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FDI VS. EXPORTS: ACCOUNTING FOR DIFFERENCES IN EXPORT-SALES INTENSITIES

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Resumen

Datos a nivel de industrias muestran diferencias sectoriales marcadas en la relación entre exportaciones y ventas de multinacionales. Nosotros identificamos lo que es necesario para generar endógenamente estos patrones de exportaciones y ventas de multinacionales. Calibrando un modelo de competencia monopolística, encontramos que diferencias en costos de transporte de los bienes no son suficientes para capturar las diferencias sectoriales observadas, como se asume generalmente. Exploramos variantes al modelo básico y mostramos que impuestos sectoriales específicos a las ventas de multinacionales y *home bias* nos permiten replicar dichas diferencias.

Abstract

Industry level data shows striking differences among sectors in ratios of exports to FDI sales. We determine what is needed to endogenously generate this pattern of export and FDI sales. By calibrating a model of monopolistic competitive firms, we find that tradability of goods is not enough to capture the observed sectoral differences, as is commonly assumed. We explore variants of the model and show that sector-specific taxes on multinationals and home bias allow us to replicate these differences.

We would like to thank the participants of the Trade and Development Workshop at the University of Minnesota for their invaluable comments. All remaining errors are ours. Contact author: Miguel Ricaurte. División de Estudios, Banco Central de Chile, Agustinas 1180, Santiago, Chile. Phone: + (56 2) 670 2895.
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1 Introduction

Industry level data shows striking differences in the choice to serve foreign markets through exporting versus through selling goods produced by a foreign affiliate (what we call FDI sales). Only recently has the "new trade theory" literature addressed this issue. Building on Melitz (2003), Helpman et al. (2004) show that models of monopolistic competition can capture firms' choice of foreign market servicing. These authors use reduced-form regression analysis to show that differences in the form of foreign market servicing across sectors can be explained by product tradability (how easy it is to actually trade/ship a product), fixed setup costs and firm productivity dispersion.

In this paper we identify varying aspects of the trade and FDI sale choice (*e.g.*, tradability and home bias) that explain the endogenous (and large) sectoral differences in the choices of exports and FDI sales that Helpman et al. (2004) and others have empirically documented. We derive a general equilibrium model of monopolistic competition where firms choose to service a market through either exports or a foreign affiliate. The model is a multi-country and multi-sector model where, using sectoral data on bilateral trade, FDI sales, employment and costs, we test whether the tradability of goods can capture the observed variations described above. We find that a measure of tradability alone is not enough to determine the ratio of exports to FDI sales.

Figure 1.1 shows the relationship between the tradability index we construct (where a higher index value implies the good is less tradable, as explained in Section 5) and the ratio of exports to FDI sales. The graph on the right omits the outlier sector of *Petroleum and Coal Products*. It is evident that no strong relationship between the form of service ratio and the tradability index exists. Moreover, Figure 1.2 shows there is no direct relationship between the index and total sector sales.

We argue that by allowing for other dimensions of the model to be sector-specific, we can improve its explanatory power. To do so, we discuss five different variants on a model of monopolistic competition, where we allow for elements such as sector-specific fixed costs, sector-specific firm productivity dispersion, sales taxes, and home product bias in the utility function. We find that sector-specific fixed costs and productivity dispersion are not sufficient to explain the observed differences in exports and FDI sales. However, sector-specific sales taxes on the operations of foreign affiliates and sector-specific home product bias allow us to do so. The latter provides more realistic results because the sales tax model requires

Figure 1.1: Exports / FDI sales vs. tradability index.

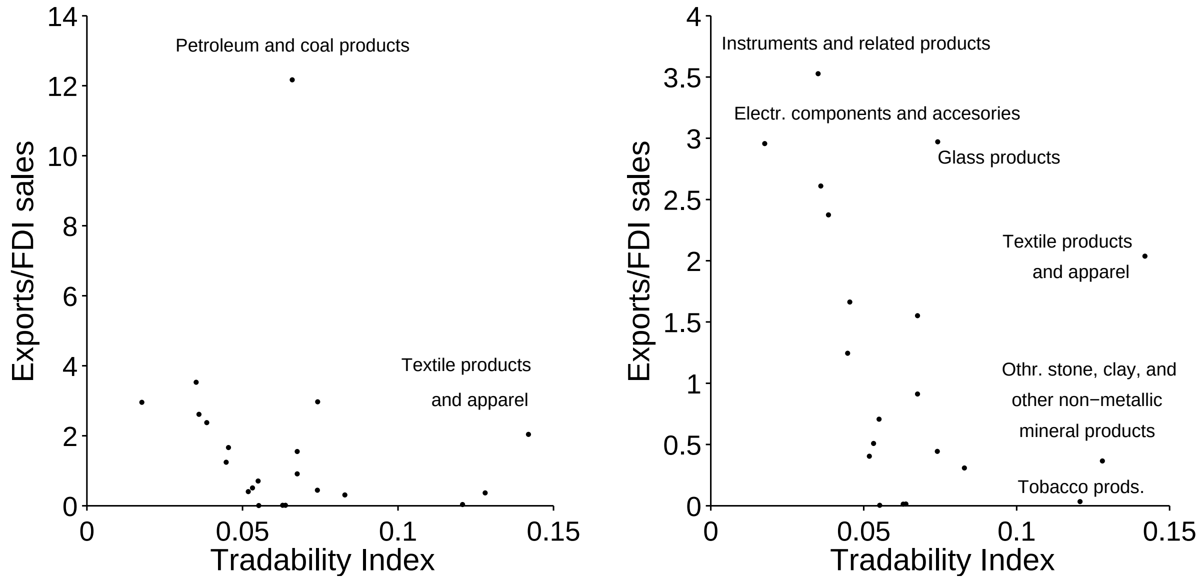
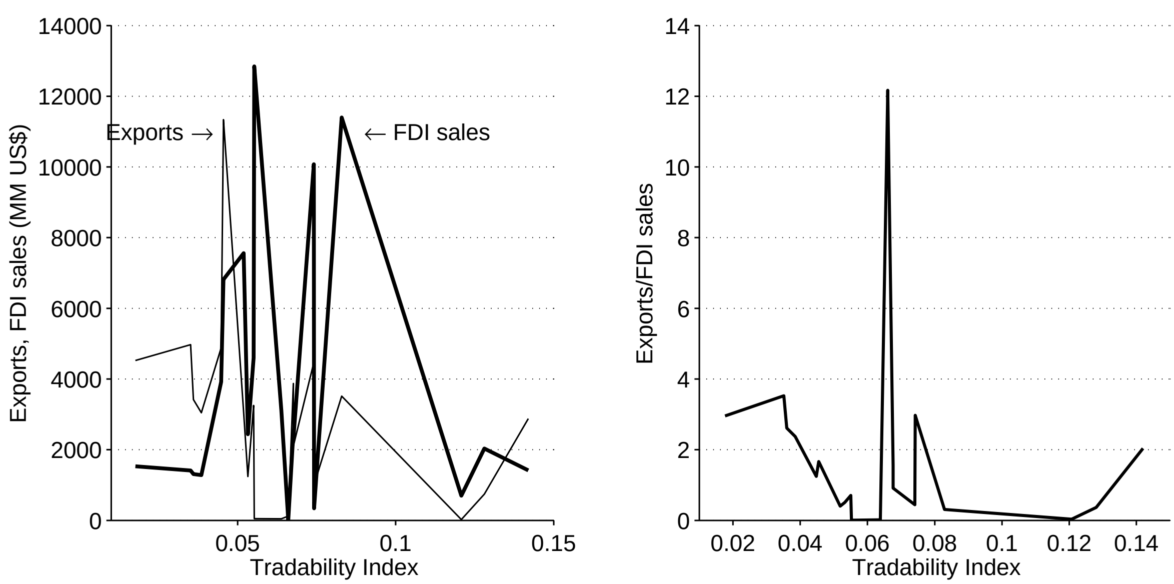


Figure 1.2: FDI sales, exports, and exports/FDI sales ratio.



implausible rates in some sectors of the economy.

The rest of the paper is organized as follows. Section 2 presents the background and motivation and discusses the related literature. In section 3, we develop the model and characterize the equilibrium of the economy. Comparative statics, discussed in section 4, explore the elements of the model that can explain foreign market servicing differences. Section 5 describes the data used in the numerical experiments presented in section 6. Finally, we draw concluding remarks in section 7.

2 FDI and the "new trade theory"

This paper is part of a literature which studies foreign production and foreign market servicing going back to Mundell (1957) and Dunning (1973). In these classical papers, trade and factor mobility (*e.g.*, investment abroad) are studied as alternative forms of foreign market servicing. Having a common starting point, the literature on foreign direct investment diverted into two clearly differentiated streams.

The first branch sought to understand the impact foreign direct investment (FDI) on the host economy rather than on the alternatives of foreign market servicing. Saggi (2002) surveys the impact of FDI-friendly policies and their impact in terms of technology transfer from developed (source) to developing (host) economies, and concludes that at the aggregate level there is a positive impact of FDI on growth of the host economy. Alternatively, Alfaro and Rodriguez-Clare (2004) find no conclusive evidence of the externalities or spillovers of multinationals on local economies; except when the degree of development of the host financial markets is taken into account (see Alfaro et al. (2004) and Alfaro et al. (2009), for example).

Our paper follows the second branch of the literature which is concerned with the choice foreign market servicing. This literature, thoroughly discussed in Markusen (2004) and Brakman and Garretsen (2008), studies foreign direct investment from an industrial organization point of view. Often referred to as "new trade theory," it explores the role of firm characteristics in foreign market servicing choices. While Dunning (1973) was the first to address the importance of ownership, location, and internalization of production processes, Dixit and Stiglitz (1977) are the ones who formalize the behavior of firm's production decisions. Helpman (1984) took the next step by modeling firms whose headquarters are in a different location from that of where production takes place, proposing the first framework for multinational corporations.

More recently, Melitz (2003) extended the monopolistic competition model of Dixit and Stiglitz (1977) to explain the impact of trade on intra-sector reallocations and changes in aggregate productivity. However, his model became more successful in the trade literature, examples of which are Helpman et al. (2004), Chaney (2005; 2006), and Arkolakis (2008). The first of these papers extends Melitz's model to allow active firms to choose between servicing the "local" market only and servicing local and foreign markets, the latter through exports or foreign affiliates, which brings us to our model.

In this paper we discuss the importance of heterogenous firms that compete in a monopolistic competition fashion in explaining the choices between serving foreign markets through exports versus FDI sales. One important assumption we make is that these two options are mutually exclusive. Blonigen (2001) documents this regularity using Japanese data. Moreover, we set up a model where horizontal FDI is the only option available to firms (*i.e.*, the whole production process is carried out through a foreign subsidiary). Although more general frameworks like Markusen (2004) allow for both horizontal and vertical FDI to coexist, we justify our decision on two criteria. The question in our paper is how do firms service foreign markets (and hence how is differing composition across sectors determined) and not how is the production process determined. Hence, in our model firms cannot choose to outsource parts of the production process, but rather choose among different alternatives of (foreign) market servicing. Additionally, Carr et al. (2001) suggests that horizontal FDI is empirically more relevant that the vertical counterpart.

Our paper builds on Helpman et al. (2004), which uses differences in fixed setup costs, as well as marginal and transportation costs to induce different choices among firms.[1] Important features of this model that we discuss later are:

(1) among firms which choose to service the foreign market, the most efficient ones engage in FDI and the least efficient, in exports;

(2) firm level heterogeneity in productivity adds an important dimension to the tradeoff between exports and FDI: *ceteris paribus*, sectors with higher dispersion in productivity have lower relative export sales (and higher FDI sales);

[1] Nocke and Yeaple (2007) extend the discussion to consider the choice between mergers and acquisitions (M&A) and greenfield FDI, which is outside the scope of this paper.

(3) when the tradability index (transportation costs in their model) varies between sectors, they find that sectors with high transport costs have lower relative export sales.

3 Benchmark model

This is an n-country model of differentiated firms making foreign market servicing decisions. A representative consumer in each country chooses consumption over the goods available in her country. Goods are produce by firms which choose whether to produce domestically and abroad. The latter decision involves choosing between exporting or engaging in FDI operations (*i.e.*, production thorough a foreign subsidiary). In what follows, we discuss the economy in detail.

3.1 Consumer's problem

The representative consumer in country i is endowed with L^i units of labor that are inelastically supplied every period and consumes a composite good:

$$C_t^i \leq \left(\int_\omega \left[\alpha^i(\omega) x_t^i(\omega) \right]^\rho d\omega \right)^{\frac{1}{\rho}}.$$

where $x_t^i(\omega)$ is consumption of each differentiated good ω and $\alpha^i(\omega)$ is the good-specific utility weight. The consumer maximizes her inter-temporal utility of consumption:

$$U^i = \sum_{t=0}^{\infty} \beta^t C_t^i;$$

subject to her budget constraint:

$$\int_\omega p_t^i(\omega) x_t^i(\omega) d\omega \leq w_t^i l_t^i + \Pi_t^i; \ \forall t,$$

where Π^i are profits of the set Ω^i of monopolistic firms owned by the consumer's country:

$$\Pi_t^i = \int_\omega \pi_t^i(\omega).$$

We make the standard assumption that $\rho \in (0,1)$. This restriction in parameters guarantees that we can aggregate consumption and endowments and solve the problem of a representative consumer in each country.

First order necessary conditions yield the demand for differentiated good $x^i(\omega)$:

$$x^i(\omega) = Y^i \left(\frac{p^i(\omega)}{\alpha^i(\omega)^\rho P^i} \right)^{\frac{1}{\rho-1}}, \tag{3.1}$$

where

$$Y^i = \left(\int_\omega \left[\alpha^i(\omega) x^i(\omega) \right]^\rho d\omega \right)^{\frac{1}{\rho}}, \tag{3.2}$$

$$P^i = \left(\int_\omega \left[\frac{p^i(\omega)}{\alpha^i(\omega)} \right]^{\frac{\rho}{\rho-1}} d\omega \right)^{\frac{\rho-1}{\rho}}, \tag{3.3}$$

are aggregate consumption and prices in country i, respectively. For notational simplicity, we omit t as the equations are the same each period.

3.2 Firm's problem

In each country there is a continuum of firms producing differentiated goods. Each firm draws two distinguishing qualities:

(1) productivity level φ, where higher φ implies higher productivity. $\varphi \in (1,\infty)$ is distributed Pareto;

(2) tradability index τ, representing the ease of international trade, where higher τ implies the good is less tradable; $\tau \in (1,\infty)$; the probability of observing τ is $q(\tau)$.

A firm producing good ω is identified by the pair (φ, τ).

Firms that enter the domestic market (d) must pay a fixed entry cost f_e prior to observing their realizations of φ and τ. If they remain in the market, they pay a fixed operational cost f_d. These firms may service foreign markets by choosing between exporting (x) and FDI (m). If they do so, firms have to pay a fixed entry cost which differs for each option of foreign market servicing (f_{ex}, to engage in exports; f_{em}, to engage in multinational operations).

Given there is no uncertainty in our model, once a firm enters the market, it will never choose to exit. There is, however, an exogenous firm death rate ($\hat{\delta} \in (0, 1)$) that bounds the value of entering the market.

As in Melitz (2003), the foreign market servicing decision is taken after a firm knows its type (φ, τ). Hence, firms are indifferent between paying a one-time entry cost (f_{ex} or f_{em}) or making per-period payments (δf_{ex} or δf_{em}), where $\delta \equiv (1 - \hat{\delta})\beta$ and β is the time discount factor.[2] For convenience we assume the latter and define:

$$f_x \equiv \delta f_{ex}$$
$$f_m \equiv \delta f_{em}$$

as the per-period fixed costs for exports (x) and multinational operations (m), respectively.

Labor is the only factor of production. The technology is determined by labor input functions that are linear in output

$$l = \frac{y}{\varphi} + f_k, \quad \text{for } k \in \{d, m\},$$
$$l = \frac{y}{\varphi}\tau + f_x,$$

where in the case of exports, the tradability index is interpreted as an iceberg cost that requires more labor be devoted to production. Marginal production costs and entry costs are paid in labor units.

For simplicity we assume international markets are segmented to preclude arbitrage of goods from occurring. Hence, we exclude the option to reexport and multinational subsidiaries cannot export their production. Hence, firm (φ, τ) maximizes profits in each market independently:

[2] This comes from the fact that the discounted present value of a per-period payment is:

$$f_e = \sum_{t=0}^{\infty} ((1 - \hat{\delta})\beta)^t f = \sum_{t=0}^{\infty} (1 - \delta)^t f = \frac{f}{\delta}.$$

$$
\begin{aligned}
\pi_d^i(\varphi,\tau) &= p_d^i(\varphi,\tau)y_d^i(\varphi,\tau) - w^i l_d^i(\varphi,\tau),\\
\pi_x^j(\varphi,\tau) &= p_x^j(\varphi,\tau)y_x^j(\varphi,\tau) - w^i l_x^i(\varphi,\tau),\\
\pi_m^j(\varphi,\tau) &= p_m^j(\varphi,\tau)y_m^j(\varphi,\tau) - w^j l_m^j(\varphi,\tau).
\end{aligned}
\tag{3.4}
$$

Firms have market power arising from the fact that they produce differentiates goods. Hence, given Bertrand competition and using the demand functions arising from the consumer's problem, the first order conditions yield pricing rules for goods sold in the domestic and foreign markets under each mode of servicing:

$$
\begin{aligned}
p_d^i(\varphi,\tau) &\leq \frac{w^i}{\rho\varphi}; \quad = \frac{w^i}{\rho\varphi} \quad \text{if} \quad y_d(\varphi,\tau) > 0,\\
p_x^j(\varphi,\tau) &\leq \frac{w^i\tau}{\rho\varphi}; \quad = \frac{w^i\tau}{\rho\varphi} \quad \text{if} \quad y_x(\varphi,\tau) > 0,\\
p_m^j(\varphi,\tau) &\leq \frac{w^j}{\rho\varphi}; \quad = \frac{w^j}{\rho\varphi} \quad \text{if} \quad y_m(\varphi,\tau) > 0.
\end{aligned}
\tag{3.5}
$$

For a draw of φ and τ, a firm will:

- enter the local market when
$$\pi_d^i(\varphi,\tau) \geq 0;$$
- service a foreign market j through exports when
$$\pi_x^j(\varphi,\tau) \geq \max\{0, \pi_m^j(\varphi,\tau)\};$$
- service a foreign market j through FDI when
$$\pi_m^j(\varphi,\tau) \geq \max\{0, \pi_x^j(\varphi,\tau)\}.$$

3.3 Feasibility and market clearing

Given prices $\{P^i\}$, wages $\{w^i\}$, and our assumption on market segmentation, in each country i, good type (φ, τ), and servicing option $k \in \{d, x, m\}$, goods markets clear when:

$$y_k^i = x_k^i.$$

Let Ω_k^i be the set of (φ, τ)-firms in country i that are actively producing for market $k \in \{d, x, m\}$. We assume that all countries have the same distributions for τ and φ. Thus, the labor market clearing condition in country i is:

$$\begin{aligned}
L^i &= \int_{(\varphi,\tau)\in\Omega_d^i} l_d^i(\varphi,\tau)dG(\varphi)dF(\tau) + \int_{(\varphi,\tau)\in\Omega_x^i} l_x^i(\varphi,\tau)dG(\varphi)dF(\tau) \\
&\quad + \sum_j \int_{(\varphi,\tau)\in\Omega_m^j} l_m^i(\varphi,\tau)dG(\varphi)dF(\tau) + M_e f_e \\
&= \int_{(\varphi,\tau)\in\Omega_d^i} \left[\frac{y_d(\varphi,\tau)}{\varphi} + f_d\right] dG(\varphi)dF(\tau) + \int_{(\varphi,\tau)\in\Omega_x^i} \left[\frac{\tau}{\varphi} y_x(\varphi,\tau) + f_x\right] dG(\varphi)dF(\tau) \\
&\quad + \sum_j \int_{(\varphi,\tau)\in\Omega_m^j} \left[\frac{y_m(\varphi,\tau)}{\varphi} + f_m\right] dG(\varphi)dF(\tau) + M_e f_e, \qquad (3.6)
\end{aligned}$$

where M_e is the mass of entrant firms.

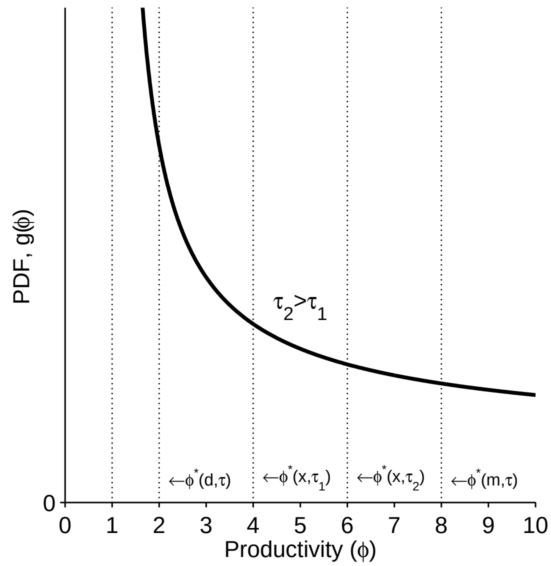
3.4 Productivity and cutoff functions

The solution to this model can be represented by the aggregate price level $\{P\}$ and three cutoff functions: $\{\varphi_d^*(\tau), \varphi_x^*(\tau), \varphi_m^*(\tau)\}$. The cutoff functions $\varphi_k^*(\tau)$ come from the zero profit conditions for each servicing scheme, given by equations (3.4). Hereafter, for notational simplicity, we write all functions of τ as: $z_\tau(\cdot) \equiv z(\tau;\cdot)$.[3] Notice we also assume that countries are symmetric, which implies prices and other aggregate variables are common across countries.

These cutoff functions segment firms into the different options of production. The segmentation within each tradability type τ, which we formally derive below, is as follows: the

[3] This is especially useful when we switch to discrete values for τ later on. Then $\alpha_\tau(\omega) = \alpha(\varphi, \tau)$ is not a function of τ, but identified according to each good ω and corresponding τ.

Figure 3.1: Cutoff values



lowest productivity group for each τ, upon paying the entry cost and realizing they are unprofitable, chooses not to produce. The firms with middle productivity will only serve the domestic market. The firms with highest productivity choose to serve the foreign market. Among this group of firms, the most productive do so through FDI sales. This is a standard assumption in the literature (see Helpman et al. (2004)). The cutoff conditions are depicted in Figure 3.1.

Cutoff equations

Let revenues be $r^i_{k,\tau}(\varphi) \equiv p^i_{k,\tau}(\varphi) y^i_{k,\tau}(\varphi)$, such that firm profits (3.4) become:

$$\begin{aligned} \pi^i_{d,\tau}(\varphi) &= r^i_{d,\tau}(\varphi)(1-\rho) - w^i f_d \\ \pi^j_{x,\tau}(\varphi) &= r^j_{x,\tau}(\varphi)(1-\rho) - w^i f_x \\ \pi^j_{m,\tau}(\varphi) &= r^j_{m,\tau}(\varphi)(1-\rho) - w^j f_m \end{aligned} \tag{3.7}$$

From (3.1), we obtain expressions for firm revenues:

$$
\begin{aligned}
r^i_{d,\tau}(\varphi) &= R\left(\frac{P\rho\varphi\alpha^i(\varphi,\tau)}{w^i}\right)^{\frac{\rho}{1-\rho}} \\
r^j_{x,\tau}(\varphi) &= R\left(\frac{P\rho\varphi\alpha^j(\varphi,\tau)}{w^i\tau}\right)^{\frac{\rho}{1-\rho}}, \\
r^j_{m,\tau}(\varphi) &= R\left(\frac{P\rho\varphi\alpha^j(\varphi,\tau)}{w^j}\right)^{\frac{\rho}{1-\rho}}
\end{aligned}
\tag{3.8}
$$

where $R = PY$. To obtain the cutoff equations we substitute (3.8) into (3.7) and set them equal to zero:

$$
\begin{aligned}
(1-\rho)R\left(\frac{P\rho\varphi\alpha^i(\varphi,\tau)}{w^i}\right)^{\frac{\rho}{1-\rho}} - w^i f_d = 0 \\
(1-\rho)\,R\left(\frac{P\rho\varphi\alpha^j(\varphi,\tau)}{w^i\tau}\right)^{\frac{\rho}{1-\rho}} - w^i f_x = 0 \\
(1-\rho)\,R\left(\frac{P\rho\varphi\alpha^j(\varphi,\tau)}{w^j}\right)^{\frac{\rho}{1-\rho}} - w^j f_m = 0
\end{aligned}
\tag{3.7$'$}
$$

so that we have:

$$
\begin{aligned}
\varphi^*_{d,\tau} &= \left(\frac{w^i f_d}{(1-\rho)R}\right)^{\frac{1-\rho}{\rho}} \frac{w^i}{P\rho\alpha^i(\varphi^*_{d,\tau})}; \\
\varphi^*_{x,\tau} &= \left(\frac{w^i f_x}{(1-\rho)R}\right)^{\frac{1-\rho}{\rho}} \frac{w^i\tau}{P\rho\alpha^j(\varphi^*_{x,\tau})}; \\
\varphi^*_{m,\tau} &= \left(\frac{w^j f_m}{(1-\rho)R}\right)^{\frac{1-\rho}{\rho}} \frac{w^j}{P\rho\alpha^j(\varphi^*_{m,\tau})}.
\end{aligned}
\tag{3.9}
$$

Recall we assume that for each τ, among the firms servicing foreign markets, the least efficient choose to export and the most efficient engage en FDI sales.[4] For this assumption to follow, we must impose conditions on fixed costs, which can be trivially derived from (3.9):

[4] This relationship is reported in other countries as well: Buch et al. (2005) and Wagner (2006) find this is the case on German firms; Head and Ries (2003) do so for Japanese firms. We explore variations of this assumption.

$$f_x > f_d \left(\max\left\{ \tfrac{\tau\alpha_d}{\alpha_x} \right\} \right)^{\frac{\rho}{\rho-1}} \qquad \Leftrightarrow \quad \varphi^*_{d,\tau} < \varphi^*_{x,\tau},\ \forall \tau$$

$$f_m > f_x \tfrac{w^i}{w^j} \left(\tfrac{w^i}{w^j} \max\left\{ \tfrac{\tau\alpha_m}{\alpha_x} \right\} \right)^{\frac{\rho}{1-\rho}} \quad \Leftrightarrow \quad \varphi^*_{x,\tau} < \varphi^*_{m,\tau},\ \forall \tau.$$

We can see in Figure 3.1 that for higher τ (implying the good is less tradable), fewer firms will find it profitable to export and the cutoff $\varphi^*_{x,\tau_1} < \varphi^*_{x,\tau_2}$ for $\tau_2 > \tau_1$.

Entry condition and average productivity

Firms entering the market pay a fixed labor cost f_e. Hence entry is conditional on the discounted present value of profits being greater than or equal to the entry cost. A general expression for the value of entry v_e is

$$\begin{aligned} v_e &= E_\tau \left\{ \mu_{e,\tau} \left(\sum_{t=0}^{\infty} (1-\delta)^t \int_0^\infty \pi_\tau(\varphi) g(\varphi) d\varphi \right) \right\} - w^i f_e \\ &= E_\tau \left\{ \mu_{e,\tau} \left(\frac{1}{\delta} \frac{1}{1-G(\varphi^*_\tau)} \int_{\varphi^*_\tau}^\infty \pi_\tau(\varphi) g(\varphi) d\varphi \right) \right\} - w^i f_e \\ &= E_\tau \left\{ \mu_{e,\tau} \frac{\overline{\pi}_\tau}{\delta} \right\} - w^i f_e \\ &= \sum_\tau \left\{ q_\tau \mu_{e,\tau} \frac{\overline{\pi}_\tau}{\delta} \right\} - w^i f_e, \end{aligned}$$

where $\mu_{e,\tau} \equiv 1 - G(\varphi^*_{d,\tau})$ is the probability of entry. Profit $\pi_\tau(\varphi)$ is:

$$\pi_\tau(\varphi) = \pi^i_{d,\tau}(\varphi) + \max\{0, \pi^i_{x,\tau}(\varphi), \pi^i_{m,\tau}(\varphi)\},$$

and $\overline{\pi}_\tau$ is the *ex-ante* expected profit for a given τ.

Let $\tilde{\varphi}_{k,\tau}(\varphi^*_{k,\tau})$ be the average productivity of firms with index of tradability τ, conditional on engaging in activity k (domestic production, exports, or FDI sales):

$$\tilde{\varphi}_{k,\tau}(\varphi^*_{k,\tau}) = \left[\frac{1}{1-G(\varphi^*_{k,\tau})} \int_{\varphi^*_{k,\tau}}^\infty \varphi^{\frac{\rho}{1-\rho}} g(\varphi) d\varphi \right]^{\frac{1-\rho}{\rho}}, \tag{3.10}$$

where $\varphi^*_{k,\tau}$ is the productivity of the marginal entrant with τ. For notational simplicity, we will refer to $\tilde{\varphi}_{k,\tau}(\varphi^*_{k,\tau})$ as $\tilde{\varphi}_{k,\tau}$.

Productivity φ is drawn randomly from a Pareto distribution with:

$$\text{CDF:}\quad G(\varphi) = 1 - \left(\tfrac{b}{\varphi}\right)^a, \quad \text{and} \quad \text{PDF:}\quad g(\varphi) = \tfrac{ab^a}{\varphi^{a+1}},$$

where b is the lower support of the distribution and a determines the shape of the distribution. Given this distribution, for a firm engaged in $k \in \{d, x, m\}$ with tradability index τ, (3.10) becomes:

$$\tilde{\varphi}_{k,\tau} = \varphi^*_{k,\tau} \left(\frac{a}{a - \frac{\rho}{1-\rho}} \right)^{\frac{1-\rho}{\rho}}. \tag{3.11}$$

We calculate average profits $\overline{\pi}_{k,\tau}$ given index τ and mode of servicing k by integrating (3.7′) over φ. It is trivial to show that average profit for firms with index τ engaged in market servicing $k \in \{d, x, m\}$ calculated this way is equal to the profits of the average producer with that tradability index servicing market k:

$$\bar{\pi}_{k,\tau} = \pi_{k,\tau}(\tilde{\varphi}_{k,\tau}),\ k \in \{d, x, m\},$$

We can rewrite the equilibrium entry condition as:

$$\begin{aligned} \sum_\tau q_\tau \left\{ (1 - G(\varphi^*_{d,\tau}))\overline{\pi}_{d,\tau} + (1 - G(\varphi^*_{x,\tau}))\overline{\pi}_{x,\tau} + (1 - G(\varphi^*_{m,\tau}))\overline{\pi}_{m,\tau} \right\} &= \delta w^i f_e \\ (1 - G(\varphi^*_d))\overline{\pi}_d + (1 - G(\varphi^*_m))\overline{\pi}_m + \sum_\tau q_\tau (1 - G(\varphi^*_{x,\tau}))\overline{\pi}_{x,\tau} &= \delta w^i f_e \end{aligned} \tag{3.12}$$

Equations (3.9) and (3.12) complete the characterization of our equilibrium.

4 Qualitative predictions

In this section, we show that we cannot use this "type" of model to reach an unequivocal conclusion about the relationship between the ratio of exports to FDI sales and tradability. Nevertheless, we show that under certain conditions, tradability and home bias can reproduce sectoral patterns observed in the data. We do so by discussing how productivity cutoffs are affected by changes in τ and α. To do so, we identify each sector by the average tradability τ of its firms (which will later be computed from the data). We look at the comparative statics for changes in a good's tradability index within sector τ and between two sectors τ and $\hat{\tau}$, as well as changes in the utility function weights α.

For computational purposes, we assume there is a discrete number S of τ's ($i.e.$, a discrete number of sectors identified by their tradability index). To simplify notation, let $\alpha(\varphi_{k,\tau}, \tau) = \alpha_{k,\tau}$. Let Ψ be the vector of parameters, $\Psi = \Big\{\{\tau_1, ...\tau_S\}, \big\{\{\alpha_{k,\tau_i}, f_{k,\tau_i}\}_{i=1}^{S}\big\}_{k=\{d,x,m\}}\Big\}$. In equilibrium we can write any function of τ as:

$$z_k(\tau) = z_{k,\tau}(\Psi).$$

From the zero profit condition and (3.9), we have a relationship between average profit and the cutoff productivities such that

$$\pi_k(\varphi^*_{k,\tau}(\Psi)) = 0 \;\Leftrightarrow\; \pi_k(\tilde{\varphi}_{k,\tau}(\Psi)) = f_k h(\varphi^*_{k,\tau}(\Psi)),\; \forall k \in \{d, x, m\},$$

where for each sector τ and mode of servicing k,

$$h(\varphi^*_{k,\tau}(\Psi)) = \left(\frac{\tilde{\varphi}_{k,\tau}(\Psi)}{\varphi^*_{k,\tau}(\Psi)}\right)^{\frac{\rho}{1-\rho}} - 1. \tag{4.1}$$

Additionally, for each τ define

$$j(\varphi^*_{k,\tau}(\Psi)) \equiv [1 - G(\varphi^*_{k,\tau}(\Psi))]h(\varphi^*_{k,\tau}(\Psi)). \tag{4.2}$$

Equation (4.2) decreases with the tradability index, as shown by its partial derivative:

$$\frac{\partial j(\varphi^*_{k,\tau}(\Psi))}{\partial \tau} = -\frac{1}{\varphi^*_{k,\tau}(\Psi)}\left(\frac{\rho}{1-\rho}\right)[1 - G(\varphi^*_{k,\tau}(\Psi))][1 + h(\varphi^*_{k,\tau}(\Psi))] < 0. \tag{4.3}$$

Using (4.2), we rewrite the entry condition (3.12) as

$$f_d j(\varphi^*_{d,\tau}(\Psi)) + f_m j(\varphi^*_{m,\tau}(\Psi)) + \sum_{\tau} q_\tau f_x j(\varphi^*_{x,\tau}(\Psi)) = \delta f_e, \tag{4.4}$$

and from (3.9) we obtain the cutoff productivity levels for firms producing domestically, exporting, and engaging in FDI sales, respectively:

$$\begin{aligned}
\varphi^*_{x,\tau}(\Psi) &= \varphi^*_{d,\tau}(\Psi)\tau \left(\frac{f_x}{f_d}\right)^{\frac{1-\rho}{\rho}} \frac{\alpha^i_{d,\tau}}{\alpha^i_{x,\tau}}, \\
\varphi^*_{x,\hat{\tau}}(\Psi) &= \varphi^*_{d,\tau}(\Psi)\hat{\tau} \left(\frac{f_x}{f_d}\right)^{\frac{1-\rho}{\rho}} \frac{\alpha^i_{d,\tau}}{\alpha^i_{x,\hat{\tau}}}, \\
\varphi^*_{m,\tau}(\Psi) &= \varphi^*_{d,\tau}(\Psi) \left(\frac{w^j f_m}{w^i f_d}\right)^{\frac{1-\rho}{\rho}} \frac{w^j}{w^i} \frac{\alpha^i_{d,\tau}}{\alpha^i_{m,\tau}}.
\end{aligned} \tag{4.5}$$

The expressions in (4.5) allow us to analyze the general equilibrium impact of changes in the tradability index (τ) and good weights in the utility function (α), as shown in the next subsections.

4.1 Changes in tradability τ

Taking the total derivative of (4.4) with respect to τ, we obtain:

$$\begin{aligned}
& f_d j'(\varphi^*_{d,\tau}(\Psi))\frac{\partial \varphi^*_{d,\tau}(\Psi)}{\partial \tau} + n_m f_m j'(\varphi^*_{m,\tau}(\Psi))\frac{\partial \varphi^*_{m,\tau}(\Psi)}{\partial \tau} \\
&\quad + q_\tau n_x f_x j'(\varphi^*_{x,\tau}(\Psi))\frac{\partial \varphi^*_{x,\tau}(\Psi)}{\partial \tau} + \sum_{\tau' \neq \tau} q_{\tau'} \left[n_x f_x j'(\varphi^*_{x,\tau'}(\Psi))\frac{\partial \varphi^*_{x,\tau'}(\Psi)}{\partial \tau}\right] = 0,
\end{aligned} \tag{4.6}$$

where n_k is the measure of firms engaged in productive activity k. We employ this expression as well as the following lemma in the propositions below.

Lemma 1 *When the marginal entrant's good in sector τ becomes harder to trade (i.e., the tradability index τ increases), the cutoff for entry into the domestic market decreases in all sectors,* i.e., $\frac{\partial \varphi^*_{d,\hat{\tau}}(\Psi)}{\partial \tau} < 0, \forall \hat{\tau}$.

Proof From (4.5), we have

$$\begin{aligned}
\frac{\partial \varphi^*_{x,\tau}(\Psi)}{\partial \tau} &= \frac{\partial \varphi^*_{d,\tau}(\Psi)}{\partial \tau}\frac{\varphi^*_{x,\tau}(\Psi)}{\varphi^*_{d,\tau}(\Psi)} + \frac{\varphi^*_{x,\tau}(\Psi)}{\tau} \\
\frac{\partial \varphi^*_{x,\hat{\tau}}(\Psi)}{\partial \tau} &= \frac{\partial \varphi^*_{d,\tau}(\Psi)}{\partial \tau}\frac{\varphi^*_{x,\hat{\tau}}(\Psi)}{\varphi^*_{d,\tau}(\Psi)}; \quad \forall \hat{\tau} \neq \tau \\
\frac{\partial \varphi^*_{m,\tau}(\Psi)}{\partial \tau} &= \frac{\partial \varphi^*_{d,\tau}(\Psi)}{\partial \tau}\frac{\varphi^*_{m,\tau}(\Psi)}{\varphi^*_{d,\tau}(\Psi)}
\end{aligned} \tag{4.7}$$

Substituting (4.7) into the total derivative (4.6), we obtain the result:

$$\begin{aligned}
&\frac{\partial \varphi^*_{d,\tau}(\Psi)}{\partial \tau} = -\frac{q_\tau}{\tau} n_x f_x j'(\varphi^*_{x,\tau}(\Psi))\varphi^*_{x,\tau}(\Psi) \times \cdots \\
&\times \frac{1}{\left(f_d j'(\varphi^*_{d,\tau}(\Psi)) + n_m f_m j'(\varphi^*_{m,\tau}(\Psi))\frac{\varphi^*_{m,\tau}(\Psi)}{\varphi^*_{d,\tau}(\Psi)} + \sum_{\tau'} q_{\tau'} n_x f_x j'(\varphi^*_{x,\tau'}(\Psi))\frac{\varphi^*_{x,\tau'}(\Psi)}{\varphi^*_{d,\tau}(\Psi)}\right)} < 0. \quad \blacksquare
\end{aligned} \tag{4.8}$$

Proposition 1 *The cutoff for exports in a sector is increasing in the sector's tradability:* $\frac{\partial \varphi^*_{x,\tau}(\Psi)}{\partial \tau} > 0$.

Proof The result follows from Lemma 1 and (4.6):

$$\begin{aligned}
&\frac{\partial \varphi^*_{x,\tau}(\Psi)}{\partial \tau} = -\frac{\partial \varphi^*_{d,\tau}(\Psi)}{\partial \tau} \times \cdots \\
&\times \frac{\left(f_d j'(\varphi^*_{d,\tau}(\Psi)) + n_m f_m j'(\varphi^*_{m,\tau}(\Psi))\frac{\varphi^*_{m,\tau}(\Psi)}{\varphi^*_{d,\tau}(\Psi)} + \sum_{\tau'\neq\tau} q_{\tau'} n_x f_x j'(\varphi^*_{x,\tau'}(\Psi))\frac{\varphi^*_{x,\tau'}(\Psi)}{\varphi^*_{d,\tau}(\Psi)}\right)}{f_x j'(\varphi^*_{x,\tau}(\Psi))} > 0. \quad \blacksquare
\end{aligned}$$

Proposition 2 *If the cutoff productivity for domestic market production is highly responsive to changes in the tradability index in sector τ, the marginal FDI-engaged firm's productivity in sector τ increase with τ, and viceversa. In other words, $\frac{\partial \varphi^*_{m,\tau}(\Psi)}{\partial \tau} < 0$ if and only if the τ-elasticity of the productivity of the domestic marginal entrant in sector τ $\left(\varepsilon_{\varphi_d,\tau} = \frac{\partial \varphi^*_d}{\partial \tau}\frac{\tau}{\varphi^*_d}\right)$ is "low enough."*

Proof Following Proposition 1, substitute (4.7) into (4.6) and use (4.8) to obtain

$$\frac{\partial \varphi^*_{m,\tau}(\Psi)}{\partial \tau} = -\frac{1}{n_m f_m j'_m(\varphi^*_{x,\tau}(\Psi))}\left(\frac{\partial \varphi^*_{d,\tau}(\Psi)}{\partial \tau}\left[f_d j'(\varphi^*_{d,\tau}(\Psi)) + \sum_{\tau'} q_{\tau'} n_x f_x j'(\varphi^*_{x,\tau'}(\Psi))\frac{\varphi^*_{x,\tau'}(\Psi)}{\varphi^*_{d,\tau}(\Psi)}\right] + \frac{\varphi^*_{x,\tau}(\Psi)}{\tau} q_\tau n_x f_x j'_x(\varphi^*_{x,\tau}(\Psi))\right) \lesseqgtr 0. \quad (4.9)$$

Equation (4.9) is negative when:

$$\varepsilon_{\varphi_d,\tau} \leq \frac{\varphi^*_{x,\tau}(\Psi) q_\tau n_x f_x j'_x(\varphi^*_{x,\tau}(\Psi))}{f_d j'(\varphi^*_{d,\tau}(\Psi))\varphi^*_{d,\tau}(\Psi) + \sum_{\tau'} q_{\tau'} n_x f_x j'(\varphi^*_{x,\tau'}(\Psi))\varphi^*_{x,\tau'}(\Psi)}.$$

The converse follows trivially from above. ∎

From the above propositions, we see that while an increase in tradability decreases exports, exports over FDI sales will only increase when the τ-elasticity of φ^*_d is low enough.

4.2 Changes in utility weights

An alternative explanation to the varying ratios of exports/FDI sales are sectoral differences in home bias. For this purpose, take the total derivative of equation (4.4) with respect to $\alpha_{x,\tau}$ to obtain:

$$f_d j'(\varphi^*_{d,\tau}(\Psi))\frac{\partial \varphi^*_{d,\tau}(\Psi)}{\partial \alpha_{x,\tau}} + n_m f_m j'(\varphi^*_{m,\tau}(\Psi))\frac{\partial \varphi^*_{m,\tau}(\Psi)}{\partial \alpha_{x,\tau}} + q_\tau n_x f_x j'(\varphi^*_{x,\tau}(\Psi))\frac{\partial \varphi^*_{x,\tau}(\Psi)}{\partial \alpha_{x,\tau}} + \sum_{\tau' \neq \tau} q_{\tau'}\left[n_x f_x j'(\varphi^*_{x,\tau'}(\Psi))\frac{\partial \varphi^*_{x,\tau'}(\Psi)}{\partial \alpha_{x,\tau}}\right] = 0 \quad (4.10)$$

Additionally, from (4.5) we have partial derivatives for cutoff productivity levels with respect to the same parameter:

$$\begin{aligned}
\frac{\partial \varphi^*_{x,\tau}(\Psi)}{\partial \alpha_{x,\tau}} &= \frac{\partial \varphi^*_{d,\tau}(\Psi)}{\partial \alpha_{x,\tau}} \frac{\varphi^*_{x,\tau}(\Psi)}{\varphi^*_{d,\tau}(\Psi)} - \frac{\varphi^*_{x,\tau}(\Psi)}{\alpha_{x,\tau}} \\
\frac{\partial \varphi^*_{x,\hat{\tau}}(\Psi)}{\partial \alpha_{x,\tau}} &= \frac{\partial \varphi^*_{d,\tau}(\Psi)}{\partial \alpha_{x,\tau}} \frac{\varphi^*_{x,\hat{\tau}}(\Psi)}{\varphi^*_{d,\tau}(\Psi)} \\
\frac{\partial \varphi^*_{m,\tau}(\Psi)}{\partial \alpha_{x,\tau}} &= \frac{\partial \varphi^*_{d,\tau}(\Psi)}{\partial \alpha_{x,\tau}} \frac{\varphi^*_{m,\tau}(\Psi)}{\varphi^*_{d,\tau}(\Psi)}.
\end{aligned} \tag{4.11}$$

We employ 4.11 along with Lemma 2 to derive two important results.

Lemma 2 *When the utility weight $\alpha_{x,\tau}$ in sector τ increases, the productivity of the marginal domestic producer in that sector increases,* i.e.,$\frac{\partial \varphi^*_{d,\tau}(\Psi)}{\partial \alpha_{x,\tau}} > 0$.

Proof Substituting (4.11) into (4.10), we have that

$$\begin{aligned}
\frac{\partial \varphi^*_{d,\tau}(\Psi)}{\partial \alpha_{x,\tau}} &= \frac{q_\tau}{\tau} n_x f_x j'(\varphi^*_{x,\tau}(\Psi)) \frac{\varphi^*_{x,\tau}(\Psi)}{\alpha_{x,\tau}} \times \cdots \\
&\times \frac{1}{\left(f_d j'(\varphi^*_{d,\tau}(\Psi)) + n_m f_m j'(\varphi^*_{m,\tau}(\Psi)) \frac{\varphi^*_{m,\tau}(\Psi)}{\varphi^*_{d,\tau}(\Psi)} + \sum_{\tau'} q_{\tau'} n_x f_x j'(\varphi^*_{x,\tau'}(\Psi)) \frac{\varphi^*_{x,\tau'}(\Psi)}{\varphi^*_{d,\tau}(\Psi)} \right)} > 0.
\end{aligned} \tag{4.12}$$

This means that if consumers' value for consuming a good increases, all other things equal, they demand less of that good and more of others. In the steady state, the aggregate price decreases, there are less firms in the market, and the marginal and average domestic firms must be more productive. ∎

Proposition 3 *The productivity of the marginal exporter in sector τ increases with that sector's home bias,* i.e., $\frac{\partial \varphi^*_{x,\tau}(\Psi)}{\partial \alpha_{x,\tau}} > 0$.

Proof Similarly, substituting (4.11) into (4.10) and using (4.12),

$$\begin{aligned}
\frac{\partial \varphi^*_{x,\tau}(\Psi)}{\partial \alpha_{x,\tau}} =& \frac{\partial \varphi^*_{d,\tau}(\Psi)}{\partial \alpha_{x,\tau}} \frac{1}{f_x j'(\varphi^*_{x,\tau}(\Psi))} \Bigg(f_d j'(\varphi^*_{d,\tau}(\Psi)) \\
& + n_m f_m j'(\varphi^*_{m,\tau}(\Psi)) \frac{\varphi^*_{m,\tau}(\Psi)}{\varphi^*_{d,\tau}(\Psi)} + \sum_{\tau' \neq \tau} q_{\tau'} n_x f_x j'(\varphi^*_{x,\tau'}(\Psi)) \frac{\varphi^*_{x,\tau'}(\Psi)}{\varphi^*_{d,\tau}(\Psi)} \Bigg) > 0.
\end{aligned} \tag{4.13}$$

As before, when $\alpha_{x,\tau}$ increases, the marginal and average exporters in sector τ must be more productive. ∎

Proposition 4 *If the cutoff productivity for domestic market production of a good is very responsive to changes in the valuation (weight) of that good, the marginal FDI-engaged firm's productivity in sector τ decrease with α. In other words, $\frac{\partial \varphi^*_{m,\tau}(\Psi)}{\partial \alpha_{x,\tau}} < 0$ if and only if the α-elasticity of the productivity of the domestic marginal entrant in sector τ $\left(\varepsilon_{\varphi_d,\alpha} = \frac{\partial \varphi^*_d}{\partial \alpha}\frac{\alpha}{\varphi^*_d}\right)$ is "high enough."*

Proof As in Proposition 3, we substitute (4.11) into (4.10) and use (4.12) to obtain

$$\begin{aligned}\frac{\partial \varphi^*_{m,\tau}(\Psi)}{\partial \alpha_{x,\tau}} = &-\frac{1}{n_m f_m j'_m(\varphi^*_{x,\tau}(\Psi))}\left(\frac{\partial \varphi^*_{d,\tau}(\Psi)}{\partial \alpha_{x,\tau}}\left[f_d j'(\varphi^*_{d,\tau}(\Psi))\right.\right.\\ &\left.\left.+\sum_{\tau'} q_{\tau'} n_x f_x j'(\varphi^*_{x,\tau'}(\Psi))\frac{\varphi^*_{x,\tau'}(\Psi)}{\varphi^*_{d,\tau}(\Psi)}\right] - \frac{\varphi^*_{x,\tau}(\Psi)}{\alpha_{x,\tau}} q_\tau n_x f_x j'_x(\varphi^*_{x,\tau}(\Psi))\right) \lesseqqgtr 0, \quad (4.14)\end{aligned}$$

Then, (4.14) is negative when

$$\varepsilon_{\varphi_d,\alpha_{x,\tau}} \geq \frac{\varphi^*_{x,\tau}(\Psi) q_\tau n_x f_x j'_x(\varphi^*_{x,\tau}(\Psi))}{f_d j'(\varphi^*_{d,\tau}(\Psi))\varphi^*_{d,\tau}(\Psi) + \sum_{\tau'} q_{\tau'} n_x f_x j'(\varphi^*_{x,\tau'}(\Psi))\varphi^*_{x,\tau'}(\Psi)}.$$

The converse follows trivially from above. ∎

In this case, we show that while an increase in home bias decreases exports, exports/FDI sales only increases when the τ-elasticity of φ^*_d is high enough.

5 Data

In this paper we test a simplified two-country version of the model presented in sections 3 and 4. To do so, we require multi-sector data in four categories: (1) bilateral trade; (2) bilateral FDI sales; (3) total employment and non-production labor, and (4) indices of transportation costs. All data is in SIC (rev 1987) format for the United States and Canada in 1997. There are two reasons we choose this year. The first one is the discontinuity in industrial classification systems: the FDI sales data was recorded in SIC prior to 1999, and in NAICS format thereafter. The other reason is that 1997 provided data for the largest number of sectors. Since the model can be treated as static, there is no need for multiple years. We organize the industry-level data into the 20 sectors presented in Table 5.1. We describe the data below.[5]

5.1 Bilateral international trade

We use import and export data from Feenstra et al. (2002) for the U.S. and Canada for 1997. The import data used is the custom value of imports (millions of U.S. dollars) and is used to weight tariff and freight data (see below). The export data we use, also in millions of U.S. dollars, is the value of exports from the U.S. to Canada.

5.2 Bilateral FDI sales

The FDI sales data used comes from the U.S. Bureau of Economic Analysis (2006). We use data on sales by all foreign affiliates by sector as well as country. In particular, we look at U.S. affiliates operating in Canada. According to the BEA, a foreign affiliate is any foreign business in which there is a direct investor from the U.S. owning or controlling at least 10% of voting securities or the equivalent. This definition indistinctly includes mergers and acquisitions as well as greenfield investment.

5.3 Employment

We use total employment by sector as well as non-production workers by sector from the 1997 Economic Census of Manufacturing published by the U.S. Census Bureau (2001). The latter is constructed from the reported data such that: non-production labor equals total employment minus production workers.

Of the 20 sectors for which we have data on exports and FDI sales, we only have employment for 15. The excluded sectors are: Instruments and Related Products; Construction, Mining, and Materials Handling Machinery; Other Electrical Equipment, Appliances, and

[5] More details are available from the authors.

Components; Other Petroleum and Coal Products; and Other Chemicals and Allied Products (see Table 5.1).

Table 5.1: Industry level data

Industry	**SIC (Rev.1987) codes**	τ	**Exports**	**FDI Sales**	**Total U.S. Employ.**	**Non-prod. Workers**
Grain Mill and Bakery Products	2041+2051+2053	1.0638	45	3,106	357,543	128,286
Other Food and Kindred Products	20-(2041+2051+2053+2082)	1.0741	4,467	10,075	1,109,413	226,363
Tobacco Products	21	1.1208	24	698	33,594	9,153
Textile Products and Apparel	22+23	1.1420	2,881	1,414	1,338,136	224,379
Lumber, Wood, Furniture, and Fixtures	24+25	1.0550	3,252	4,600	570,034	93,809
Paper and Allied Products	26	1.0519	3,054	7,560	574,274	134,178
Chemical Products, nec	2819+2869+2879+2899	1.0676	3,874	2,497	882,645	370,493
Soap, Cleaners, and Toilet Goods	2841+2842	1.0532	1,240	2,438	126,446	48,692
Other Chemicals and Allied Products	28-(2813+2819+2821+2822) -(2869+2879+2899+2841) -(2842+2879)	1.0829	3,514	11,399	nr	nr
Petroleum and Coal Products, nec	2999	1.0660	122	10	107,625	36,071
Other Petroleum and Coal Products	29-2911-2999	1.0552	49	12,844	nr	nr
Rubber Products	301+302+305+306	1.0676	2,104	2,306	202,353	41,081
Glass Products	321+322+323	1.0742	1,013	341	128,565	23,514
Other Stone, Clay, and Other Nonmetallic Mineral Products	32-(321+322+323)	1.1280	744	2,035	372,906	89,059
Primary and Fabricated Metals	33+34	1.0455	11,337	6,815	2,368,857	562,252
Construction, Mining, and Materials Handling Machinery	353	1.0385	3,046	1,283	nr	nr
Household Audio and Video, and Communications Equipment	365+366	1.0360	3,417	1,309	294,865	159,552
Electronic Components and Accessories	367	1.0176	4,523	1,530	593,802	161,529
Other Electrical Equipment, Appliances, and Components	36-363-365-366-367-369	1.0448	4,881	3,921	nr	nr
Instruments and Related Products	38	1.0351	4,973	1,410	nr	nr

Exports and FDI sales in Millions of U.S. Dollars.
Employment in thousands.
nr = Data not reported.
Sources = See section 5.

5.4 Tradability index

In our model, we use data on freight costs and tariffs to construct a tradability index. This data is collected by Schott (nd) in SIC rev. 1987 format according to year and sector. The tariff rates are import-weighted, implicit averages, calculated for each year as:

$$\text{tariff} = \frac{\text{duties}}{\text{customs value}}. \tag{5.1}$$

The freight rates are also import-weighted for each year as:

$$\text{freight} = 1 - \frac{\text{cost insurance freight (cif) imports}}{\text{free on board (fob) imports}}. \tag{5.2}$$

Thus, the *tradability index* τ is defined by:

$$\tau \equiv (1 + \text{freight})(1 + \text{tariff}), \tag{5.3}$$

where a higher index implies the good is less tradable. We calculate these indices by sectors according to the concordance described in Table 5.1 (through import-weighting).

6 Numerical experiments

In this section we present five variations of our model in an attempt to match the observed ratio of exports to FDI sales for Canada and the U.S. in 1997 for 20 sectors. Recall that we identify sectors by their average tradability τ as constructed from the data. Moreover, we assume the marginal exporter in each sector has that τ. Alternative approaches to sector classification can be considered however, they are outside of the scope of this paper.

We interpret the utility function weights (α) as home-product bias, *i.e.*, taste differences for goods produced at home (by domestic and foreign multinational firms) versus abroad (imported). We normalize $\alpha^i(\hat{\varphi}^i_{d,\tau}, \tau) = \alpha^i(\hat{\varphi}^j_{m,\tau}, \tau) = 1$, where $\hat{\varphi}^i_{d,\tau}$ is the productivity of firms producing domestically in i and $\hat{\varphi}^j_{m,\tau}$ that of foreign subsidiaries producing in i. Finally, we assume the two countries are symmetric for computational simplicity.

The mass of operating firms in autarky

In the case of autarky, it is trivial to calculate the (endogenously determined) mass M of operating firms. The tradability index τ is not relevant here, so we can simplify notation. From (3.1) we have that for any two firms with productivity φ and $\tilde{\varphi}$:

$$\frac{x(\varphi)}{x(\tilde{\varphi})} = \left(\frac{p(\varphi)}{p(\tilde{\varphi})}\right)^{\frac{1}{\rho-1}} = \left(\frac{\tilde{\varphi}}{\varphi}\right)^{\frac{1}{\rho-1}}. \tag{6.1}$$

We can use the above to re-write (3.2):

$$\begin{aligned} Y^i &= \left(\int_\varphi M x^i(\varphi)^\rho d\varphi\right)^{\frac{1}{\rho}} \\ &= M^{\frac{1}{\rho}} \left(\int_\varphi x^i(\tilde{\varphi})^\rho \left(\frac{\tilde{\varphi}}{\varphi}\right)^{\frac{\rho}{\rho-1}} d\varphi\right)^{\frac{1}{\rho}} \\ &= M^{\frac{1}{\rho}} x(\tilde{\varphi}) \left(\frac{1}{\tilde{\varphi}}\right)^{\frac{1}{1-\rho}} \left(\int_\varphi (\varphi)^{\frac{\rho}{1-\rho}} d\varphi\right)^{\frac{1}{\rho}} \\ &= M^{\frac{1}{\rho}} x(\tilde{\varphi}) = M^{\frac{1}{\rho}} Y \left(\frac{p(\tilde{\varphi})}{P}\right)^{\frac{1}{\rho-1}} \\ \Rightarrow M &= \left(\frac{p(\tilde{\varphi})}{P}\right)^{\frac{\rho}{1-\rho}}. \end{aligned} \tag{6.2}$$

Hence, M is the autarky mass of operating firms in any given country.

The mass of operating firms in the open economy

We define the mass of domestically operating firms as in (6.2). This comes from the fact that the most inefficient active firm in all sectors τ is the same (and given by (3.9)). Thus, the mass of firms in each sector τ is:

$$M_\tau = q_\tau M. \tag{6.2a}$$

Additionally, the mass of firms within each τ is:

$$M_{x,\tau} = \frac{1 - G(\varphi^*_{x,\tau})}{1 - G(\varphi^*_{d,\tau})} M_\tau = \mu_{x,\tau} M_\tau,$$
$$M_{m,\tau} = \frac{1 - G(\varphi^*_{m,\tau})}{1 - G(\varphi^*_{d,\tau})} M_\tau = \mu_{m,\tau} M_\tau.$$

$\mu_{k,\tau}$ is the probability of engaging in foreign market servicing $k \in \{x, m\}$ in sector τ, conditional on being an active firm. The first expression is the measure of firms servicing foreign markets via exports and the second, that of FDI conditional on operating in sector τ. Adding the three expressions above, we get:

$$\mathcal{M}_\tau = M_\tau + n\left(M_{x,\tau} + M_{m,\tau}\right), \tag{6.2b}$$
$$\mathcal{M} = \sum_\tau \mathcal{M}_\tau; \tag{6.2c}$$

where n is the number of countries in the world. Equation (6.2b) is the total measure of firms operating in sector τ and (6.2c) is the total measure of firms operating. The symmetry assumption across countries implies this is the total number of firms a country's representative consumer owns.

Given the definitions above, we write an expression similar to (3.6) which indicates employment in each sector τ:

$$L^i_\tau = f_e M_{e,\tau} + \left[f_d + n(\mu_{x,\tau} f_x + \mu_{m,\tau} f_m)\right] M_\tau$$

so that $L^i = \sum_\tau L^i_\tau$ is aggregate labor. Since aggregate payments to production workers must be equal to the difference between aggregate revenue and profits, and normalizing wages to 1, production labor $L_p = R - \Pi$. Additionally, market clearing conditions imply that labor devoted to pay entry costs is $L_e = M_e f_e$. In a steady state equilibrium, firm entry and exit are equal, *i.e.*, $(1 - G(\omega^*))M_e = \delta M$. Hence the free entry condition implies:

$$L_e = M_e f_e = \frac{\delta M}{(1 - G(\omega^*))} f_e = M\bar{\pi} = \Pi$$

Together, these conditions imply aggregate revenues $R = L_p + \Pi = L_p + L_e = L$. This condition completes our system of equations.

Ratio of exports to FDI sales

To calculate the ratio of exports to FDI sales, we construct total sector sales in the model. We fix the probability q_τ of being in sector τ as the fraction of that sector's total exports and FDI sales over total sales for the 20 sectors, as found in the data:

$$q_\tau = \frac{\text{FDI sales}_\tau + \text{exports}_\tau}{\sum_s (\text{FDI sales}_s + \text{exports}_s)}.$$

Additionally, we choose the fixed costs of production for each sector, to match the measure of firms that operate in each sector and mode of servicing. To see this, consider the measure of firms exporting in sector τ:

$$\begin{aligned} M_{x,\tau} &= \frac{1 - G(\varphi^*_{x,\tau})}{1 - G(\varphi^*_d)} q_\tau M \\ &= \left(\frac{f_d}{f_x}\right)^{a\left(\frac{1-\rho}{\rho}\right)} q_\tau \left(\frac{\alpha_{x,\tau}}{\tau}\right)^a M \\ \Rightarrow \frac{M_{x,\tau}}{M} &= \left(\frac{f_d}{f_x}\right)^{a\left(\frac{1-\rho}{\rho}\right)} q_\tau \left(\frac{\alpha_{x,\tau}}{\tau}\right)^a \end{aligned}$$

which relies only on parameters.

The ratio of aggregate sector exports to FDI sales come from the expression above and (3.8):

$$\begin{aligned} \frac{\text{exports}_\tau}{\text{FDI sales}_\tau} &= \frac{r^j_{x,\tau}(\tilde{\varphi}_{x,\tau})}{r^j_{m,\tau}(\tilde{\varphi}_{m,\tau})} \frac{M_{x,\tau}}{M_{m,\tau}} \\ &= \frac{R\left(\frac{P\rho\tilde{\varphi}_{x,\tau}\alpha_{x,\tau}}{w^i\tau}\right)^{\frac{\rho}{1-\rho}}}{R\left(\frac{P\rho\tilde{\varphi}_{m,\tau}}{w^j}\right)^{\frac{\rho}{1-\rho}}} \frac{(1 - G(\varphi^*_{x,\tau}))q_\tau M}{(1 - G(\varphi^*_{m,\tau}))q_\tau M} \\ &= \left(\frac{\varphi^*_{x,\tau}}{\varphi^*_{m,\tau}}\right)^{\frac{\rho}{1-\rho} - a} \left(\frac{\alpha_{x,\tau}}{\tau}\right)^{\frac{\rho}{1-\rho}} \\ &= \left(\frac{f_{x,\tau}}{f_{m,\tau}}\right)^{1 - a\frac{1-\rho}{\rho}} \left(\frac{\alpha_{x,\tau}}{\tau}\right)^a. \end{aligned} \tag{6.3}$$

6.1 Benchmark model: common fixed costs, $\alpha_\tau = 1$

In the benchmark model, the fixed costs are assumed to be county-specific (as opposed to sector-specific). All utility weights are set equal to one. We use the parameters shown in Table 6.1 and τ from Table 5.1, as well as q_τ described in section 5. Figure 6.1, shows this version of the model grossly missed the observed ratio of exports to FDI sales.

Table 6.1: Parameters for baseline model

Parameter	**Value**	**Description**
ρ	0.5	utility function parameter
α_τ	1	utility weights
w^h	1	home country's wage
w^f	1	foreign country's wage
L	65,000	labor endowment
f_e	65	fixed entry cost
f_d	1.3	fixed domestic cost
f_x	1.5	fixed export cost
f_m	2.2	fixed FDI cost
$\hat{\delta}$	0.03	death rate of firms
S	20	# sectors in the economy
a	2	shape parameter Pareto distrib.
b	1	lower support Pareto distrib.

All labor units are in thousands.
Targets are described in the discussion.

6.2 Sector-specific fixed costs, $\alpha_\tau = 1$

In this specification, each sector has different fixed costs. We modify our assumptions on the fixed costs from the benchmark model to satisfy the following conditions:

$$\begin{aligned} f_{x,\tau} &> f_d \left(\frac{\tau}{\alpha_{x,\tau}}\right)^{\frac{\rho}{\rho-1}} && \Leftrightarrow \quad \varphi^*_{d,\tau} < \varphi^*_{x,\tau},\ \forall\tau \\ f_{m,\tau} &> f_{x,\tau}\frac{w^i}{w^j}\left(\frac{w^i}{w^j}\frac{\tau}{\alpha_{x,\tau}}\right)^{\frac{\rho}{1-\rho}} && \Leftrightarrow \quad \varphi^*_{x,\tau} < \varphi^*_{m,\tau},\ \forall\tau; \end{aligned}$$

to be consistent with empirical observations reported in Helpman et al. (2004).

We determine $f_{x,\tau}$ according to the following rule:

$$f_{x,\tau} = f_d \tau^{\frac{\rho}{\rho-1}+2},$$

Figure 6.1: Estimated vs. actual exports/FDI sales: benchmark model.

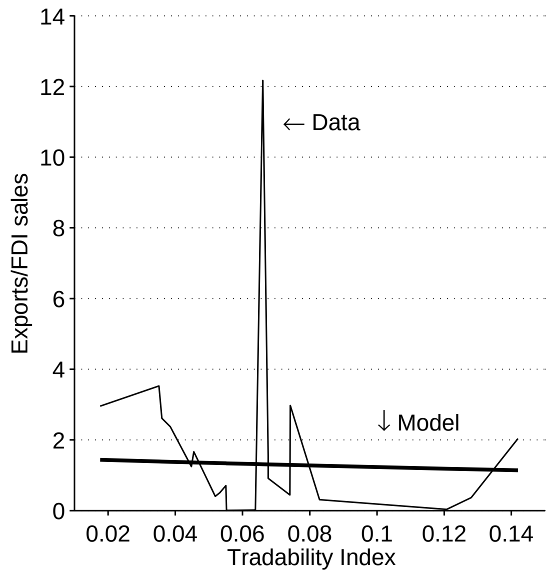


Figure 6.2: Estimated vs. actual exports/FDI sales with sector-specific fixed costs.

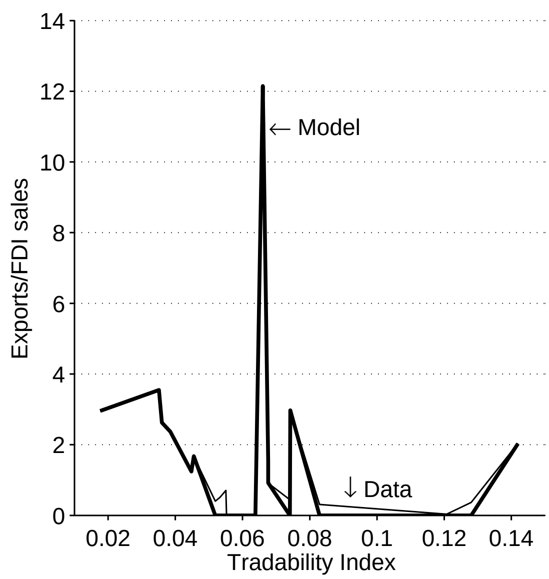
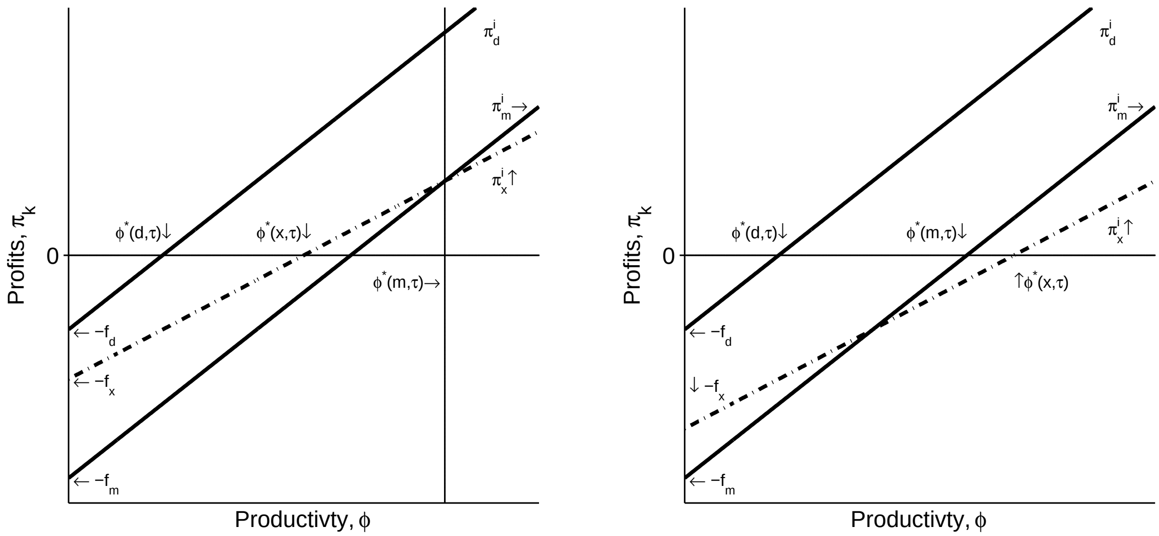


Figure 6.3: Cutoffs with sales taxes.



which satisfies the first restriction. Finally, we choose $f_{m,\tau}$ to match exports to FDI sales data, provided this does not violate the rule above. All other parameters are as in Table 6.1. Under these assumptions, the marginal producers for exports and FDI-sales are:

$$\begin{aligned}\varphi^*_{x,\tau} &= \left(\frac{w^i f_{x,\tau}}{(1-\rho)R}\right)^{\frac{1-\rho}{\rho}} \frac{w^i\tau}{P\rho}\\ \varphi^*_{m,\tau} &= \left(\frac{w^j f_{m,\tau}}{(1-\rho)R}\right)^{\frac{1-\rho}{\rho}} \frac{w^j}{P\rho}\end{aligned} \tag{6.4}$$

and the entry condition (3.12) becomes:

$$(1-G(\varphi^*_d))\overline{\pi}_d + \sum_\tau q_\tau \left\{(1-G(\varphi^*_{m,\tau}))\overline{\pi}_{m,\tau} + (1-G(\varphi^*_{x,\tau}))\overline{\pi}_{x,\tau}\right\} = \delta w^i f_e. \tag{6.5}$$

As shown in Figure 6.2, the model fails to match the observed data for some sectors. From equation (6.3), it is trivial to see that in this variant of the model, calibrating fixed costs does not suffice to match the data. This is because f_m has to be so small that there is no incentive to export, *i.e.*, we would violate $\varphi^*_{x,\tau} < \varphi^*_{m,\tau}$ (see the right panel in Figure 6.3).

6.3 Sector-specific productivity dispersion, $\alpha_\tau = 1$

In this variant of the model, we test the claim from Helpman et al. (2004) that there is a high cross-sectoral relationship between productivity dispersion and firms' choices of foreign market servicing. We allow for the productivity distributions to be sector-specific and we set $\alpha_\tau = 1$. Specifically, we allow for a, the shape parameter of the Pareto distribution (see Section 3) to vary among sectors. Moreover, sectoral differences are the same across countries, in line with our assumption of symmetry.

Equation (3.11) requires the following restriction on parameters:

$$\frac{\rho}{1-\rho} - a_\tau < 0, \quad \forall\tau. \tag{6.6}$$

Additionally, from (6.3), recall the equation for the export-to-FDI sales ratio when $\alpha_\tau = 1$ is:

$$\frac{\text{exports}_\tau}{\text{FDI sales}_\tau} = \left(\frac{f_{x,\tau}}{f_{m,\tau}}\right)^{1-a_\tau\frac{1-\rho}{\rho}} \left(\frac{1}{\tau}\right)^{a_\tau},$$

and the fact that

$$f_m > f_x \frac{w^i}{w^j}\left(\frac{w^i}{w^j}\tau\right)^{\frac{\rho}{1-\rho}}$$

is needed for consistency with empirical observations of firm productivity cutoffs.

For the limit case where the above expression is satisfied with equality, (6.3) reduces to:

$$\frac{\text{exports}_\tau}{\text{FDI sales}_\tau} = \tau^{\frac{\rho}{\rho-1}}.$$

where we applied symmetry across countries. From the data we have $\tau > 1$ so we can see that:

(1) for $\rho < 1$, we are only able to match those sectors with lower exports than FDI sales: $\frac{\text{exports}_\tau}{\text{FDI sales}_\tau} < \tau^{\frac{\rho}{\rho-1}} < 1$;

(2) for $\rho > 1$, we are only able to match those sectors with higher exports than FDI sales: $\frac{\text{exports}_\tau}{\text{FDI sales}_\tau} > \tau^{\frac{\rho}{\rho-1}} > 1$.

Hence, it is evident that under the assumptions made, this variant will fail to replicate the intra-sectoral variability in the exports-to-FDI sales ratio as observer in the data.

In the case where $f_m > f_x \frac{w^i}{w^j}\left(\frac{w^i}{w^j}\tau\right)^{\frac{\rho}{1-\rho}}$, under certain parameters could we replicated the data observed. Notice that this inequality implies:

$$\frac{\text{exports}_\tau}{\text{FDI sales}_\tau} = \left(\frac{f_x}{f_m}\right)^{1-a\frac{1-\rho}{\rho}} \tau^{-a} > \tau^{\frac{\rho}{\rho-1}}. \tag{6.7}$$

With $\rho < 1$ as we assume, $\tau^{\frac{\rho}{\rho-1}} < 1$, such that the ratio of exports to FDI sales could be smaller or larger than 1. However, parameter restrictions would not allow to accommodate for the large intra-sectoral variation.

6.4 Sector-specific tax on multinational sales, $\alpha_\tau = 1$

This variant of the model is one of the two cases where we are able to match the data, as depicted in Figure 6.4. We allow for sector-specific sales taxes on multinational operations, along with sector-specific fixed costs (to satisfy $\varphi^*_{x,\tau} < \varphi^*_{m,\tau}$). In this case, the profits of the multinational firm become:

$$\pi^j_{m,\tau}(\varphi) = \sigma_\tau p^j_{m,\tau}(\varphi) y^j_{m,\tau}(\varphi) - w^j l^j_{m,\tau}(\varphi),$$

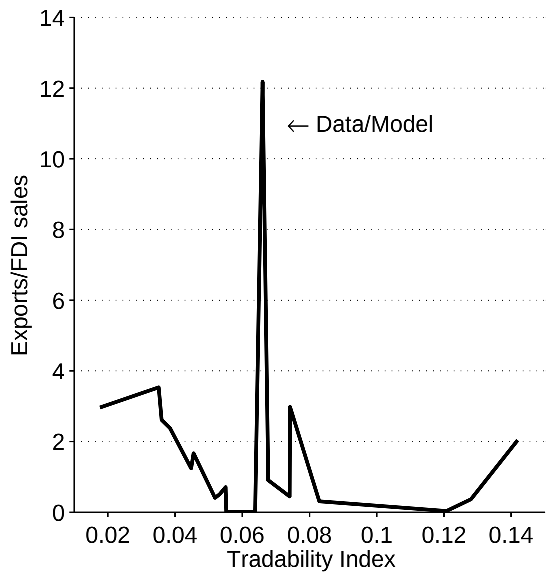
where $\sigma_\tau - 1$ is the sales tax, when $\sigma_\tau < 1$, or subsidy, when $\sigma_\tau > 1$. We leave other goods untaxed for computational simplicity and because what matters are sales taxes in a sector relative to other sectors. The price multinational firms charge becomes:

$$p_{m,\tau} = \frac{w^j}{\rho\sigma_\tau\varphi_{m,\tau}}.$$

and other price equations remain unchanged. The zero profit condition for firms engaged in multinational operations yields:

$$\varphi^*_{m,\tau} = \left(\frac{w^j f_m}{(1-\rho)R}\right)^{\frac{1-\rho}{\rho}} \frac{w^j}{P\rho}\sigma_\tau^{-\frac{1}{\rho}}$$

Figure 6.4: Estimated vs. actual exports/FDI sales with sector-specific fixed taxes/fixed costs.



As before, we can write the ratio of exports to FDI sales as:

$$\frac{\text{exports}_\tau}{\text{FDI sales}_\tau} = \left(\frac{f_{x,\tau}}{f_{m,\tau}}\right)^{1-a\frac{1-\rho}{\rho}} \left(\sigma_\tau^{\frac{1}{\rho}}\tau\right)^{-a}. \tag{6.8}$$

In Table 6.2 we show the calibrated sales taxes for each sector. Notice that in order to preserve the relationship $\varphi^*_{x,\tau} < \varphi^*_{m,\tau}$, and have non-zero exports, for a large enough σ_τ, $f_{m,\tau}$ must increase. This relationship is depicted in Figure 6.5. A downside to this variant is that implausible tax rates are required for Petroleum and Coal Products and Electronic Components and Accessories, as well as large subsidies for other sectors. The reason for this is that with constant markups, the only way to generate high enough differences between FDI sales and exports is by affecting supply side components of prices.

Notice that given our calibration algorithm, the model predicts total sector exports and FDI sales which are very close to the observed values (see Figure 6.6). Additionally, the left panel of Figure 6.7 shows total sector employment arising from the model against observed employment. As in Helpman et al. (2004), we compare non-production workers to fixed FDI costs. This relationship is positive and shown on the right panel of Figure 6.7.

Figure 6.5: Cutoffs with sector-specific fixed taxes/fixed costs.

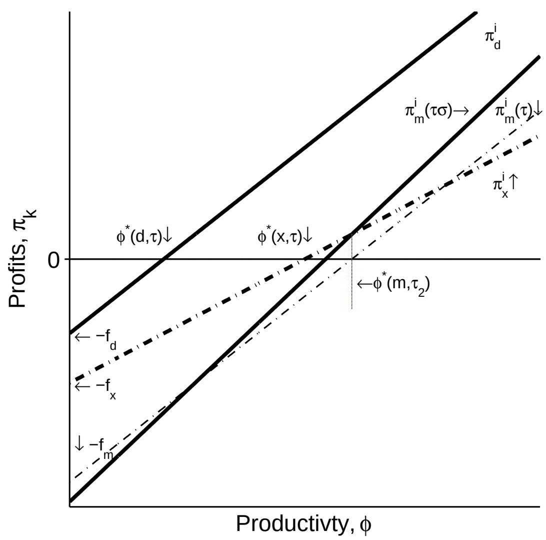


Table 6.2: Industry-specific sales tax

Industry	$\sigma_\tau - 1$
Grain Mill and Bakery Products	-0.234
Other Food and Kindred Products	-0.264
Tobacco Products	-0.207
Textile Products and Apparel	-0.186
Lumber, Wood, Furniture, and Fixtures	-0.043
Paper and Allied Products	-0.110
Chemical Products, nec	0.539
Soap, Cleaners, and Toilet Goods	0.368
Other Chemicals and Allied Products	0.162
Petroleum and Coal Products, nec	14.852
Other Petroleum and Coal Products	7.046
Rubber Products	-0.456
Glass Products	-0.090
Other Stone, Clay, and Other Nonmetallic Mineral Products	0.041
Primary and Fabricated Metals	0.452
Construction, Mining, and Materials Handling Machinery	-0.224
Household Audio and Video, and Communications Equipment	0.735
Electronic Components and Accessories	4.151
Other Electrical Equipment, Appliances, and Components	0.562
Instruments and Related Products	-0.134

Figure 6.6: Exports and FDI sales.

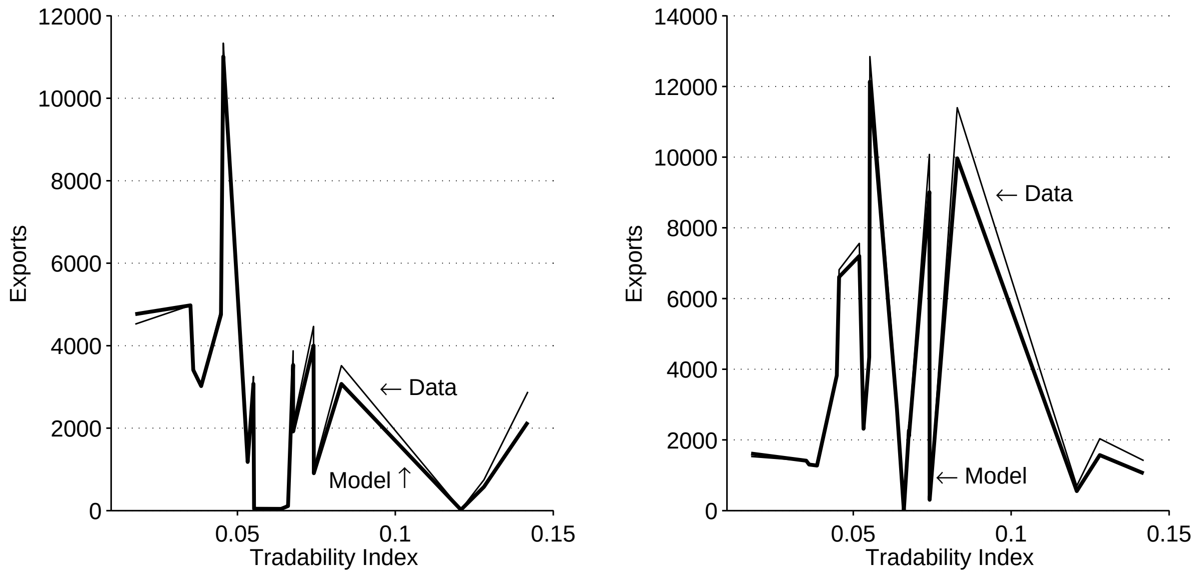


Figure 6.7: Total sector employment and non-prod. workers vs. fixed FDI Cost

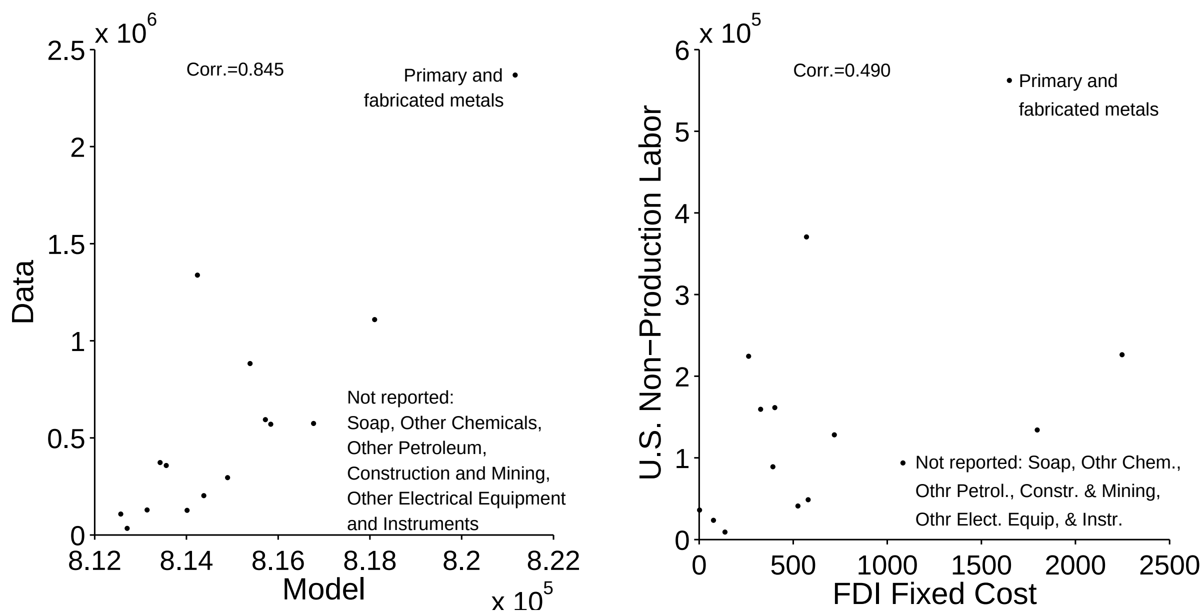
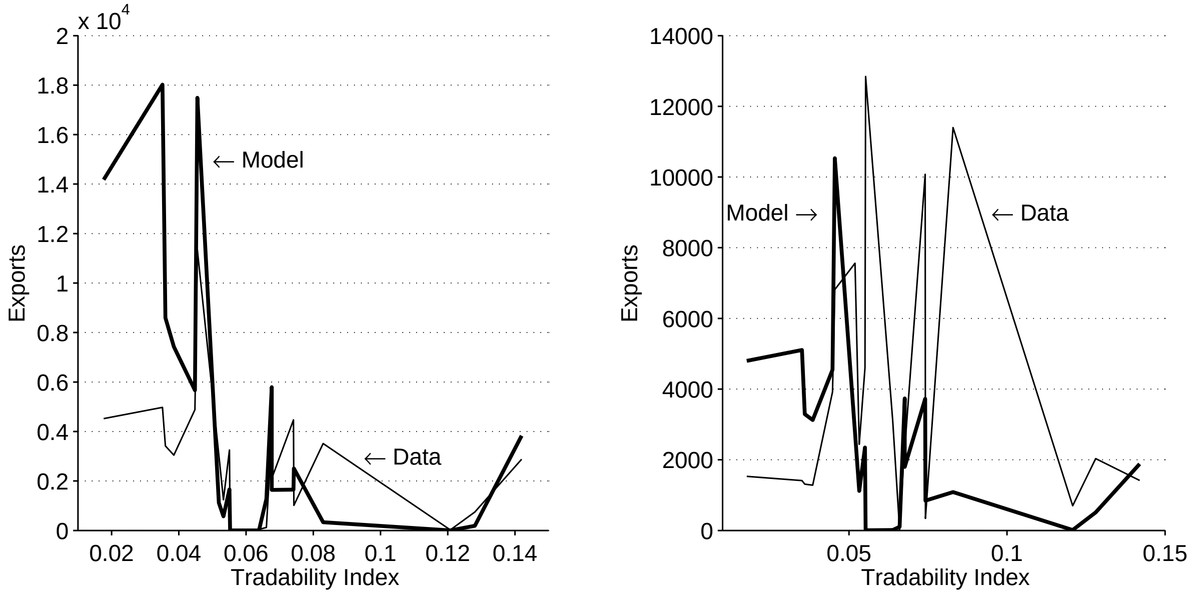


Figure 6.8: Exports and FDI sales



6.5 Sector-specific utility weights (home bias)

For this specification, we assume that $\alpha_{d,\tau} = \alpha_{m,\tau} = 1, \ \forall \tau$ and allow for sector-specific $\alpha_{x,\tau}$. We interpret this formulation as consumers having different preferences on locally- versus foreign-produced goods (commonly known as home product bias in the trade literature).

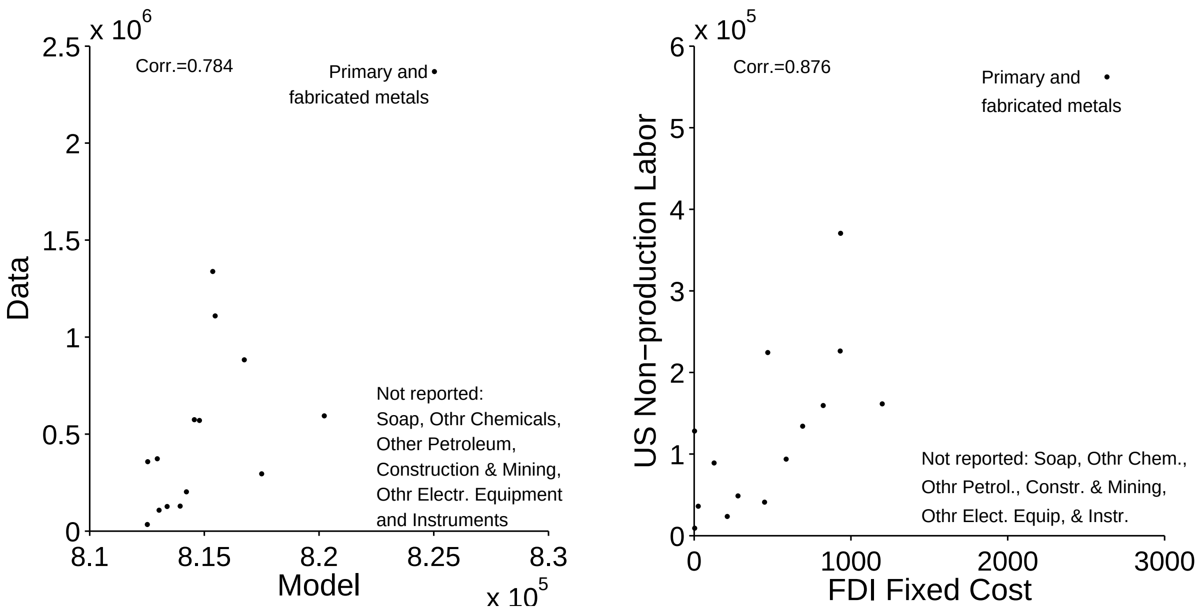
The pricing rules are given by (3.5), the cutoff values by (3.9), and the fixed costs of production must follow:

$$\begin{aligned} f_x > f_d \left(\frac{\tau}{\alpha_x}\right)^{\frac{\rho}{\rho-1}} \quad &\Leftrightarrow \quad \varphi^*_{d,\tau} < \varphi^*_{x,\tau}, \ \forall \tau \\ f_m > f_x \frac{w^i}{w^j} \left(\frac{w^i}{w^j} \frac{\tau}{\alpha_x}\right)^{\frac{\rho}{1-\rho}} \quad &\Leftrightarrow \quad \varphi^*_{x,\tau} < \varphi^*_{m,\tau}, \ \forall \tau \end{aligned}$$

to guarantee consistency with empirical cutoffs. We calculate total sector sales using (3.8) and the corresponding mass of firms. The model can match the ratio of exports to FDI sales, although it fails to match the absolute sectoral sales, as shown in Figure 6.8. This occurs because weights $\alpha_{x,\tau}$ are chosen to match the ratios, directly affecting the cutoff productivities for exporting firms, which did not previously occur.

In spite of this, total sectoral employment in the model is highly correlated with the data (corr.=0.784), which is also the case for non-production workers and fixed FDI costs

Figure 6.9: Total sector employment and non-prod. workers vs. fixed FDI Cost



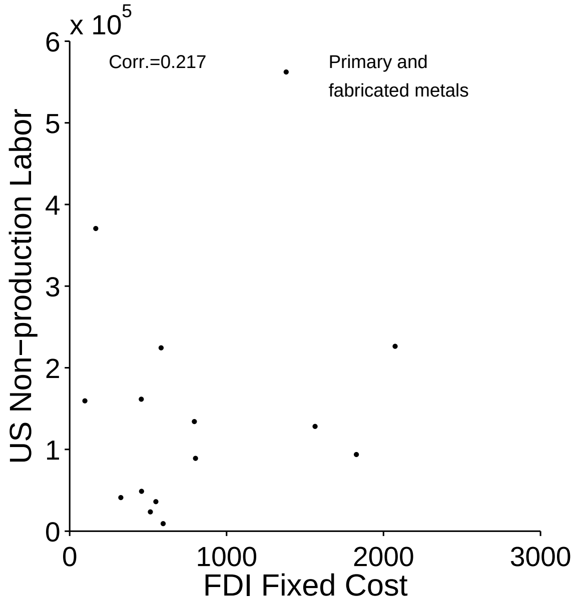
(corr.=0.876, see Figure 6.9). The latter result provided the possibility of calibrating these fixed costs with non-production labor data. Since this data is only available for 15 of the sectors, we recalibrated this version of the model to these 15 sectors. Although we match the ratio of exports to FDI sales, we no longer have a strong relationship between non-production labor and fixed FDI cost (figure 6.10), hence, we did not pursue this calibration exercise.

7 Conclusions

In this paper we determine what is needed to endogenously generate the large variations of exports to FDI sales among sectors. To do so, we build on the Helpman et al. (2004) model of monopolistic competition where firms can choose between the foreign market servicing options of exports and FDI sales. To calibrate this model, we aggregate firms into sectors and we show that tradability and productivity dispersion are not enough to match sectoral data on exports and FDI sales for the U.S. and Canada in 1997.

We offer two alternative variations of our benchmark model that allow us to match these sectoral differences. The first variation is a model with sector-specific taxes on multinational operations and the second one has sectoral home product bias. It is important to note that

Figure 6.10: Non-production workers vs. fixed FDI Cost (15 sectors)



the required tax rates on multinational firms are in some cases implausible, hence the home product bias model is more appealing.

Future research is required to find less restrictive approaches in sector classification. In particular, our assumption that all the firms in a sector have the same tradability index for their good is inflexible. Additionally, empirical validation of the utility function weights is needed. In spite of the limitations that this class of models present, we believe they have the potential to provide important policy insights regarding foreign market servicing.

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