the sectoral level among the top firms in the sector and direct technology transfers between sectors. Using a technology choice model similar to Bustos (2011), the study explores the potential impact of trade and the arrival of multinational companies on the productivity of domestic firms in an environment with these two types of spillovers together. My model allows us to distinguish between the types of spillovers estimated in the literature and analyze how each of them independently affects the economy in equilibrium and how they interact with each other. In particular, while the aggregate spillover is modeled following literature (Buera and Oberfield 2020; Perla and Tonetti 2014), technology transfers are not treated as externalities that companies disregard when making decisions. In my model, both suppliers and buyers are aware that they can enhance their productivity by working together, so they partially incorporate these spillovers into their ex-ante decisions of technology adoption.

To guide my theoretical approach, I developed a three-sector static model. While the

most important parts of the model are the *Upstream* (U) and *Downstream* (D) sectors, I close the model with a *General* (G) sector. I introduce technology choice in a model of trade with heterogeneous firms and a one-to-one match between buyers (D) and suppliers (U). In the model, the benefit of the adoption of technology is proportional to revenues, while its cost is fixed. As a result, more productive firms make higher revenues and therefore are the ones that find paying the fixed costs to adopt the better technology profitable, a result that is a direct consequence of having an economy as in Melitz (2003). The key insight of the model is that the increment in productivity when a firm adopts is endogenous rather than exogenous as in Bustos (2011). While this coefficient is exogenous from the perspective of the firm, it is endogenously determined as a function of the average productivity of those firms that invest. In this sense, we combine the structure of Bustos (2011) with Buera & Oberfield (2020) and Perla & Tonetti (2014). In this setup, I introduce trade and multinational production in a symmetric two-country economy.

I show that a bilateral reduction in tariffs reduces the price level, increases the endogenous productivity gain of adopting the better technology and so the share of firms adopting technology in the tradable sectors, changing the composition of firms adopting in the sector. Moreover, if the technology transfers from buyers (tradable) to suppliers (non-tradable) is positive and both countries are symmetric, the reduction in the mass of firms entering the market and in the mass of firms adopting the new technology reduces the technology transfer from buyers to suppliers. As a result, the impact of trade in the non-tradable sector is negative.

Similarly, I show that an inflow of multinational corporations in the tradable sectors has the same effect as trade but is amplified in the tradable sectors. Multinational production increases aggregate spillovers more than trade. However, it also reduces the mass of firms by more. Given a positive transfer of technology from buyers to suppliers, multinational

production will also have a negative impact relative to autarky in the non-tradable sector given the exit of a sizable mass of firms in the tradable sector. The main result of the paper is that, while being matched with a multinational corporation increases productivity (and profits) by more than a domestic firm, the sectorial impact is negative given the reduction in the mass of buyers. The key assumption driving this result is the fact that buyer-supplier technology transfer happens with any buyer in the economy, no matter the country of origin and both countries are symmetric.

I Literature Review

The model developed in this paper builds on extensive theoretical literature analyzing the effects of trade and multinational production on domestic firm productivity and technological change. In particular, I combine Helpman et al. (2004), Yeaple (2005) and Bustos (2011). Following Bustos (2011), the main difference with Yeaple (2005) is that I allow heterogeneity in the productivity of the firms. In addition, the model I present differs from Bustos in that the technology shifter parameter is endogenous rather than exogenous. Instead of having a constant parameter, it is a function of the average productivity of firms investing in the sector. Finally, I introduce multinational production in this setup in a similar way as Helpman et al. (2004): there is a trade-off between exporting and paying the iceberg trade cost or paying a higher fixed cost and opening an affiliate in the other country to save the iceberg fixed cost. My model differs from Helpman et al. (2004) as I have non-tradable suppliers. As a result, the decision to export or open an affiliate depends not only on wage differences and the iceberg trade cost but also on the different quality of the suppliers in each country.

In addition to the structure mentioned above, I extend the standard Melitz model by adding a one-to-one match between buyers and suppliers. Moreover, following empirical literature, I add technology transfers from buyers to suppliers. Javorcik (2004), based on firm-level data from Lithuania, produces evidence consistent with positive productivity spillovers from FDI taking place through contacts between foreign affiliates and their local suppliers in upstream sectors. In the same line, Alfaro-Urena et al. (2022), using firm-to-firm data from Costa Rica, reveals that domestic firms experience strong and persistent gains in performance after supplying to a first MNC buyer, increasing their TFP between 4% to 9%. Finally, Amiti et al. (2023) shows that starting to supply a superstar firm (large domestic firms, exporters, and multinationals) boosts productivity by 8% in the medium run. Taking this into account, I model technology transfers in the matching process following Cai et al. (2022b).

Finally, the model is related to the literature about aggregate spillovers. The empirical literature has well-documented positive aggregate spillovers. For example, Alfaro-Urena et al. (2021), Greenstone et al. (2010), and Setzler & Tintelnot (2021) found positive aggregate spillovers on domestic firms and workers. On the other side, the theoretical literature has worked with aggregate spillovers in the context of trade and multinational production in several ways. Buera & Oberfield (2020) modeled aggregate spillovers in the context of a dynamic model. In particular, the initial productivity draw depends on the actual distribution of productivity in the economy. In this sense, the *stock of knowledge* determines the initial productivity distribution. When trade is free, the stock of knowledge is higher and so the aggregate spillovers are positive. Perla & Tonetti (2014) developed a dynamic model where the initial productivity distribution is exogenous but every firm can pay a second fixed cost and receive a new shock which is independent of the first productivity draw and depends on the distribution of the firms that invest. As a result, the left tail of

the distribution receives the aggregate spillovers, and they called this mechanism *immitation*. In this paper. I follow Perla & Tonetti (2014) but in a different way: given an initial productivity draw that depends on exogenous parameters, firms can pay a fixed cost and increase their productivity proportionally to their initial productivity level. As a result, the change in the productivity level after investing depends on your initial productivity. For simplicity, I assume that this shift in productivity is deterministic but endogenous: it depends on the average productivity within the firms that invest in the sector. Although it seems to be similar to Perla & Tonetti (2014), the fact that the change in productivity is productivity-dependent rather than iid implies that aggregate spillovers are going to affect only the right tail of the distribution. Therefore, aggregate spillovers affect only the more productive firms in each sector. Finally, while the papers mentioned above focused on the effect of trade, I contributed to the literature by adding multinational production in this environment.

The remainder of the paper is organized as follows. The next section presents the structure of the economy in more detail. Section III presents the closed economy equilibrium and the implications of different magnitudes of aggregate spillovers and firm-to-firm technology transfers. Section IV to VI shows how introducing trade and multinational production affect technology choice decisions and the impact of aggregate spillovers and firm-to-firm technology transfers. Section VI introduces both trade and multinational production together. In the last two sections, I discuss the results.

II Setup of the model

Each country is endowed with L units of labor used to produce in the Upstream Sector (U), Downstream Sector (D), and General Sector (G). While I present the result as a general case, I assume symmetry for simulations. The symmetry assumption ensures that wages, which are the numeraire, and all aggregate variables are the same for both countries. I present the discussion from the point of view of the home country. I will describe each sector separately.

Upstream Sector (U)

Entry. — This sector is characterized by monopolistic competition. Each variety is produced by a single firm, and there is free entry into the industry. Firms are heterogeneous in terms of marginal cost. I denote z_u the productivity of a firm in this sector. To enter the industry in a given country, firms pay a fixed cost of F_u^e in units of labor. Entrants then draw their productivity from a known Pareto cumulative distribution with shape parameter θ and scale parameter $T \geq 1$.

Technology. — After observing their productivity firms decide whether to exit the market or pay a fixed cost F_u (in units of labor) and produce. Firms can choose to upgrade their productivity level. If they pay a second fixed cost F_u^I (in units of labor) and increase their productivity from z_u to $Z_u^\gamma z_u$, where Z_u is the average productivity within the firms that decided to upgrade their technology. The resulting total cost function is $(F_u + \frac{y_u}{z_u})$ if they do not upgrade or $(F_u + F_u^I + \frac{y_u}{Z_u^\gamma z_u})$ if they upgrade.

Supplying Downstream Sector (d). — Every firm can sell its production as a final good

under monopolistic competition. In addition, If a firm does not upgrade its productivity level, it can not supply the downstream sector. If a firm upgrades its productivity level, with a positive probability they are going to be matched with a firm in the downstream sector. In particular, given random matching, the probability of having a match equals the ratio between the mass of firms in sector d, M_d, and the mass of firms in sector u conditional on upgrading their technology, M_u^I. We assume that the value of the parameters is such that this ratio is less than 1.

Downstream Sector (D)

Entry. — This sector is characterized by perfect competition with decreasing returns to scale. As before, there is free entry into the industry. Firms are heterogeneous in terms of marginal cost. I denote z_d the productivity of a firm in this sector. To enter the industry in a given country, firms pay a fixed cost of F_d^e in units of labor. Entrants then draw their productivity from the exact same distribution as sector u.

Technology. — After observing their productivity firms decide whether to exit the market or pay a fixed cost F_d (in units of labor) and produce. Similarly to sector u, firms can choose to upgrade their productivity level. If they do not upgrade their productivity, the production function is $y_d = z_d x_d^\alpha L_d^\beta$, where x_d is the inputs from sector u and $\alpha + \beta < 1$. If they upgrade, they pay a second fixed cost F_d^I and their production function is $y_d = Z_d^\gamma z_d x_d^\alpha L_d^\beta$.

General Sector (G)

Entry. — The structure of the sector is similar to sector u. However, they only sell their production as a final good. I denote z_g the productivity of a firm in this sector. To enter the industry in a given country, firms pay a fixed cost of F_g^e in units of labor. Entrants then draw their productivity from a known Pareto cumulative distribution with shape parameter θ and scale parameter $T \geq 1$.

Technology. — After observing their productivity firms decide whether to exit the market or pay a fixed cost F_g (in units of labor) and produce. Firms can choose to upgrade their productivity level. If they pay a second fixed cost F_g^I (in units of labor) and increase their productivity from z_g to $Z_g^\gamma z_g$, where Z_g is the average productivity within the firms that decided to upgrade their technology. The resulting total cost function is $(F_g + \frac{y_g}{z_g})$ if they do not upgrade or $(F_g + F_g^I + \frac{y_g}{Z_g^\gamma z_g})$ if they upgrade.

Demand

There is a representative agent who consumes the final good production of each sector. In the Upstream Sector and the General Sector, preferences across varieties have the standard CES form, with an elasticity of substitution σ, common across sectors. With respect to the downstream sector, there is a homogeneous good. The utility function is $U(C_u, C_d, C_g) = C_u^{\rho_u} C_d^{\rho_d} C_g^{1-\rho_u-\rho_d}$. Given CES, we can define the price index in Sector u and Sector g following the literature:

$$P_i = \left[\int_z p(z)^{1-\sigma} M_i \phi_i(z) dz \right]^{\frac{1}{\sigma-1}} \quad \text{for i=u,g.}$$

Where $\phi_i(z)$ is the observed distribution of productivities.

Matching Structure

Conditional on a match, firms in the upstream sector and the downstream sector maximize total profits together. Starting with the upstream sector, the variable profits of a firm with productivity z'_u matched with a buyer with productivity z'_d are:

$$\pi_{u,v}(z'_u, z'_d) = \underbrace{p_u(z'_u)x_d}_{\text{Sales to Downstream Sector}} + \underbrace{p_u(z'_u)^{1-\sigma}P_u^{\sigma}C_u}_{\text{Final Good Sales}} - \underbrace{\frac{w}{z'_u}\left[x_d + \left(\frac{P_u}{p_u(z'_u)}\right)^{\sigma} C_u\right]}_{\text{Total Cost of Production}}$$

Where we introduce the standard residual demand generated by CES preferences over varieties in the upstream sector. Similarly, the variable profits of the downstream firm are:

$$\pi_{d,v}(z'_u, z'_d) = p_d z'_d x_d^{\alpha} l_d^{\beta} - w l_d - p_u(z'_u)\, x_d$$

Where $z'_u = Z_u^{\gamma}(z'_d)^{\mu} z_u$, i.e. a firm with initial productivity z_u can supply a firm in the downstream sector only if they adopt the better technology. This is captured by the first term. In addition, conditional on a matched with a buyer with productivity z'_d, the supplier receives $(z'_d)^{\mu}$ of its productivity. Following the literature, we call the first term *aggregate spillovers* and the second term *firm-to-firm technology transfers*. In addition, γ captures the intensity of the aggregate spillovers and μ the intensity of the firm-to-firm technology transfer. Furthermore, if the downstream firm decides to invest $z'_d = Z_d^{\gamma} z_d$. In contrast, if they do not decide to invest $z'_d = z_d$, their initial productivity.

Maximizing total profits implies that the optimal price is $p_u = \frac{\sigma}{\sigma-1}\frac{w}{Z_u^{\gamma}(z_d')^{\mu}z_u}$. Therefore, variable profits in the upstream sector are:

$$\pi_{u,v}(z_u, z_d') = \underbrace{\left(\frac{Z_u^{\gamma}z_u(z_d')^{\mu}}{w}\right)^{\sigma-1}\frac{P_u^{\sigma}C_u}{\sigma-1}\left(\frac{\sigma-1}{\sigma}\right)^{\sigma}}_{\text{Final Good Profits}} + \underbrace{\frac{1}{\sigma-1}\left(\frac{p_d(z_d')^{1+\mu\alpha}(Z_u^{\gamma}z_u)^{\alpha}}{w^{\alpha+\beta}}\alpha^{1-\beta}\beta^{\beta}\right)^{\frac{1}{1-\alpha-\beta}}}_{\text{Intermediate Good Profits}}$$

Similarly, in the downstream sector:

$$\pi_{d,v}(z_d', z_u) = \left(\frac{p_d(z_d')^{1+\mu\alpha}(Z_u^{\gamma}z_u)^{\alpha}}{w^{\alpha+\beta}}\right)^{\frac{1}{1-\alpha-\beta}} \underbrace{\alpha^{\frac{\alpha}{1-\alpha-\beta}}\beta^{\frac{\beta}{1-\alpha-\beta}}\left[1-\beta-\frac{\sigma}{\sigma-1}\alpha\right]}_{=B}$$

I assume that $\frac{1-\beta}{\alpha} > \frac{\sigma}{\sigma-1}$. As a result, firms in the downstream sector have higher benefits if they are matched with a more productive supplier. Similarly, firms in the upstream sector have higher benefits if they are matched with a more productive buyer.

III Closed Economy

Taking into account the structure of the economy, I start by showing the equilibrium in a closed economy. To do that, I will show separately firm behavior, optimal consumer choice, and market clearing conditions.

Firm Behaviour

As before, I will start with the upstream sector and the downstream sector. Then, I am going to show the results for the general sector.

If a firm in the upstream sector decides not to adopt the better technology, its variable profits come from selling as a final good to the representative agent:

$$\pi_{u,v}(z_u) = \left(\frac{z_u}{w}\right)^{\sigma-1} \frac{P_u^{\sigma} C_u}{(\sigma-1)} \left(\frac{\sigma-1}{\sigma}\right)^{\sigma}$$

If a firm in the upstream sector decides to adopt, there are two possible outcomes. With positive probability, they are not matched with a firm in the downstream sector. Then:

$$\pi_{u,v}(z_u) = \left(\frac{Z_u^{\gamma} z_u}{w}\right)^{\sigma-1} \frac{P_u^{\sigma} C_u}{(\sigma-1)} \left(\frac{\sigma-1}{\sigma}\right)^{\sigma}$$

In contrast, with probability M_d/M_u^I they are matched with a firm in the downstream sector, and their variable profits are the ones defined in the last subsection. It is easy to show that the expected variable profits of adopting the better technology are higher than the variable profits of not adopting it. In particular, the higher z_u is, the higher the incentives to adopt the better technology. As a result, we can define $\overline{z}_u$ and $\overline{z}_u^I$, the threshold to start producing and the threshold to adopt the better technology respectively:

$$\overline{z}_u^{\sigma-1} = \frac{w^{\sigma} F_u (\sigma-1)}{P_u^{\sigma} C_u} \left(\frac{\sigma}{\sigma-1}\right)^{\sigma}$$

$$(\overline{z}_u^I)^{\sigma-1} = \overline{z}_u^{\sigma-1} \frac{\left[F_u^I - \frac{M_d}{M_u^I}\frac{\alpha}{\sigma-1}\frac{1}{\left[1-\beta-\frac{\sigma}{\sigma-1}\alpha\right]}\frac{\kappa_2}{\kappa_3}\left[F_d + \left(\frac{\overline{z}_d}{\overline{z}_d}\right)^{\theta} F_d^I\right]\right]}{\left[Z_u^{\gamma(\sigma-1)}\left(1 + \frac{M_d}{M_u^I}\left(\frac{\theta A_1(\overline{z}_d, \overline{z}_d^I)}{\theta-\mu(\sigma-1)} - 1\right)\right) - 1\right] F_u}$$

Where $A_1(\overline{z}_d, \overline{z}_d^I) = \left[\overline{z}_d^{\mu(\sigma-1)} + (\overline{z}_d^I)^{\mu(\sigma-1)}\left(\frac{\overline{z}_d}{\overline{z}_d^I}\right)^{\theta}(Z_d^{\gamma\mu(\sigma-1)} - 1)\right]$ captures the intensity of the technology transfer from the downstream sector to the upstream sector. In addition, $\kappa_2 = \theta - \frac{\alpha}{1-\alpha-\beta}$ and $\kappa_3 = \theta - \frac{(1+\mu\alpha)}{1-\alpha-\beta}$. We assume the value of the parameters

such that $\overline{z}_u^I > \overline{z}_u$, i.e. only a subset of the firms that enter the market adopt the better technology. If a firm pays the fixed cost F_u^I and adopts the better technology, it automatically gets the expected profits due to supplying the downstream sector. This is captured by the numerator. In addition, they shift their productivity from z_u to $Z_u^\gamma z_u$. However, there is a second effect on their productivity. With probability M_d/M_u^I, they are going to be matched with a firm in the downstream sector. As a result, they are going to receive technology transfers. These two effects are captured in the denominator. It is easy to show that, if $\mu = 0$, the denominator is simplified to $(Z_u^{\gamma(\sigma-1)} - 1)$.

Similarly, if a firm in the downstream sector does not adopt the better technology, its variable profits are:

$$\pi_{d,v}(z_d, z_u) = B \left(\frac{p_d(z_d)^{1+\mu\alpha}(Z_u^\gamma z_u)^\alpha}{w^{\alpha+\beta}} \right)^{\frac{1}{1-\alpha-\beta}}$$

If it adopts the better technology, variable profits are:

$$\pi_{d,v}(z_d, z_u) = B \left(\frac{p_d(Z_d^\gamma z_d)^{1+\mu\alpha}(Z_u^\gamma z_u)^\alpha}{w^{\alpha+\beta}} \right)^{\frac{1}{1-\alpha-\beta}}$$

As before, given the structure of the economy, there exists $\overline{z}_d$ such that a firm enters the market only if $z_d > \overline{z}_d$, with:

$$\overline{z}_d = \left(\frac{F_d \kappa_2}{\theta B} \right)^{\frac{1}{\tilde{\mu}}} \left(\frac{w}{p_d} \frac{1}{(Z_u^\gamma \overline{z}_u^I)^\alpha} \right)^{\frac{1}{1+\mu\alpha}}$$

We define $\tilde{\mu} = \frac{1+\mu\alpha}{1-\alpha-\beta}$ and $\tilde{\alpha} = \frac{\alpha}{1-\alpha-\beta}$ to simplify notation. Moreover, there exist $\overline{z}_d^I$ such

that a firm adopts the better technology if $z_d > \overline{z}_d^I$, with:

$$\overline{z}_d^I = \overline{z}_d \left(\frac{F_d^I}{\left(Z_d^{\gamma\tilde{\mu}} - 1 \right) F_d} \right)^{\frac{1}{\tilde{\mu}}}$$

We assume that $F_d^I / \left(Z_d^{\gamma\tilde{\mu}} - 1 \right) > F_d$ such that a subset of the firms in the market adopts the better technology.

Finally, I can compute the same thresholds for the general sector. Given that it only uses labor to produce, this sector follows exactly the same structure as in Melitz (2003). As a result, the threshold to enter the market and the threshold to adopt the better technology are:

$$\overline{z}_g = \left[\left(\frac{\sigma}{\sigma - 1} \right)^{\sigma} \frac{(\sigma - 1)}{P_g^{\sigma} C_g} w^{\sigma} F_g \right]^{\frac{1}{\sigma - 1}}$$

$$\overline{z}_g^I = \overline{z}_g \left[\frac{F_g^I}{\left(Z_g^{\gamma(\sigma-1)} - 1 \right) F_g} \right]^{\frac{1}{\sigma - 1}}$$

Firms with productivity $z_g < \overline{z}_g$ do not enter the market, firms with productivity $\overline{z}_g < z_g < \overline{z}_g^I$ enter the market and keep their initial productivity. Finally, firms with productivity $z_g > \overline{z}_g^I$ enter the market and adopt the better technology.

Demand

Given our assumption of representative agent, the household maximize $U(C_u, C_d, C_g) = C_u^{\rho_u} C_d^{\rho_d} C_g^{1-\rho_u-\rho_d}$ such that she satisfies the resource constraint $wL = p_d C_d + P_u C_u + P_g C_g$, where C_d and C_g are decomposed in the standard CES way.

Equilibrium

Given the optimal choice of firms and the representative agent, an equilibrium is characterized by a set of prices $\{P_u, P_g, p_d\}$ and a mass of firms $\{M_u, M_g, M_d\}$ such that ex-ante expected profits are zero (free entry) and markets clear in each sector. In addition, normalizing wages to 1, aggregate spillovers are endogenously determined in each sector. In the downstream sector we have:

$$Z_d^{\gamma} = \left(\int_{\overline{z}_d^I}^{\infty} Z_d^{\gamma} z \, \frac{\theta (\overline{z}_d^I)^{\theta}}{z^{\theta+1}} dz \right)^{\gamma}$$

$$\left(\frac{\theta - 1}{\theta} \right)^{\theta} \frac{F_d^e}{T^{\theta}} \, Z_d^{\theta(1-\gamma)} = \left(\frac{\tilde{\mu}}{\theta - \tilde{\mu}} \right) \left[\left(\frac{F_d^I}{F_d \left(Z_d^{\gamma \tilde{\mu}} - 1 \right)} \right)^{\frac{\theta}{\tilde{\mu}}} F_d + F_d^I \right]$$

It is easy to show that there exists a unique solution $Z_d^{\gamma} > 1$ such that this equality holds. In addition, we have the following proposition.

Proposition 1. *A higher technology diffusion parameter γ implies higher aggregate spillovers. In contrast, the effect of μ on aggregate spillovers depends on θ. If θ is high (low) relative to $\tilde{\mu}$, then aggregate spillovers are lower (higher) when μ increases.*

The next step is finding aggregate spillovers in the upstream sector. To begin, note that a firm adopting the better technology with initial productivity z_u is going to have an expected productivity of:

$$Z_u^{\gamma} z_u \left(1 + \frac{M_d}{M_u^I} \frac{\theta}{\theta + \mu} \left[\overline{z}_d^{\mu} + \left(Z_d^{\gamma \mu} - 1 \right) \left(\overline{z}_d^I \right)^{\mu} \left(\frac{\overline{z}_d}{\overline{z}_d^I} \right)^{\theta} - 1 \right] \right)$$

Then, the aggregate spillover is:

$$Z_u^{1-\gamma} = \frac{\theta}{\theta-1}\overline{z}_u^I \left(1 + \frac{M_d}{M_u^I}\frac{\theta}{\theta+\mu}\left[\overline{z}_d^{\mu} + \left(Z_d^{\gamma\mu}-1\right)\left(\overline{z}_d^I\right)^{\mu}\left(\frac{\overline{z}_d}{\overline{z}_d^I}\right)^{\theta} - 1\right]\right)$$

We do not have an explicit solution for the aggregate spillovers. However, it is easy to show that a higher γ will increase aggregate spillovers as in the downstream sector. In addition, a higher μ reduces the threshold to invest: expected profits of adopting the better technology increase with μ. This effect reduces aggregate spillovers. There is also a direct effect. More technology transfer implies a higher expected productivity for a firm in the upstream sector conditional on adopting the better technology. Moreover, there is also another indirect effect through the probability of matching. A higher μ reduces the probability of a match with a buyer.

Finally, we can show aggregate spillovers in the general sector. Following the same procedure as before, aggregate spillovers are:

$$\left(\frac{\theta-1}{\theta}\right)^{\theta}\frac{F_g^e}{T^{\theta}}\frac{(\theta-\sigma+1)}{\sigma-1}Z_g^{\theta(1-\gamma)} = \left(\frac{F_g^I}{F_g\left[Z_g^{\gamma(\sigma-1)}-1\right]}\right)^{\frac{\theta}{\sigma-1}} F_g + F_g^I$$

IV Trade

Following the structure of the previous section, I introduce trade into the model. To simplify, I assume that there are two countries, denoted as h (home) and f (foreign). Following standard notation, I use x for variable x in the home country and x^* in the foreign country. Firms in sectors u and g can engage in exports.

Entry. — Firms in the downstream and general sector can pay a fixed cost F_d^X and F_g^X

respectively to export to the other country. While the payment is done in terms of labor in the destination country as in Helpman et al. (2004), the symmetry assumption implies that it is the same.

Given the Cobb-Douglas preferences of the representative agent, we can write the gains from trade as $GT = GT_d^{\rho_d} GT_u^{\rho_u} GT_g^{1-\rho_d-\rho_u}$, where GT_i is the ratio between the price level in sector i under autarky divided by the price level in sector i under trade. Starting with the downstream sector, it is easy to show that there exists a threshold $\overline{z}_d^X$ such that a firm exports only if $z_d > \overline{z}_d^X$, with:

$$\overline{z}_d^X = \frac{1}{Z_d^\gamma} \left(\frac{w^* F_d^X \kappa_2}{B\theta} \right)^{\frac{1}{\tilde{\mu}}} \left(\frac{\tau_d w^{\alpha+\beta}}{p_d^*(Z_d^\gamma \overline{z}_d^I)^\alpha} \right)^{\frac{1}{1+\mu\alpha}}$$

In this context, I can show that the gains from trade in the downstream sector are:

$$GT_d = \underbrace{\left(\frac{Z_u}{Z_u^A} \right)^{\gamma\alpha} \left(\frac{\overline{z}_u^I}{\overline{z}_u^{I,A}} \right)^{\alpha}}_{\text{Change in quality}} (\lambda_d^T)^{-\frac{(1+\mu\alpha)}{\theta}} \underbrace{G_d(Z_d, Z_d^A)}_{\text{Externality}}$$

The first term captures the change in the threshold to invest in the upstream sector. From the perspective of firms in sector d, more (less) suppliers adopting the better technology decreases (increases) expected profits. This is captured by the first term. The second term captures the traditional gains from trade as in Arkolakis et al. (2012), where λ_d^T is the domestic trade share. It is worth mentioning that the technology transfer coming from the matching process influences the trade elasticity. Given the assumptions of my model, trade elasticity is lower in comparison with traditional models: while in the standard Melitz model, the elasticity is the Pareto shape parameter θ, here we have $\theta/(1+\mu\alpha)$. Finally, the third term captures the effect of the change in the aggregate spillovers in the composition

of firms adopting vs not adopting the better technology in the sector. In particular:

$$G_d(Z_d, Z_d^A) \equiv \left(\frac{1 + (F_d/F_d^I)^{\frac{\theta}{\tilde{\mu}}-1} \left(Z_d^{\gamma\tilde{\mu}} - 1 \right)^{\frac{\theta}{\tilde{\mu}}}}{1 + (F_d/F_d^I)^{\frac{\theta}{\tilde{\mu}}-1} \left((Z_d^A)^{\gamma\tilde{\mu}} - 1 \right)^{\frac{\theta}{\tilde{\mu}}}} \right)^{\frac{(1+\mu\alpha)}{\theta}}$$

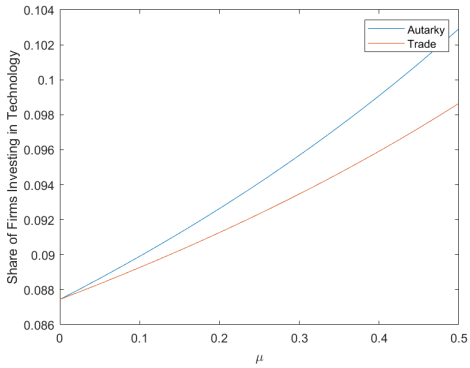
To know if this function G_d is greater or lower than 1, we can calculate aggregate spillovers in equilibrium. Following the same procedure as before:

$$\left(\tfrac{\theta-1}{\theta}\right)^{\theta} \tfrac{F_d^e}{T^\theta} \, Z_d^{\theta(1-\gamma)} = \left(\tfrac{\tilde{\mu}}{\theta-\tilde{\mu}}\right) \left[\left(\frac{F_d^I}{F_d\left(Z_d^{\gamma\tilde{\mu}}-1\right)} \right)^{\frac{\theta}{\tilde{\mu}}} F_d + F_d^I + \underbrace{\left(\frac{(wF_d^I)/(w^*F_d^X)}{Z_d^{\gamma\tilde{\mu}} - 1} \right)^{\frac{\theta}{\tilde{\mu}}} \left(\frac{Z_d^\gamma}{\tau_d^{\frac{1}{1+\mu\alpha}}} \right)^{\theta} w^* F_d^X}_{>0} \right]$$

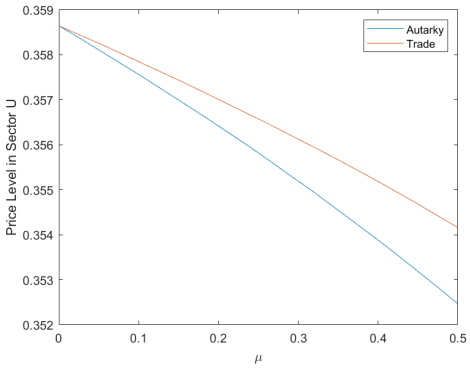
Note that the LHS is the same as in autarky. In addition, the RHS under trade is strictly greater than the RHS under autarky. As a result, it is easy to show that aggregate spillovers are higher under trade.

Proposition 2. *Aggregate spillovers are higher under trade in sector d. As a consequence, the share of firms adopting the better technology is also higher.*

While the gains from trade have a close-form solution for the downstream sector. There is no expression for the upstream sector. To show qualitative results, I set $\theta = 5$, $\sigma = 2$, $\gamma = 0.3$ and show how different values of μ impact the gains from trade in the nontradable sector u:



Share of firms adopting

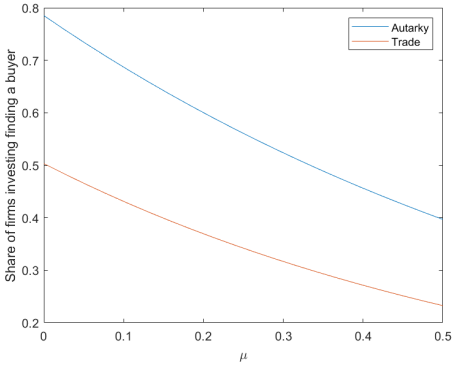


Price Level

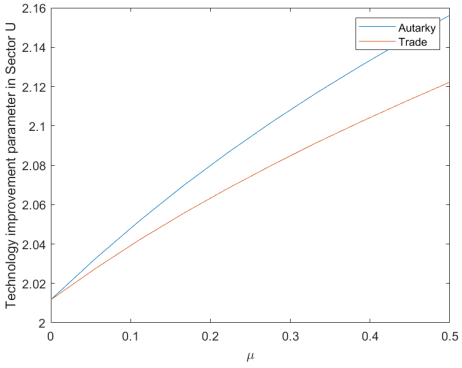
Figure 1: Trade and the Effect of Technology Transfers

Following the last section, I compare a situation where $\tau_d = 1$ (free trade) against a situation where $\tau_d = 50$ (almost closed economy).

Despite these seemingly contradictory results, the explanation is straightforward: the number of firms in sector d has decreased with the liberalization of the economy, and both thresholds in sector d are now higher. Consequently, there are fewer technology transfers to the non-tradable sector. This can be observed in the following graph:



Share of firm's matched



Aggregate spillovers

Figure 2: Trade and the Effect of Technology Transfers

While aggregate spillovers are not internalized by domestic firms, the transfer of technology from buyers to suppliers is internalized by firms in the economy. As a result, the higher the value of μ, the greater the incentives to adopt the better technology and so the lower the aggregate spillovers. In addition, a higher μ reduces the share of firms matched with a buyer. This also reduces aggregate spillovers. Finally, a higher μ implies higher transfers of technology by definition. Therefore, it also implies a higher productivity average within firms that adopt the better technology. This direct effect dominates for these parameters. Furthermore, we can see that the main driver for the losses from trade is the reduction in the share of suppliers in the upstream sector, i.e. the probability of being matched (and receiving the technology transfer) is lower than before.

Finally, we can calculate the gains from trade and the change in aggregate spillovers in the general sector. Given the standard profits of exporting in a Melitz economy, the gains from trade are:

$$\left(\frac{\theta-1}{\theta}\right)^{\theta}\frac{F_g^e(\theta-\sigma+1)}{T^{\theta}(\sigma-1)}(Z_g)^{\theta(1-\gamma)}=$$
$$\left(\frac{F_g^I}{[(\phi_1^s)^{\sigma-1}-1]F_g}\right)^{\frac{\theta}{\sigma-1}}F_g+F_g^I+\left(\frac{F_g^I}{[Z_g^{\gamma(\sigma-1)}-1]F_g^X}\right)^{\frac{\theta}{\sigma-1}}\left(\frac{Z_g^{\gamma}}{\tau_g}\right)^{\theta}F_g^X$$

Given that the last term is greater than 0, $Z_g > Z_g^A$, i.e. aggregate spillovers are higher under trade. This will generate the same mechanisms as in the downstream sector. To conclude, the gains from trade are:

$$GT_g=(\lambda_g^T)^{-\frac{1}{\theta}}\underbrace{G_g(\phi_1^s,\phi_1)}_{>1}$$

We can see that the gains from trade have a simpler expression than the downstream

sector. The first term captures the traditional gains from trade and the second captures the change in the composition of firms adopting the better technology.

V Multinational Production

To demonstrate the impact of the arrival of multinational corporations on the domestic economy, I will abstract from the possibility of exporting and importing. Specifically, a firm can only access the international market by opening a subsidiary in the other country.

Entry. — Firms in the downstream and general sector can pay a fixed cost F_d^M and F_g^M respectively to open an affiliate in the other country. As before, while the payment is done in terms of labor in the destination country as in Helpman et al. (2004), the symmetry assumption implies that it is the same.

Beginning with the downstream sector, it is straightforward to show that there exists a threshold $\overline{z}_d^M$ such that a firm opens an affiliate in the other country if and only if $z_d > \overline{z}_d^M$, where:

$$\overline{z}_d^M = \frac{1}{Z_d^\gamma}\left(F_d^M \frac{\kappa_2}{B\theta}\right)^{\frac{1}{\mu}} \left(\frac{1}{p_d^*}\frac{w^*}{((Z_u^*)^\gamma \overline{z}_u^{I*})^\alpha}\right)^{\frac{1}{1+\mu\alpha}}$$

If a firm opens an affiliate in the other country, it has to use labor and intermediate inputs from the other country to produce. Under symmetry, they are equal to labor and intermediate inputs in the domestic country respectively. Following the same procedure as before, we show the gains from multinational production (GMP) in the downstream sector:

$$GMP_d = \left(\frac{Z_u}{Z_u^A}\right)^{\gamma\alpha} \left(\frac{\bar{z}_u^I}{\bar{z}_u^{I,A}}\right)^{\alpha} \left(\lambda_d^M\right)^{-\frac{(1+\mu\alpha)}{\theta}} G_d(Z_d, Z_d^A)$$

Again, we can see that, despite having a matching mechanism in place, the structure for calculating gains is tractable. In particular, we can decompose the gains from multinational production into the same three components as before. In this case, λ_d^M is the traditional gain from MP as in Ramondo & Rodríguez-Clare (2013). Following the same procedure, I can show that aggregate spillovers under MP are higher than under autarky:

$$(Z_d)^{1-\gamma} = \frac{M_d \left(\frac{\overline{z}_d}{\overline{z}_d^I}\right)^\theta \frac{\theta}{\theta-1}\overline{z}_d^I + M_d^* \left(\frac{\overline{z}_d^*}{\overline{z}_d^{M*}}\right)^\theta \frac{\theta}{\theta-1}\overline{z}_d^{M*} \left(\frac{Z_d^*}{Z_d}\right)^\gamma}{M_d \left(\frac{\overline{z}_d}{\overline{z}_d^I}\right)^\theta + M_d^* \left(\frac{\overline{z}_d^*}{\overline{z}_d^{M*}}\right)^\theta}$$

In the absence of multinationals, we revert to the same formula as in the closed economy case. The presence of multinational corporations, by definition, increases the average productivity of firms that have adopted the best technology. In the symmetric case, $Z_d = Z_d^*$, and therefore the last term is simplified. In the asymmetric case, this term captures the difference in productivity between the two countries. Moreover, we have the following proposition:

Proposition 3. *If $F_d^M = F_d^X$, aggregate spillovers are higher under MP than under Trade.*

The proof of this proposition is straightforward. In a scenario where $\tau_d = 1$, the same amount of firms are going to export if we only allow exports or open affiliates if we only allow MP. Then, the direct impact on the price level is going to be the same. However, in the case of MP, those firms are going to influence directly the aggregate spillover. As a result, the effect on the latter is going to be higher. Note that we are going to have second-order effects: the price level is going to be lower under MP. Consequently, the mass of firms in sector d is lower under MP in comparison with trade.

Similar to the previous section, I continue with the upstream sector. Given the relevance of technology transfer in the sector, the threshold at which firms decide whether to

adopt the new technology or not is now:

$$\left(\overline{z}_u^I\right)^{\sigma-1} = \frac{\left[F_u^I - \frac{\alpha}{\sigma-1}\frac{1}{\left[1-\beta-\frac{\sigma}{\sigma-1}\alpha\right]}\frac{\kappa_2}{\kappa_3}\left[\frac{M_d}{M_u^I}\left(F_g + \left(\frac{\overline{z}_d}{\overline{z}_d^I}\right)^{\theta} F_d^I\right) + \left(\frac{M_d^*}{M_u^I}\left(\frac{\overline{z}_d^*}{\overline{z}_d^{M*}}\right)^{\theta} F_g^M\right)\right]\right]}{\left[(Z_u^{\gamma})^{\sigma-1}\left(1 + \frac{M_d}{M_u^I}\left(\frac{\theta A_1(\overline{z}_d, \overline{z}_d^I)}{\theta-\mu(\sigma-1)} - 1\right) + \frac{M_d^*}{M_u^I}\left(\frac{\overline{z}_d^*}{\overline{z}_d^{M*}}\right)^{\theta}\left(\frac{\theta(Z_d^{\gamma}\overline{z}_d^{M*})^{\mu(\sigma-1)}}{\theta-\mu(\sigma-1)} - 1\right)\right) - 1\right] F_u} \overline{z}_u^{\sigma-1}$$

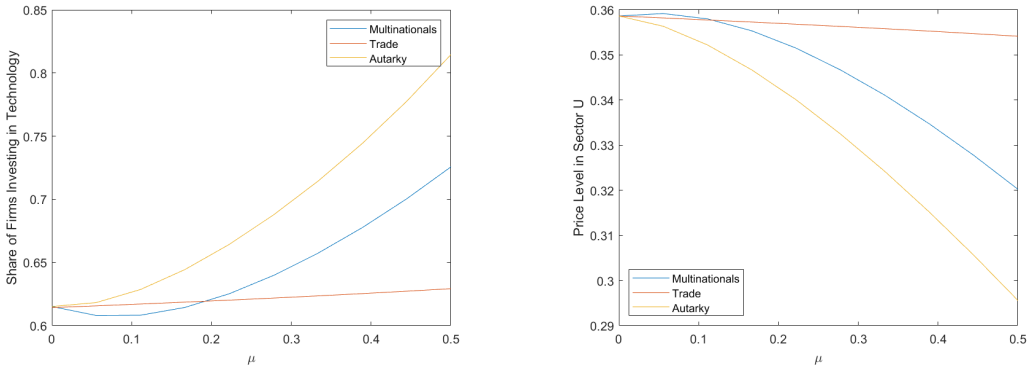
In the symmetric case, the entire effect in the numerator (the change in expected demand) is null. Therefore, the denominator captures the spillover effects. As we saw earlier, if $\mu = 0$, the denominator converges to $Z_u^{\gamma(\sigma-1)} - 1$. However, when $\mu > 0$, multinational corporations affect technology transfer in two ways. First, similar to the case of trade, they reduce the number of domestic firms in the downstream sector. However, this reduction in the mass of firms is higher under MP. Second, multinational corporations generate a direct effect through the technology transfer they give when they are matched with a supplier. With a probability of $\left(\frac{\overline{z}_d^*}{\overline{z}_d^{M*}}\right)^{\theta}\frac{M_d^*}{M_u^I}$, a domestic firm in the upstream sector will receive technology transfers from multinational corporations. Since only the best firms from the other country will open affiliates in the home country, technology transfers will be higher on average even in the symmetric case. Similar to the closed economy, we can calculate aggregate spillovers under MP. The expected productivity of a supplier with initial productivity z_u that adopts the better technology is:

$$Z_u^{\gamma} z_u \left(1 + \frac{M_d}{M_u^I}\frac{\theta}{\theta+\mu}\left[\overline{z}_d^{\mu} + \left(Z_d^{\gamma\mu} - 1\right)\left(\overline{z}_d^I\right)^{\mu}\left(\frac{\overline{z}_d}{\overline{z}_d^I}\right)^{\theta} - 1\right] + \frac{M_d^*}{M_u^I}\left(\frac{\overline{z}_d^*}{\overline{z}_d^{M*}}\right)^{\theta}\left[\left(Z_d^*\right)^{\gamma\mu}\left(\overline{z}_d^{M*}\right)^{\mu} - 1\right]\right)$$

Then, the aggregate spillover is:

$$Z_u^{1-\gamma} = \frac{\theta \overline{z}_u^I}{\theta - 1} \left(1 + \frac{M_d}{M_u^I} \frac{\theta}{\theta + \mu} \left[\overline{z}_d^{\mu} + \left(Z_d^{\gamma\mu} - 1 \right) \left(\overline{z}_d^I \right)^{\mu} \left(\frac{\overline{z}_d}{\overline{z}_d^I} \right)^{\theta} - 1 \right] + \frac{M_d^*}{M_u^I} \left(\frac{\overline{z}_d^*}{\overline{z}_d^{M*}} \right)^{\theta} \frac{\theta}{\theta + \mu} \left[\left(Z_d^* \right)^{\gamma\mu} \left(\overline{z}_d^{M*} \right)^{\mu} - 1 \right] \right)$$

Taking this into account, we simulate the gains from multinational production (MP) in the same way as in the case of trade. To facilitate comparisons, we use $F_d^M = F_d^X$ so that in both cases, we have the same entry cost into the other country (this assumption will be relaxed in the next section when FDI and exports interact). We observe the following behavior:



Share of firms adopting Price Level

Figure 3: Multinational Production and the Effect of Technology Transfers

I assume $\theta = 5$ and $\sigma = 2$. In addition, I assume $\gamma = 0.3$. I introduce a price distortion τ_d as in the Trade Section.

We can see that, if $\mu = 0$, the share of firms investing is the same in each of the three cases. This is because under symmetry the demand effect is the same. If there are no technology transfers, the problem of the suppliers is the same. If $\mu > 0$, the price level is always lower under autarky. The main driver of this result is the reduction in the mass

of firms in the downstream sector. The key assumption that drives this result is that there are positive externalities from any buyer to a supplier, disregarding the fact that the buyer is a national firm or a multinational corporation. Moreover, we can see that the relation between μ and the share of firms adopting in the upstream sector is not monotonic when we consider MP. For low values of μ, the reduction in the probability of being matched with a supplier is more relevant than the new (and low) probability of being matched with a multinational. For μ high, this latter effect dominates and the share of firms adopting start to increase.

Finally, we can show the gains from MP in the general sector. Following the same procedure as before, the gains from MP in the general sector are:

$$GMP_g = \left(\lambda_g^M\right)^{-\frac{1}{\theta}} G_g(Z_g, Z_g^A)$$

Again, the first term is the traditional gains from MP as in Ramondo & Rodríguez-Clare (2013) and the second term captures the change in the share of firms adopting the new technology. Similar to the downstream sector, aggregate spillovers are higher under MP than under autarky. Therefore, $G_g(Z_g, Z_g^A) > 1$.

VI Trade and Multinational Production

To conclude, we can calculate the gains from openness in each sector in a context with trade and MP together. Given the structure of the model as in Helpman et al. (2004), opening an affiliate and exporting are substitutes. A firm can pay a higher fixed cost F^M to open an affiliate and save the variable trade cost τ. In contrast, a firm can pay a lower

fixed cost F^X and pay the variable cost τ. As a result, there exist two thresholds $\overline{z}^X$ and $\overline{z}^M$ such that a firm export if $\overline{z}^X < z < \overline{z}^M$ and a firm open an affiliate if $z > \overline{z}^M$.

Starting with the downstream sector, the threshold to export is the same as in section IV. In addition, a firm opens an affiliate if $z_d > \overline{z}_d^M$ with:

$$\overline{z}_d^M = \frac{1}{Z_d^\gamma}\left(\frac{w^*(F_d^M - F_d^X)}{\left[\left(\frac{((Z_u^*)^\gamma \overline{z}_u^{I*})^\alpha}{(w^*)^{\alpha+\beta}}\right)^{\frac{1}{1-\alpha-\beta}} - \left(\frac{(Z_u^\gamma \overline{z}_u^I)^\alpha}{\tau_d (w)^{\alpha+\beta}}\right)^{\frac{1}{1-\alpha-\beta}}\right]}\frac{\kappa_2}{B\theta_2}\right)^{\frac{1}{\tilde{\mu}}} \frac{1}{(p_d^*)^{\frac{1}{1+\mu\alpha}}}$$

Under symmetry, wages and the quality of the nontradable suppliers are the same in both countries. Then, it is easy to show that:

$$\frac{\overline{z}_d^M}{\overline{z}_d^X} = \left(\frac{(F_d^M - F_d^X)}{F_d^X}\frac{1}{\left(\tau_d^{\frac{1}{1-\alpha-\beta}} - 1\right)}\right)^{\frac{1}{\tilde{\mu}}}$$

If $\tau_d \to 1$, every firm decides to export and there are no multinational firms. This equation is similar to Helpman et al. (2004). The gains from openness in the downstream sector are:

$$GO_d = \left(\frac{Z_u}{Z_u^A}\right)^{\gamma\alpha}\left(\frac{\bar{z}_u^I}{\bar{z}_u^{I,A}}\right)^{\alpha}\left(\lambda_d^M\right)^{-\frac{(1+\mu\alpha)}{\theta}}\left(\lambda_d^{M,D}\right)^{-\frac{(1+\mu\alpha)}{\theta}} G_d(Z_d, Z_d^A)$$

As I mentioned before, the structure of the model allows us to keep a tractable formula for the gains from openness. In particular, we have four different components. First, the change in the suppliers' quality. This is captured by the change in the threshold to adopt in the upstream sector in comparison with autarky and the change in the aggregate spillovers

in the same sector. Second, we have the traditional gains from MP as in Ramondo & Rodríguez-Clare (2013), this is captured by λ_d^M. The third term captures the domestic-output share for the domestic market by domestic firms in sector d. Note that, by definition, $\lambda_d^{M,D} < \lambda_d^T$. In other words, given that foreign multinational corporations only sell to the domestic market in this two-country economy, the domestic trade share is larger than $\lambda_d^{M,D}$. Finally, the last term captures the effect of the change in the composition of firms adopting in sector d. Given that trade and MP separately increase the share of firms adopting, by definition this is also going to happen when we have both effects together.

Furthermore, given that the effect of trade and MP separately in the upstream sector is very similar (but not equal in magnitude), we are going to get the same results as in sections IV and V. Therefore, I continue with the general sector. Similar to the downstream sector, we can define the export and FDI thresholds:

$$\frac{\overline{z}_d^M}{\overline{z}_d^X} = \left[\frac{(F_g^M - F_g^X)}{\left(\left(\frac{w\tau_g}{w^*} \right)^{\sigma-1} - 1 \right)} \right]^{\frac{1}{\sigma-1}}$$

In the symmetric case, we do not need to impose any restriction given $w = w^*$. The intuition for this expression is the same as in the case of the downstream sector. Finally, the gains from openness in this sector are:

$$GO_g = (\lambda_g^{M,D})^{-\frac{1}{\theta}} \left(\lambda_g^M \right)^{-\frac{1}{\theta}} G_g(Z_g, Z_g^A)$$

When comparing the gains from openness in the general sector against the downstream sector, we can observe the impact of considering nontradable suppliers. Firstly, there is an additional term that influences the gains in the current context: the change in the quality

of suppliers. Secondly, we can note that matching influences trade elasticity. This is evident in the exponents of the traditional terms. While in the general sector, it is the conventional $1/\theta$, in the case of the downstream sector, it is $(1 + \mu\alpha)/\theta$. As expected, aggregate spillovers in sector g are higher than under autarky. As a result, the last term is greater than one.

VII Discussion

The new result in the model is that the reduction in variable trade costs or MP costs induce a higher share of active firms to upgrade technology in the tradable but not in the non-tradable sector. While the effect on the tradable sector stems from the change in the aggregate spillover for that sector, the impact on the non-tradable sector arises directly from the firm-to-firm technology transfer that the latter receives and the change in the mass of active firms in the downstream sector.

While the theoretical literature has focused on the macroeconomic effects of trade and multinational production in the context of tradable goods, I have modeled the economy in such a way that I can introduce facts from the empirical literature in a general equilibrium model and I show that the aggregate results can be contradictory with the firm-to-firm facts. While local producers increase their productivity when multinational companies start working with them, i.e. they are not hired as tradable intermediate inputs but interact with them only when they are located in the same country, the exit of domestic buyers in the tradable sector has a negative impact on nontradable suppliers. As a result, the impact in the nontradable sector is negative. The key mechanism behind this result is that technology transfers from buyers to suppliers are independent of the origin country of the

firm. In addition, the fact that this transfer of technology happens at no cost implies that every buyer transfers technology when they are matched, and so suppliers are affected by the reduction in the mass of firms even in the case that the exit happens in the left tail of the distribution. This implies that, if we model firm-to-firm technology transfers in another way, results could change dramatically.

VIII Conclusion

The model developed in this paper suggests that the gains from trade and multinational production are higher in the tradable sectors when we allow technology choice in the context of aggregate spillovers and firm-to-firm technology transfers. In addition to this, I showed that in a context where firms can invest in improving their productivity, distinguishing between firm-to-firm technology transfers and aggregate spillovers is relevant. While the latter is exogenous from the firm's perspective, the former is partially internalized. The fact that both buyers and suppliers are aware of how their benefits change and consider that suppliers increase their productivity when matched with a buyer influences decision-making in terms of technology choice. In addition, I show that adding nontradable suppliers and a one-to-one random match with technology transfers between buyers and suppliers implies that the trade elasticity is lower than in traditional models. Furthermore, it is the parameter of technology transfer intensity that propels the reduction in trade elasticity.

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