Innovation and the Trade Elasticity*

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Abstract

The reaction of trade volumes to tariffs is far larger than what current models predict. One reason for this is that they abstract from endogenous productivity choices ("innovation"), which amplify this reaction. To show this, I develop a model of international trade with innovation, and calibrate it to Canada and United States before the Free Trade Agreement. Feeding in the tariff drops observed during the agreement, the increase in the trade volumes is within the empirical estimates. Without innovation, the change in trade volumes is too low, and similar to what current models without innovation have found.

Keywords: Canada-U.S. Free Trade Agreement; Innovation and Trade; Trade Elasticity.

JEL Codes: F12; F41

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1 Introduction

A classic question in international trade concerns the effect of tariff reductions on trade volumes. Empirical evidence indicates that this effect is large: for example, studies of the Free Trade Agreement between Canada and the United States conclude that a one percentage point drop in tariffs leads to an increase in trade volumes of around ten percentage points. While this empirical fact is well documented, the literature has yet to produce an empirically reasonable model that can generate effects of these magnitudes.

This paper develops a new model of international trade and assesses its ability to generate responses to tariffs consistent with the data. The key novel feature is that firms make a costly decision that determines their productivity ("innovation"). When calibrated to data on Canada and the United States, it accounts for the entire effect of the reduction of tariffs on trade volumes during the free trade agreement from 1988 to 1996.

The notion that adding an innovation decision increases the response of trade volumes results from two basic observations. First, the incentive to innovate depends critically on market size, since resources devoted to innovation represent an up front cost. Second, tariff reductions lead to increased demand for imports, and thereby to a larger market size for exporters. Thus, a reduction in tariffs increases exporter innovation. This drives exporters to lower their prices, increasing trade beyond the increase in a model without innovation.

The incentives to increase productivity are largest among those firms that adjust along the extensive margin, that is, firms that start to export when the tariff is reduced. The reason is that these firms face the largest increases in demand. This is consistent with the empirical evidence, as documented by Lileeva (2008) and Lileeva and Trefler (2010) for Canada; De Loecker (2007) and Kostevc and Damijan (2008) for Slovenia; Van Biesebroeck (2005) for Sub-Saharan Africa; Eslava, Haltiwanger, Kluger and Kluger (2013) for Colombia; Bustos (2011) for Argentina; and Aw, Roberts and Xu (2008) for Taiwan.

The model is based on Melitz (2003).[1] There are two countries of possibly different size. Each country has a tradable and a nontradable sector. The tradable sector consists of a continuum of firms that produce distinct varieties of goods with heterogeneous technologies. To export, firms must incur a fixed export cost. The novelty is that firms can increase their productivity through costly innovation. The gain from innovating an additional unit is heterogeneous across firms, so in equilibrium productivities are heterogeneous. In fact, the equilibrium of the model is similar to Melitz (2003), with only large firms exporting. The difference is that in my model, when tariffs change, productivities change, and consequently the response of trade volumes.

The model is calibrated to study the effects of the reductions in tariffs during the Canada-U.S. Free Trade Agreement. The main advantage of using this episode is the extensive work done in the past. Head and Ries (2001), Clausing (2001) and Romalis (2007) provide detailed estimates of the trade elasticity, and Trefler (2004) does similarly for productivity.

A key element of the calibration is the response of firm productivity to innovation expenses. The larger this response is, the larger the response of trade volumes to reductions in tariffs. Ideally, one would identify independent measures of the cost of innovation to calibrate the innovation function, but I have been unable to find such targets. Alternatively, the cost of innovation directly affects the productivity gains from tariff reduction. Thus, the calibration works by forcing the increase in industry productivity after the Free Trade Agreement in the model to match the increase in Canadian industry productivity in Trefler.

My main finding is that a 1 percentage point drop in tariffs increases imports by 9.3 percentage points. This is well within the range of empirical estimates. To my knowledge, this is the first paper to successfully account for the entire reaction of trade volumes within an empirically plausible model of international trade.[2] The most successful contribution so far

[1] In Melitz, firms make positive profits, leaving room for innovation, as opposed to Eaton and Kortum (2002) and Alvarez and Lucas (2007), with no profits. An alternative would be Bernard et al. (2003).

[2] See Kehoe (2003) for a survey on prior attempts to account for this elasticity.

has been Ruhl (2008), who builds a Melitz type model (without innovation) that accounts for about two thirds of the observed increase in trade volumes. Closing the innovation channel down, my model generates the same elasticity as Ruhl.

Productivity gains from trade are highly asymmetric. While the productivity gain in Canada is calibrated to match the observed increase of 5%, the model predicts that the productivity gain in the U.S. (which is not targeted) is just 0.1%. This is consistent with empirical studies that find no significant effects of trade liberalization on firm productivity in U.S. (see Bernard and Jensen, 1999). The reason is that the reduction in tariffs increases the market size in the small country by much more than in the large country.

One key feature of the model is that it is static, while the effects of trade liberalization may be dynamic. Alternatively, one could write down a dynamic model, calibrate it so that the gains from trade during the years studied by Trefler (2004) are 5 percent, and measure the increase in trade volumes. The dynamic model could generate effects that extend beyond the period of tariff reductions. However, there is no evidence of such.

Tariffs were not the only source of increases in trade during this period. For example, Feinberg and Keane (2009) show that 45% percent of merchandise trade can be accounted for by intrafirm trade, and this is not very responsive to tariffs. By abstracting from this channel, this paper focuses only on the trade elasticity to tariffs, as found by the literature.

My model has implications that go beyond the Canada-U.S. Free Trade Agreement. In particular, the model can capture reasonably well the behavior of U.S. trade volumes from the early 1960s to the late 1990s. Yi (2003) concludes that this is challenging for models based on Krugman (1980) or Backus, Kehoe and Kydland (1994). When feeding the observed reduction in tariffs between 1962 and 1999 into my model, it generates two thirds of the observed increase in trade volumes.

Another implication is that productivity gains from trade depend critically on the costs of innovation. Larger innovation costs reduces the gains from trade. Developing countries are likely to have higher innovation costs due to highly regulated markets (see Heckman and Pagés, 2004) and poor enforcement of property rights (see Djankov et. al. 2002). Thus the model is consistent with Clerides, Lach and Tybout (1998) who find no gains from trade in Colombia, Mexico, and Morocco and Havrylyshyn (1990), who finds no evidence of productivity gains from trade among developing countries. In the model, increasing innovation costs by 50% eliminates productivity gains from trade.

My work falls into a growing literature on innovation and international trade. Two papers are closely related to mine. The first is Costantini and Melitz (2008), who describe the transition from a high tariff steady state to a low tariff steady state when firms can innovate. The second is Atkeson and Burstein (2010), who develop a dynamic trade model with innovation and conclude that innovation has fairly small effects on aggregate productivity.[3] Caliendo and Rossi-Hansberg (2012) develop a model that can be interpreted as a microfoundation for my mechanism, where innovation takes the form of organizational reestructuring. Caliendo et al. (2012) find empirical evidence for this effect. This is also related to work that adds capital to trade models, such as Brooks and Dovis (2012) and Leibovici (2012). The difference is that with innovation, firms have increasing returns, while the models with capital usually assume constant returns to scale. Other related papers that derive theoretical mechanisms for the relation between innovation and trade are Yeaple (2005) and Ederington and McCalman (2008).

The outline is as follows. Section 2 describes the model and the equilibrium. Section 3 describes the Free Trade Agreement between Canada and the United States. Section 4 calibrates. Section 5 presents the results. Section 6 studies the effects of U.S. tariffs on trade volumes from the 1960s to the 1990s. Section 7 discusses how innovation can address some empirical observations that have not been accounted for. Section 8 concludes.

[3]An Online Appendix shows that both models have similar implications for the effects of trade costs on aggregate productivity (available at https://sites.google.com/a/asu.edu/loris-rubini/Online_App_Rubini.pdf?attredirects=0&d=1).

2 Model and Equilibrium

The environment is static. There are two countries, indexed by $i = 1, 2$. The only factor of production is labor. Country i is populated by a measure N_i of identical individuals, each endowed with one unit of labor. There are two sectors in each country, a tradable and a non tradable sector. The tradable sector is comprised by a continuum of differentiated goods $\omega \in \Omega_i$, with $\Omega_1 \cap \Omega_2 = \emptyset$. The set Ω_i has measure M_i. There is a single non tradable good produced and sold in both countries.

Monopolists produce and sell tradable goods. A good $\omega \in \Omega_i$ is associated with a technology parameter $\gamma(\omega) \in \Gamma \subset \mathbb{R}_{++}$, where Γ is the same in both countries. γ determines the marginal gain from innovation and is the source of heterogeneity: the larger the γ, the greater the effect of an additional unit of innovation. The technology to produce good ω is

$$y(\omega) = A(\gamma(\omega), z)n$$

where $y(\omega)$ is output, $A(\gamma, z) = \gamma z$ is productivity, n is labor services, and z is innovation.

Firms choose prices, domestic quantities, exports, and productivity to maximize profits subject to the demand function of domestic and foreign consumers. Innovation determines productivity. To set innovation to level z, a firms must incur $c(z)$ units of labor, where

$$c(z) = z^{\alpha}, \alpha \geq 0$$

Firms export by incurring a fixed export cost κ, as in Melitz (2003). This is in units of labor. Let $\mathcal{I}(\omega) = 1$ denote the decision of monopolist ω in country i to export, $\mathcal{I}(\omega) = 0$ otherwise. Additionally, there are tariffs collected on goods traded.

A key difference with Melitz (2003) and Atkeson and Burstein (2010) is that there is no fixed cost of operation or entry. The online Appendix[4] extends the model to accomodate these. Quantitatively, they do not have much effect on the results.

The non tradable sector in country i is perfectly competitive. A stand-in firm produces this good, labeled S_i (for services), with linear technology $S_i = N_{s_i}$, where N_{s_i} is labor units.

Preferences are defined over tradable goods produced domestically, tradable goods imported, and the domestic non tradable good. Tradable goods are aggregated through a CES function. Let $q_i(\omega)$ be the quantity of good ω consumed in country i by each consumer. The country i CES aggregate over tradable goods is, for $i \neq j$

$$C_i = \left[\int_{\Omega_i} q_i(\omega)^{\frac{\sigma-1}{\sigma}} d\omega + \int_{\Omega_j} q_i(\omega)^{\frac{\sigma-1}{\sigma}} d\omega \right]^{\frac{\sigma}{\sigma-1}}$$

where σ is the elasticity of substitution between tradable goods. $\sigma \in (1, 1+\alpha)$ guarantees that the monopolist's profit maximizing problem is well defined.

Following Helpman and Itskhoki (2007), the utility function of a country i consumer is

$$U(C_i, s_i) = \eta \log C_i + s_i \tag{1}$$

where s_i is the quantity of the non tradable good consumed by an individual in country i.

Consumers maximize (1) subject to the budget constraint. Income is determined by wage earnings, profits from the firms and tax rebates. Denote the wage rate in country i by w_i and set $w_1 = 1$ as the numeraire. Let $\pi(\omega)$ denote the profits of monopolist ω.

The expenditure side consists of payments for domestic tradable goods, imports, and the non tradable good. In equilibrium, perfect competition and linear technologies guarantee that the price of the non tradable good in country i is w_i. Denote by $p(\omega)$ the price of a good ω. In equilibrium, the producer sets the same price for its exports and domestic sales, so $p(\omega)$ is not indexed by the market in which the good is sold.

[4]https://sites.google.com/a/asu.edu/loris-rubini/Online_App_Rubini.pdf?attredirects=0&d=1

A consumer in country i that imports a good from country j pays a tariff τ_i on this good, equal across all country i imports. The amount paid in country i per unit of good ω imported from country j is $(1+\tau_i)p(\omega)$. Tariffs are paid to a domestic government. The government rebates these revenues lump sum back to the consumers. Let G_i denote total rebates in country i, and $g_i = \frac{G_i}{N_i}$ the rebates to each individual. G_i satisfies

$$N_i \tau_i \int_{\Omega_j} \mathcal{I}(\omega) p(\omega) q_i(\omega) d\omega = G_i$$

The budget constraint for a country i individual is[5]

$$\int_{\Omega_i} p(\omega) q_i(\omega) d\omega + (1+\tau_i) \int_{\Omega_j} p(\omega) q_i(\omega) d\omega + w_i(s_i - g_i) = w_i + \frac{\int_{\Omega_i} \pi_i(\omega) d\omega}{N_i} + g_i \qquad (2)$$

Notice that the budget constraint, together with government budget balance, imply that trade balances, that is, for $i \neq j$,

$$N_j \int_{\Omega_i} \mathcal{I}(\omega) p(\omega) q_j(\omega) d\omega = N_i \int_{\Omega_j} \mathcal{I}(\omega) p(\omega) q_i(\omega) d\omega$$

The labor market clears. Total labor supply equals total labor used for the production of the tradable and the non tradable goods. Supply in country i is N_i. Demand is the sum of what is used for production, innovation, exporting in the manufacturing sector and production in the service sector.

$$N_i = \int_{\Omega_i} \left[n(\omega) + c(z(\omega)) + \mathcal{I}(\omega)\kappa \right] d\omega + N_{s_i}$$

Output of each tradable good equals consumption. In country i, for $i \neq j$, for all $\omega \in \Omega_i$

[5] To solve for the equilibrium, impose sufficient conditions so that $s_i - g_i > 0$.

$$\gamma(\omega)z(\omega)n(\omega) = N_i q_i(\omega) + \mathcal{I}(\omega)N_j q_j(\omega)$$

Non tradable market clearing is $S_i = N_i s_i$. The price index for the aggregate good C_i is

$$P_i = \left[\int_{\Omega_i} p(\omega)^{1-\sigma}d\omega + (1+\tau_i)^{1-\sigma}\int_{\Omega_j} p(\omega)^{1-\sigma}d\omega\right]^{\frac{1}{1-\sigma}} \tag{3}$$

A last key ingredient is the demand functions for tradable goods. These functions map prices into the quantity of each γ type good that maximizes utility subject to the budget constraint. These are $q_i(p(\omega); w_i, P_i)$ for $\omega \in \Omega_i$ and $q_i((1+\tau_i)p(\omega); w_i, P_i)$ for $\omega \in \Omega_j$.

Monopolists take these demand functions as given and maximize profits. This problem is

$$\begin{aligned} \pi_i(\omega) = \max_{z,x,p_d,p_x,Q_d,Q_x,n} \ & p_d Q_d + x p_x Q_x - w_i n - w_i z^\alpha - x w_i \kappa \\ s.t. \quad & Q_d = N_i q_i(p; w_i, P_i), \quad Q_x = N_j q_i((1+\tau_i)p; w_i, P_i), \quad Q_x + Q_d = \gamma(\omega) z n \\ & Q_d \geq 0, Q_x \geq 0, n \geq 0, x \in \{0,1\}, z \geq 0 \end{aligned} \tag{4}$$

2.1 Equilibrium Definition

An equilibrium is a list of monopolists' decisions $x(\omega), z(\omega), p(\omega)$, profits $\pi(\omega)$ for all ω, demand functions $q_i(p(\omega); w_i, P_i)$, for $\omega \in \Omega_i$, $q_i((1+\tau_i)p(\omega); w_i, P_i)$, for $\omega \in \Omega_j$, allocations n_{s_i}, g_i, S_i, and prices w_i, P_i for $i, j \in \{1,2\}, i \neq j$ such that (i) consumers maximize equation (1) subject to equation (2); (ii) P_i satisfies equation (3); (iii) monopolists maximize profits subject to the demand functions from the consumers; (iv) non tradable firms maximize profits taking prices as given; (v) markets clear; and (vi) government balances budget.

2.2 Change of Variables

Recall that each good ω is associated with a technology parameter γ. In equilibrium, two firms in the same country with the same γ make the same decisions. It is convenient to concentrate on the space of γ's and country of origin rather than the space of ω's.

Define $\mathcal{I}_i(\gamma)$ as the export decision of a type γ monopolist in country i, and define $z_i(\gamma), p_i(\gamma)$, and $\pi_i(\gamma)$ similarly. Next let $q_{di}(p_i; w_i, P_i)$ be the demand in country i for a tradable good produced domestically, and $q_{mi}((1+\tau_i)p_j; w_i, P_i)$ the demand in country i for an imported good. Let $f(\gamma)$ denote the distribution of firms (same for both countries).

The list of variables that define the equilibrium are monopolists' decisions $\mathcal{I}_i(\gamma), z_i(\gamma), p_i(\gamma)$, profits $\pi_i(\gamma)$, demand functions $q_{di}(p_i; w_i, P_i), q_{mi}(p_j; w_i, P_i)$, allocations n_{s_i}, g_i, S_i, and prices w_i, P_i for $i, j \in \{1, 2\}, i \neq j$ where

$$P_i = \left[\int p_i(\gamma)^{1-\sigma} M_i f(\gamma) d\gamma + (1+\tau_i)^{1-\sigma} \int p_j(\gamma)^{1-\sigma} M_j f(\gamma) d\gamma \right]^{\frac{1}{1-\sigma}} \tag{5}$$

where M_i denotes the measure of goods in country i.

2.3 Equilibrium Properties

In equilibrium, (i) price is a constant mark-up over marginal cost; (ii) exporting follows a cut-off rule; and (iii) innovation increases with γ. Firm choices solve the profit maximizing problem, taking the demand functions for their products as given. From the solution to the consumer problem, these demand functions are

$$q_{di}(p_i; w_i, P_i) = \omega w_i P_i^{\sigma-1} p_i^{-\sigma} \qquad \text{and} \qquad q_{mi}(p_j; w_i, P_i) = \omega w_i P_i^{\sigma-1} \left((1+\tau_i)p_j\right)^{-\sigma}$$

They feature a constant elasticity of demand σ on own price. P_i summarizes the relevant information on the price of all other tradable goods available for consumption (domestic and imported). An increase in the price of another tradable good in country i increases the price index P_i, and this increases the demand for each tradable good, since $\sigma > 1$.

As in Dixit and Stiglitz (1977), price is a markup over marginal cost, except that marginal cost is endogenous given innovation, so that $p_i(\gamma) = \left(\frac{\sigma}{\sigma-1}\right)\frac{w_i}{\gamma z_i(\gamma)}$. Note that this implies that prices before tariffs are the same in both countries.

Define $\pi_i^v(\gamma; z, x)$ as the variable profits of a type γ in country i with innovation level z and export status x. Given the mark-up rule, $\pi_i^v(\gamma, z, x)$ is increasing in γ, z and x

$$\pi_i^v(\gamma, z, 1) = (K_{di} + K_{xi}) z^{\sigma-1}\gamma^{\sigma-1} \tag{6}$$

$$\pi_i^v(\gamma, z, 0) = K_{di} z^{\sigma-1}\gamma^{\sigma-1} \tag{7}$$

where $K_{di} = \left(\frac{\sigma}{\sigma-1}\right)^{1-\sigma} N_i w_i^{2-\sigma}\gamma P_i^{\sigma-1}$ and $K_{xi} = \left(\frac{\sigma}{\sigma-1}\right)^{1-\sigma} N_j w_j^{1-\sigma}\gamma P_j^{\sigma-1}(1+\tau_j)^{-\sigma} w_i$.

Firms choose innovation and export status to maximize total profits. Innovation choices are as follows. From the first order conditions, optimal expenditures on innovation are proportional to $\pi_i^v(\gamma, z, x)$. Let $z_{xi}(\gamma)$ be the maximizing level of innovation for a type γ exporter in country i and define $z_{di}(\gamma)$ similarly. The first order conditions set

$$\begin{aligned} w_i z_{xi}(\gamma)^\alpha &= \frac{\sigma-1}{\alpha}\tilde{\pi}_i(\gamma, z_{xi}(\gamma), 1) \\ w_i z_{di}(\gamma)^\alpha &= \frac{\sigma-1}{\alpha}\tilde{\pi}_i(\gamma, z_{di}(\gamma), 0) \end{aligned}$$

This implies that innovation is increasing in γ and in export status. That is, for all γ,

$$z'_{xi}(\gamma) > 0, \qquad z'_{di}(\gamma) > 0, \qquad z_{xi}(\gamma) > z_{di}(\gamma) \tag{8}$$

The export decision is determined by a cut-off rule, as in Melitz (2003). Firms decide whether to export or not by comparing the profits from being an exporter with the profits from not being an exporter. The cut-off result follows from a single crossing argument. Specifically, type γ in county i exports if and only if the following holds[6]

$$\begin{aligned}&\pi_i^v(\gamma, z_{xi}(\gamma), 1) - w_i z_{xi}(\gamma)^\alpha - [\pi_i^v(\gamma, z_{di}(\gamma), 0)) - w_i z_{di}(\gamma)^\alpha] \geq w_i \kappa \Leftrightarrow \\ &\left(\frac{\alpha + 1 - \sigma}{\alpha}\right)(\pi_i^v(\gamma, z_{xi}(\gamma), 1) - \pi_i^v(\gamma, z_{di}(\gamma), 0)) \geq w_i \kappa \end{aligned} \tag{9}$$

Equation (9) can hold with equal sign for at most one γ. Differentiating equations (6) and (7) with respect to γ and considering that $z_{xi}(\gamma) > z_{di}(\gamma)$ shows that

$$\frac{\partial \pi_i^v(\gamma, z_{xi}(\gamma), 1)}{\partial \gamma} > \frac{\partial \pi_i^v(\gamma, z_{di}(\gamma), 0)}{\partial \gamma}$$

Therefore, the left hand side of expression (9) is strictly increasing in γ. Thus, if type γ^* chooses to export, so do every type $\gamma \geq \gamma^*$.

Finally, the export cost shifts the exporter profits downwards. If Γ is a convex set, and there exist $\underline{\gamma} \in \Gamma$ and $\bar{\gamma} \in \Gamma$ such that

$$\left(\frac{\alpha + 1 - \sigma}{\alpha}\right) \pi_i^v(\underline{\gamma}, z_{xi}(\underline{\gamma}), 1) < w_i \kappa < \left(\frac{\alpha + 1 - \sigma}{\alpha}\right) [\pi_i^v(\bar{\gamma}, z_{xi}(\bar{\gamma}), 1) - \tilde{\pi}_i(\bar{\gamma}, z_{di}(\bar{\gamma}), 0)]$$

then there is exactly one γ such that (9) holds with equality[7], and therefore the single crossing property holds. This is illustrated in figure B.2. The cut-off level is γ_1 in the figure.

Conditions (8), plus the export cut-off rule, imply that innovation is a strictly increasing function of γ with a discontinuous "jump" at the export cut-off $\hat{\gamma}_i$, as in figure 4.

[6]Indifferent firms arbitrarilly choose to export. Since there is only one type which is indifferent, and the measure of that type is zero, there is no loss of generality. This assumption is convenient because it means innovation is a function of γ. Otherwise, it is a correspondence that is not single valued at $\hat{\gamma}_i$. The Berge theorem guarantees that this correspondence is upper hemi continuous.

[7]This is an application of the Brower fixed point theorem, since the Berge theorem guarantees that the left hand side of expression 9 is continuous. Uniqueness comes from strict monotonicity.

3 The Canada-U.S. Free Trade Agreement

I calibrate the model to evaluate the effects of the reductions in tariffs in the Free Trade Agreement between Canada and the United States. The choice of this episode is based on (i) we have good, reliable, tariff data; and (ii) several studies have focused on this episode, providing a good understanding of the effect of the reduction in tariffs.

The agreement eliminated tariffs between the United States and Canada over a course of ten years. It was entered into in January 1, 1989. Broadly speaking, the agreement divided all goods into three categories. The tariffs of the first group would be eliminated immediately, the second group would eliminate them proportionally over 5 years, and the third would eliminate them proportionally over 10 years.

The results of two papers that study this episode are crucial for my analysis: Trefler (2004), and Head and Ries (2001). These analyses end, respectively, in 1996 and 1995. This is not a problem, since by 1996 most of the effects of the agreement had already taken place. To put this in perspective, in 1988, the average tariff was close to 6%. One in 4 tariffs was over 10%. By 1996, the average tariffs were close to 1%, and no tariff was over 5%.

Head and Ries estimate the effect of the reductions in tariffs on trade volumes. The authors identify the effect of tariff reductions by isolating it from other factors such as non tariff trade barriers. Their measure of trade volume in industry i is the ratio of bilateral manufacturing industry i exports to total manufacturing industry i output minus total manufacturing industry i exports. In this way, the authors abstract from trade with other countries (see Appendix A for details on their estimation). This delivers two estimates of the trade elasticity to tariffs: 7.88 and 11.41. Clausing (2001) finds similar results.

Trefler (2004) focuses on the effect of tariffs on Canadian productivity, and estimates that they account for an increase between 5% and 8.3%. Productivity is measured as value added per production worker, in 1992 constant prices. Potentially, this increase could be due to the reallocation of resources from least productive to more productive firms. However, it is unlikely that this reallocation has big effects on measured productivity.[8] Furthermore, the online Appendix shows that in the context of my model the reallocation of resources has no effects on measured productivity in constant or chain weighted prices with no innovation.

To further explore the effect of the agreement on firm behavior, Lileeva and Trefler (2010) study the productivity and innovation patterns of firms that entered the export market during the agreement years. The innovation study is based on an innovation survey in Canada. Their findings suggest that firms entering the export market increased their innovation and their labor productivity relative to non exporters, or firms that were exporting before 1989. Given the lack of data on capital, the authors question whether the increases in labor productivity are due to these new exporters becoming larger, and therefore hiring more capital services. If this were the case, and the total factor productivity had stayed constant, then the price of these goods relative to other goods should not change, and consequently the domestic market share of these firms should remain unaltered. However, they find that these market shares increased, suggesting that total factor productivity increased.

4 Calibration

Country 1 is the U.S., and country 2 is Canada. The tradable sectors are matched to the manufacturing sectors in the data, as suggested in Valentinyi and Herrendorf (2008).

The exogenous distribution of firms $f(\gamma)$ and the set Γ are as follows: $\Gamma = [1, \bar{\gamma}]$, and $f(\gamma)$ is a truncated Pareto density function, as in Ruhl (2008) and Leal (2014), among others. This function is $f(\gamma) = \frac{\theta}{1-\bar{\gamma}^{-\theta}}\gamma^{\theta-1}$. where $\gamma \in [1, \bar{\gamma}]$ and $\theta > 0$ is a curvature parameter. A consequence of this functional form is that the distribution of exporters according to employees in equilibrium is close to Pareto shaped. This is consistent with the findings of

[8] Gibson (2006) and Kehoe and Ruhl (2008) show that a reallocation of resources has small, if any, effects on real productivity when measured in constant or chain weighted prices.

Luttmer (2007) for large U.S. manufacturing firms.

The measure of firms in the U.S. is normalized to 1 and the measure of firms in Canada is M, to be calibrated. The elasticity of substitution σ is key, since the reaction of trade volumes to tariff reductions is very sensitive to this parameter. The parameter σ must be consistent with empirical estimates. Broda and Weinstein (2006) provide the most detailed study of import elasticities, in which they estimate over 30,000 elasticities. The medians reported vary from 2.2 to 3.1, depending on the level of aggregation.[9] This study makes adjustments for the changing number of imported goods, as first suggested in Feenstra (1994). Other studies such as Reinert and Roland-Holst (1992) and Blonigen and Wilson (1999) do not make this adjustment, and estimate elasticities at the industry level, with average elasticities close to 1, and a maximum of 3.5. Ruhl (2008) shows that $\sigma = 2$ is consistent with these studies, justifying my choice of $\sigma = 2$.

The parameter η is set so that the ratio of tradable output to total output is of 15% in U.S. This implies a share in Canada is very close to that of U.S. in equilibrium, consistent with the data. Populations are $N_{US} = 1$ (normalized), and $N_{CA} = 0.11$, to match the ratio of population in Canada and U.S. in 1988.

The remaining parameters are calibrated jointly. θ and $\bar{\gamma}$ are calibrated to minimize the sum of squared difference between the employee size distribution of manufacturing firms in the U.S. data and model in 1992.[10] These data come from the 1992 Census of Manufactures. The census provides the share of firms with less than H_i employees, for given H_i's. A problem in this calibration is that due to the discrete jump between exporters and non exporters, the equilibrium distribution might have no firms with exactly H_i employees. To solve this, when minimizing the difference between the employee size distribution in the data and model, find

[9] Medians are more meaningful than averages because the authors restrict the elasticities to be larger than 1, which biases in the average elasticity, but the median does not change.

[10] There is no data for 1988. The closest census available is 1992. This is not a problem because the distribution of firms in the U.S. hardly changes, as Figure 2 shows. This is not the same for Canada, where Gu et al. (2003) show that firm size increased considerably.

the maximum number of employees in each bin so that the fraction of firms in that bin is the same in the model and the data. The parameters are therefore a solution to

$$\min_{\theta,\bar{\gamma}} \sum_{i=2}^{7} \left(\frac{H_m(\gamma_i)}{H_m(\gamma_1)} - \frac{H_d(\gamma_i)}{H_d(\gamma_1)} \right)^2$$

where $H_d(\gamma_i)$ is labor in the firm γ_i in the data and $H_m(\gamma_i)$ is the equivalent in the model. Figure 1 shows the proportion of firms in the data and model according to the employee bins in the data. These are also the bins in Ruhl (2008). Recall that in equilibrium, the model might feature no firm with exactly H_i employees. Thus, to compare the model distribution with the data, add (or subtract) employees to each bin in the model, and extrapolate linearly the share of firms. The resulting distribution is plotted in figure 1.

The parameter α is harder to pin down. This represents the elasticity of productivity to innovation expenses, and I found no reliable estimates of this elasticity. Alternatively, the productivity gains from trade are highly sensitive to α. Thus, the calibration sets α to match the gains found in the data associated with tariffs. Trefler (2004) finds that the average Canadian labor productivity increased by between 5% and 8.3% due to the tariffs.

The fixed export cost κ and the measure of firms in Canada M are calibrated to match export shares. Define trade volumes as Head and Ries (2001) (for details, see Appendix A). These were, in 1988, 3% in U.S. and 29% in Canada. The data are from the OECD STAN Database for Structural Analysis.

Tariffs come from Trefler (2004). He provides tariffs for bilateral trade per industry per year between 1980 and 1996. Tariffs in the model before trade liberalization are equal to the average across industries in 1988 and equal to the average in 1996 after trade liberalization. 1996 is the last year of tariff drops in Trefler, in spite of the reduction continuing until 1998.[11] The calibrated parameters are in Table 1.

[11] Tariffs in 1996 are small but positive. The results hardly change by setting tariffs to zero.

5 Findings

The proceedure is as follows. The first step is to compute the equilibrium in the model using the calibrated parameters in table 1, with 1988 tariffs. This determines an initial trade volume in each country m_{i0}. The second step keeps all parameters fixed except the tariff rates, and replace them with their values for 1996. This results in a second trade volume m_{i1}. The trade volumes are computed as in Head and Ries (2001) and detailed in Appendix A. The trade elasticity is the percentage point change in the geometric average of trade volumes per percentage point change in tariffs (b in Appendix A).

5.1 Equilibrium Pre-Liberalization

Figure B.2 shows the profits of firms in the United States. Profits in Canada are similar. These are an increasing, continuous function of type, with a kink at the cut-off type $\hat{\gamma}_i$. Figure 5 shows the innovation rules for U.S. and Canada with 1988 tariffs.

Innovation is higher for firms in U.S. This is because the domestic market in U.S. is much larger than in Canada. The "jump" in innovation from non exporters to exporters is larger in Canada than in U.S., since the foreign market is more important in Canada.

5.2 Reducing Tariffs

The reduction in tariffs increases the measure of exporters (extensive margin), and their sales (intensive margin). This drives exporters to increase innovation, since its cost can be spread over a larger sales volume. This increase in innovation is greatest among new exporters, given that they face the largest increase in sales.

Non exporters in each country decrease their innovation. This is because the price P_i in country i drops, reducing domestic domestic demand for all firms. There are four factors that contribute to this. First, the tariff falls in each country. Second, the prices of all goods that are exported drop. Third, the price of imported goods drop. And fourth, the measure of imported goods increases. All these factors contribute to lowering the index price P_i in each country (see equation 3). While exporters can overcompensate this decrease in domestic demand with the increase in foreign demand, and therefore increase innovation, non exporters cannot, decreasing innovation.

Figures 6 and 7 show the change in innovation in each country. Quantitatively, only the extensive margin changes in U.S. Changes are larger in Canada. This is natural since the changes introduced by the Free Trade Agreement had a much larger effect in Canada than in the United States, since Canada is small relative to the U.S.

The resulting trade elasticity is 9.34. This is measured as in Head and Ries and detailed in Appendix A. Roughly, it is the change in the geometric average of inverse of the trade volumes in each country with respect to the average bilateral tariff in each country. This is within the empirical estimates found by Head and Ries (2001) (between 7.88 and 11.41) and Clausing (2001) (between 8.9 and 9.6).[12] The elasticity per country, not reported by Head and Ries is 9.05 in Canada and 10.05 in U.S.

The effects on productivity are highly asymmetric. While the increase in Canadian productivity is calibrated to match 5%, the increase in productivity in U.S. is 0.1%. This is because the expansion in Canadian firms is much larger than the expansion in U.S. firms. The small effect on U.S. industries is consistent with Bernard and Jensen (1999), who argue that there is no evidence of productivity gains from trade among U.S. manufacturers.

Without innovation ($\alpha \to \infty$), the increase in measured productivity is zero (Appendix B). Calibrating the model without innovation to match the previous targets except the productivity increase (see Table 1) delivers a trade elasticity of 6.2. Thus, innovation amplifies the response of trade to tariffs by 50 percent. This elasticity is below the empirical estimates. This result is very close to Ruhl's (2008), which is noteworthy given the models are very

[12]Targeting a productivity increase of 8.3% (Trefler's upper bound) delivers an elasticity of 10.01.

different. The results follow from having the same mechanism and using the same data.

5.3 Sensitivity Analysis

This section explores how the response of trade volumes to tariffs changes when two parameters change: the elasticity of substitution σ, and the elasticity of productivity to innovation α. The sensitivity analysis is based on two types of exercises. The first changes one parameter while keeping the rest of the parameters fixed. Obviously the model misses the targets discussed in section 4. Missing some of this targets is costly, leading to corner solutions with no exporters, for example. Thus, the margin of change in some of these parameters, especially σ, is very limited. To address this issue, I perform a second kind of sensitivity analysis that changes the value of a parameter such as σ and calibrates the remaining parameters to match the targets in section 4.

Table 2 reports the changes in trade volumes, productivity, and the extensive margin under different σ's. Except for the elasticity, these changes are Canada's. The changes for the U.S. are smaller in magnitude, but in the same direction. Column 1 uses the benchmark calibration, column 2 reduces σ by five percent and leaves all other parameters unchanged, and column 3 sets $\sigma = 1.75$ and calibrates all other parameters to match section 4 targets.

A lower elasticity of substitution implies that the response of the intensive margin is lower, since demands are less elastic. This accounts for the lower aggregate trade elasticity when σ is smaller. Also, the productivity increase is smaller. Notice however that the change in the extensive margin is larger when σ is smaller. This is consistent with Chaney (2008). He argues that tariffs have larger effects on the extensive margin when σ is small. When tariffs fall, firms with lower γ enter the export market. When the elasticity of substitution is high, competition is high, and therefore a lower productivity is a severe disadvantage. Instead, when this elasticity is low, firms are protected from competition, and more firms choose to enter the export market. Notice that the amplification effects of innovation are less when σ is low. This is because when the elasticity of substitution is low, the incentives to innovate of the new exporters are lower, since innovation is not so powerful at preventing competition.

Table 3 reports the changes when the parameter α changes. Column 2 reduces α by one percent, and column 3 sets $\alpha = 1.75$. A reduction in α means that productivity reacts more to innovation expenses. Consequently, the increase in the trade volumes and productivity is larger. The changes in the extensive margin are smaller when α is small. Intuitively, the effects of cheaper innovation are similar to the effects of more elastic demands. Inelastic demands reduce the returns from innovating, since a drop in price has small effects, and therefore the incentives to innovate are small. Cheaper innovation increases these incentives by reducing the cost to lower the marginal cost, and hence the price. Therefore, the effect is similar as the effect of increasing σ. Notice that the amplification effect is larger when innovation is cheaper. Since the effects of cheaper innovation are similar to the effects of a larger σ, amplification effects are increasing in σ.

6 Revisiting Yi's Calculations

This section evaluates time series effects of tariffs on trade volumes, revisiting Yi (2003)'s findings. Yi, finds that models of the Krugman (1980) and Backus et al. (1994) types fail when accounting for the effects of tariffs on trade volumes.

Yi builds a model with two symmetric countries, and calibrates it to U.S. data in 1962. By dropping tariffs to the level in 1999, and computing the change in trade volume, he concludes that these models need an elasticity parameter between 12 and 13 to generate an increase in trade volumes of the magnitude in the data, which is much higher than the empirical estimates. This exercise is subject to a wide variety of critiques, which mainly imply studying the historic effect of tariffs on U.S. trade volumes using a model with two symmetric countries. Notwithstanding, it has generally been successful in showing that these models perform poorly from a quantitative perspective.

Tariffs in U.S. roughly decreased from 14% in 1962 to 3% in 1999 (Yi, 2003). Trade volumes (manufacturing exports relative to manufacturing output minus manufacturing exports) in 1963 are 4.3% and 13.8% in 1997, an increase of 220%. Data come from BEA's Benchmark Input Output Tables (1963 and 1997).

To study the symmetric country case, parameters change as follows. Symmetry implies $N_1 = N_2 = M = 1$. The export cost is such that the model generates a trade volume as in the data in 1962. The rest of the parameters do not change from section 4. The resulting increase in trade volumes in the model is of 140%, about 2/3 of the actual increase in the data. In the model with no innovation, the increase is half as much, and in Krugman type models, the increase is only one tenth of the increase in the data.

Thus, the model with innovation can account for a much larger share of the increase in trade volumes than the Krugman model or the model with no innovation. It is important to note that we should not expect the drop in tariffs to account for all the increase in trade volumes. Other factors, including changes in non tariff barriers and transportation costs, are also responsible. Many of the GATT Rounds for trade liberalization concentrated more on non tariff barriers than on tariffs. For example, the Uruguay Round, from 1986 through 1993, concentrated on issues such as farming subsidies and intellectual property rights. Bridgman (2008) finds that energy prices, and therefore costs of transportation, played an important role in the increase in trade in the 1980s.

7 Discussion

This study can help understand why productivity gains from trade differ across countries. Empirically, productivity gains from trade are large in small industrialized countries. Trefler (2004) finds productivity gains of up to 15% in the industries in Canada which faced the largest reduction in U.S. tariffs during the Free Trade Agreement. De Loecker (2007) finds productivity gains from trade liberalization at the firm level in Slovenia close to 50%.

The evidence is less conclusive for developing economies. While Van Biesebroeck (2005) finds gains from trade among African countries, Havrylyshyn (1990) concludes that there is no evidence of gains from trade among developing countries based on a survey of studies, and Clerides, Lach and Tybout (1998) do not find evidence of productivity gains from trade among exporting firms in Colombia, Mexico and Morocco. Furthermore, Eslava et al. (2013) find productivity gains from trade in Colombia during a different time period.

My model suggests that the different findings can at least in part be attributed to differences in innovation costs: larger innovation costs reduce the productivity gains. For example, increasing α by 13% reduces the gains in Canada by half. Increasing it by 30% produces gains of less than 1%. Increasing it by 50%, the productivity gains are almost zero (0.2%).

In developing countries these costs are likely to be higher. The reason is that institutions and policies are generally an important determinant of innovation costs. In developing countries, high labor market regulation, corruption, and low enforcement of intellectual property rights tend to increase the costs of innovation. Botero et al. (2004) find that the labor market is more heavily regulated in developing economies. Heckman and Pagés (2004) find that Latin American labor markets are more heavily regulated. Among developing economies, corruption is usually higher, and the enforcement of intellectual property rights lower (Djankov et al. (2002)).

This explanation complements that of Kambourov (2009), who argues that highly regulated labor markets reduce the productivity gains from trade by making the reallocation of workers to more productive sectors slower. Innovation provides a second channel through which developing countries should expect lower gains from trade.

8 Conclusion

This paper develops a model of international trade with a costly productivity decision, using a framework based on Melitz (2003). Recently, the international trade literature has made extensive use of Melitz type models to model trade patterns. While these models have been concentrating in accounting for aspects more related to the industrial organization literature, such as firm entry, exit, export, and growth, they have not successfully accounted for the effects of trade liberalization. This lack of success led Arkolakis, Demidova, Klenow and Rodríguez Clare (2008) to the conclusion that the only attraction of these models is their power to qualitatively account for many micro level observations, such as exporters being relative larger than non exporters, and entry and exit patterns into the economy and into the export market.

This paper is a successful attempt to quantitatively account for the effect of reductions in tariffs on *aggregate* trade volumes. The main result is that introducing innovation to a model of international trade amplifies the effect of trade liberalization on trade volumes considerably, by about 50 percent, placing it within the empirical estimates. Without innovation, the model accounts for an increase in trade volumes that is similar to other models without innovation, and below the empirical estimates.

APPENDIX

A Measuring the Elasticity of Trade Volumes

Trade volume in country i is

$$m_i = \frac{\text{Country } i \text{ Exports}}{\text{Country } i \text{ Total Tradable Output sold in North America}}$$

The numerator is the average between exports from U.S. to Canada and from Canada to U.S. The denominator is country $i's$ total manufacturing output minus exports to countries other than Canada or the United States. Notice that this measure excludes all trade with countries other than the United States or Canada.

Based on the measure m_i, Head and Ries construct the indicator b to measure the trade elasticity:

$$b = \sqrt{\left(\frac{1 - m_{US}}{m_{US}}\right) \times \left(\frac{1 - m_{CA}}{m_{CA}}\right)} = \sqrt{\frac{D_{US}}{X} \times \frac{D_{CA}}{X}}$$

where D_i is output for domestic absorption in country i and X is bilateral exports. The measure is at the industry level. They regress the difference between two consecutive periods of the log of this measure against the log of the difference in tariffs. Tariffs are the arithmetic average of one plus the industry tariff in Canada for U.S. imports and one plus the industry tariff in U.S. for Canadian imports. That is, they perform the following regression

$$\Delta \log(b_i) = a_0 + a_1 \Delta \log(1 + \tau_i) + \text{ other controls}$$

where $\Delta \log(b_i) = \log(b_{i,t+1}) - \log(b_{i,t})$, $\Delta \log(1 + \tau_i) = \log(1 + \tau_{i,t+1}) - \log(1 + \tau_{i,t})$, where i stands for industry and $\tau_{i,t} = \frac{\tau_{CA,i,t} + \tau_{US,i,t}}{2}$, and $\tau_{j,i,t}$ for $j = US, CA$ is the tariff in country

j, industry i and time t. Head and Ries show that a_1 is equal to the trade elasticity minus 1, and its estimate is between 6.88 and 10.41, implying that the trade elasticity is between 7.88 and 11.41.

B Measuring Productivity Increase in the Model

I measure the increase in productivity using chain weighted prices. In the data, real productivity is measured by calculating current productivity, and deflating it by some price level. The price level is built by choosing a bundle off goods, and computing the value of that bundle using current and base period prices.

Denote by period 0 variables those variables in the equilibrium with high tariffs and period 1 variables the low tariff variables. Deflate the productivity increase in current prices by two price deflators, one that uses period 0 quantities and one that uses period 1 quantities. The final increase in productivity is a geometric average of the increase using both indices, that is, a chain weighted productivity increase.

The increase in current price productivity in country i is

$$\Delta Prod_i = \frac{\dfrac{\int_{\Omega_i} p_1(\omega)Q_1(\omega)d\omega}{\int_{\Omega_i} h_1(\omega)d\omega}}{\dfrac{\int_{\Omega_i} p_0(\omega)Q_0(\omega)d\omega}{\int_{\Omega_i} h_0(\omega)d\omega}} = \frac{w_1}{w_0} \tag{10}$$

where $h_t(\omega)$ is labor used in production of good ω in period t and $Q_t(\omega) = Q_{1t}(\omega) + Q_{2t}(\omega)$ is total output of good ω in period t.

Finally, deflate $\Delta Prod_i$ using two price indeces, one using period 0 quantities (Laspeyres), and a second one using period 1 quantities (Paasche). These deflators are

$$P_L = \frac{\int_{\hat{\Omega}_i} p_1(\omega)Q_0(\omega)d\omega}{\int_{\hat{\Omega}_i} p_0(\omega)Q_0(\omega)d\omega}$$

$$P_P = \frac{\int_{\hat{\Omega}_i} p_1(\omega)Q_1(\omega)d\omega}{\int_{\hat{\Omega}_i} p_0(\omega)Q_1(\omega)d\omega}$$

where $\hat{\Omega}$ is the set of goods in the bundle chosen to calculate the price deflator.

B.1 No Innovation

The set of goods is constant across periods, so $\hat{\Omega}_i = \Omega_i$. The model with no innovation has no increases in real productivity from lower tariffs. In this case, $P_L = P_P = \frac{w_1}{w_0}$, so that the deflated $\Delta Prod$ equals 1. This follows from, for $t = 0, 1$, $Q_t(\omega) = K_t p_t(\omega)^{-\sigma}$, where K_t is a constant that does not depend on ω, and $p_t(\omega) = \frac{\sigma}{\sigma-1}\frac{w_t}{\theta(\omega)}$.

B.2 Model with Innovation

As in the case with no innovation, in the base model $\hat{\Omega}_i = \Omega_i$. Moreover, in this case, deflating the current price productivity increase amounts to computing the productivity increase in constant prices. First, deflate the productivity increase given by equation (10) using the Laspeyres (subindex L) price index and Paasche (P).

$$\Delta Prod_{iL} = \frac{\frac{\int_{\Omega_i} p_1(\omega)Q_1(\omega)d\omega}{\int_{\Omega_i} h_1(\omega)d\omega}}{\frac{\int_{\Omega_i} p_0(\omega)Q_0(\omega)d\omega}{\int_{\Omega_i} h_0(\omega)d\omega}} \div P_L = \frac{\frac{\int_{\Omega_i} p_1(\omega)Q_1(\omega)d\omega}{\int_{\Omega_i} h_1(\omega)d\omega}}{\frac{\int_{\Omega_i} p_1(\omega)Q_0(\omega)d\omega}{\int_{\Omega_i} h_0(\omega)d\omega}}$$

$$\Delta Prod_{iP} = \frac{\frac{\int_{\Omega_i} p_1(\omega)Q_1(\omega)d\omega}{\int_{\Omega_i} h_1(\omega)d\omega}}{\frac{\int_{\Omega_i} p_0(\omega)Q_0(\omega)d\omega}{\int_{\Omega_i} h_0(\omega)d\omega}} \div P_P = \frac{\frac{\int_{\Omega_i} p_0(\omega)Q_1(\omega)d\omega}{\int_{\Omega_i} h_1(\omega)d\omega}}{\frac{\int_{\Omega_i} p_0(\omega)Q_0(\omega)d\omega}{\int h_0(\omega)d\omega}}$$

Next compute the chain weighted price productivity increase as the geometric average between these two productivity increases

$$\Delta Prod_i = \sqrt{\Delta Prod_{iP} \times \Delta Prod_{iL}}$$

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Parameter	Target	Value Innov.	Value No Innov.
α	CA Prod. Increase = 5%	2.01	∞
σ	Estimated demand elast. for imports	2.00	2.00
θ	U.S. distribution of firms	2.01	1.01
$\bar{\gamma}$	U.S. distribution of firms	26.32	664.32
η	Share of manufacturing output	0.30	0.30
κ	CA and U.S. trade volumes	4.34	3.67
N_1	Normalization	1.00	1.00
N_2	Pop. CA rel to U.S.	0.11	0.11
M	CA and U.S. trade volumes	0.86	0.27
τ_{10}	Avg. U.S. tariffs for CA imports 1988	4.00%	4.00%
τ_{20}	Avg. CA tariffs for U.S. imports 1988	8.2%	8.20%
τ_{11}	Avg. U.S. tariffs for CA imports 1996	0.81%	0.81%
τ_{21}	Avg. CA tariffs for U.S. imports 1996	1.45%	1.45%

Table 1: Calibrated parameters and targets matched in the models with and without innovation.

	$\sigma = 2.00$ Benchmark	$\sigma = 1.98$ Other parameters fixed	$\sigma = 1.75$ Calibrate other parameters
Elasticity	9.34	9.89	7.94
Δ productivity	5.00%	4.55%	5.00%
$\Delta\hat{\theta}$	-3.24%	-3.52%	-4.65%
Elasticity no innovation	6.18	6.02	5.21
Amplification	51.13%	64.29%	52.40%

Table 2: The trade elasticity under different values for the elasticity of substitution between varieties (σ). The first column shows the benchmark parameterization, the second shows the effect of reducing σ and leaving all other parameters fixed. The third shows the effects of changing σ and all other parameters to match the targets in the benchmark calibration. The rows are: the trade elasticity, the change in measured productivity, the change in the extensive margin of trade, all of these under the model where innovation is possible. The following row shows the results with no innovation, and the last shows the amplification in the elasticity due to innovation.

	$\alpha = 2.01$ Benchmark	$\alpha = 1.91$ Other parameters fixed	$\alpha = 1.75$ Calibrate other parameters
Elasticity	9.63	10.13	10.57
Δ productivity	5.00%	6.48%	12.49%
$\Delta\hat{\theta}$	-3.24%	-2.79%	-2.05%
Elasticity no innovation	6.18	6.18	6.18
Amplification	51.13%	63.92%	71.04%

Table 3: The trade elasticity under different values for the elasticity of productivity to innovation expenses (α). The first column shows the benchmark parameterization, the second shows the effect of reducing α and leaving all other parameters fixed. The third shows the effects of changing α and all other parameters to match the targets in the benchmark calibration. The rows are: the trade elasticity, the change in measured productivity, the change in the extensive margin of trade, all of these under the model where innovation is possible. The following row shows the results with no innovation, and the last shows the amplification in the elasticity due to innovation.

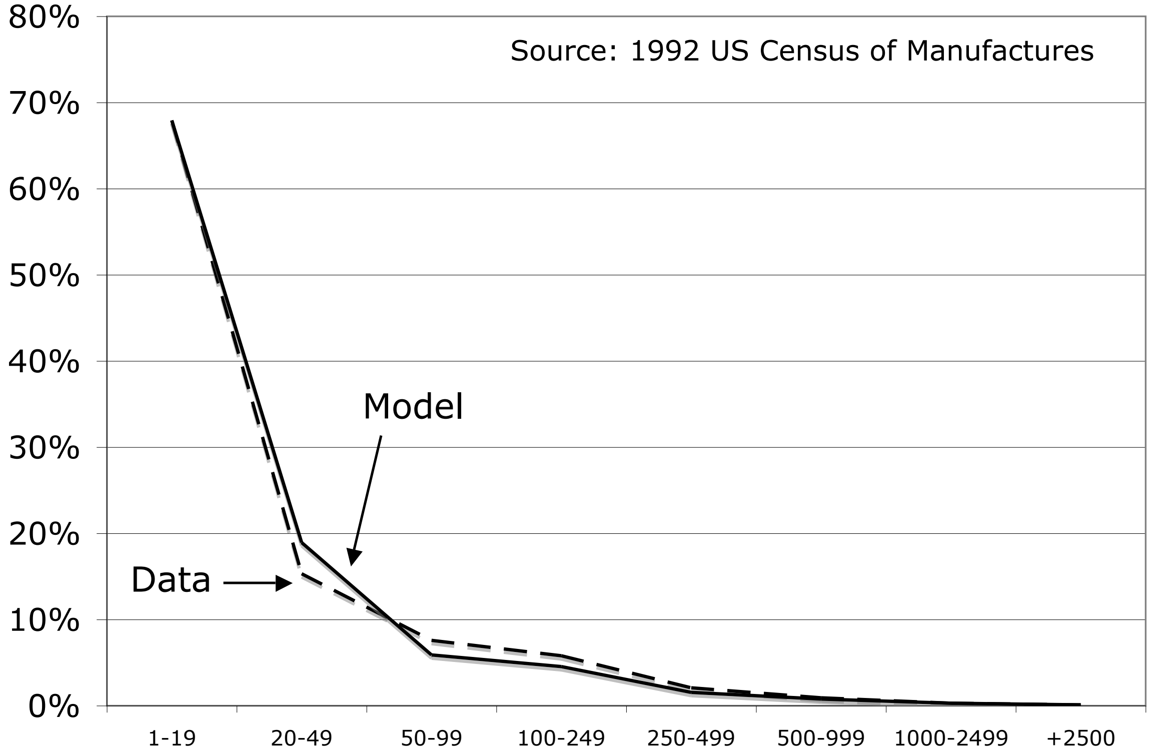

Figure 1: Fit of the Size Distribution of Firms. The dashed line shows the firm size distribution by employees in the manufacturing sector in the United States. The solid line shows the distribution generated by the model in equilibrium in the United States. Source: 1992 Census of Manufactures.

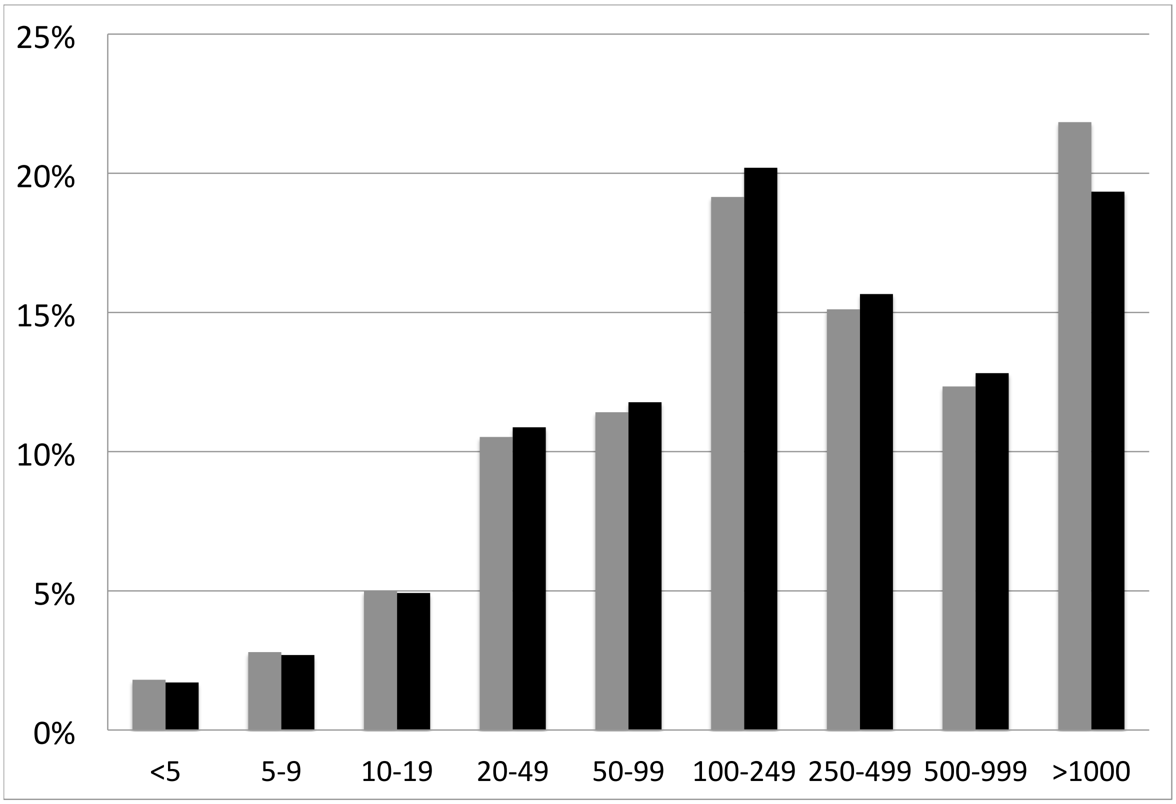

Figure 2: Comparison of the 1992 and 1997 firm size distributions in the United States. The grey bars show the firm size distribution by employees in the manufacturing sector in the United States in 1992, and the black bars are for 1997. The vertical axis shows the percentage of employees in firms of size x. The horizontal axis shows the size of the different firms in terms of employees. Source: Bureau of Labor Statistics.

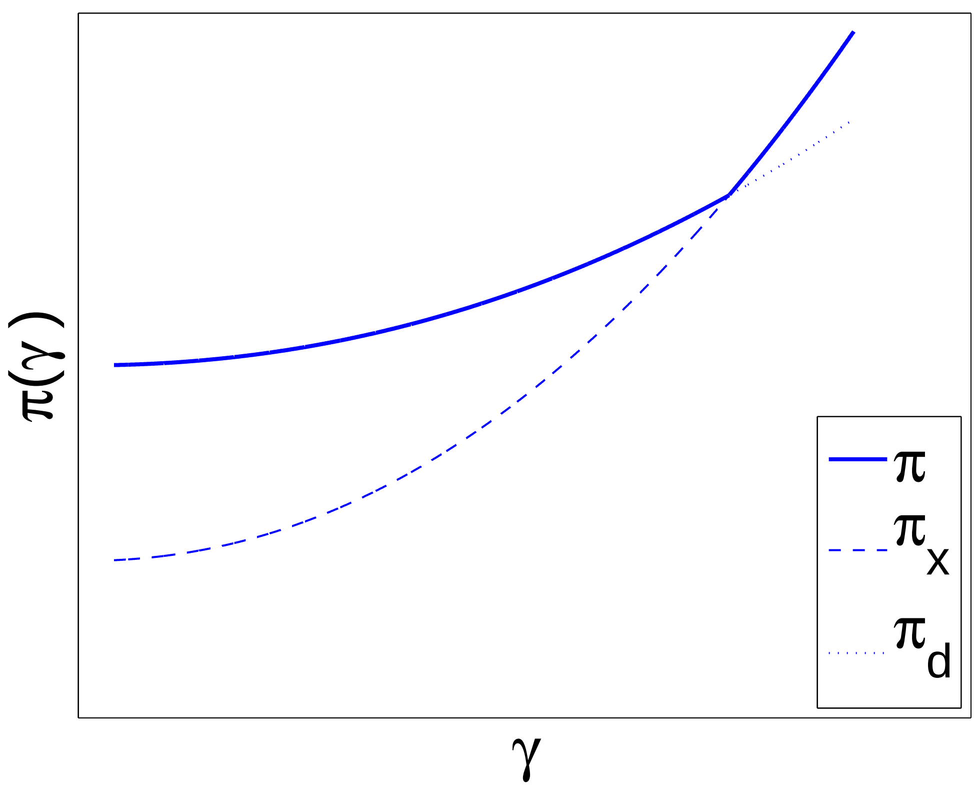

Figure 3: Profits as a function of firm type ($\pi(\gamma)$). The solid line is the actual profit of the firm. The dashed line is the profit function of an exporter, and the dotted line is the profit function for a non exporter.

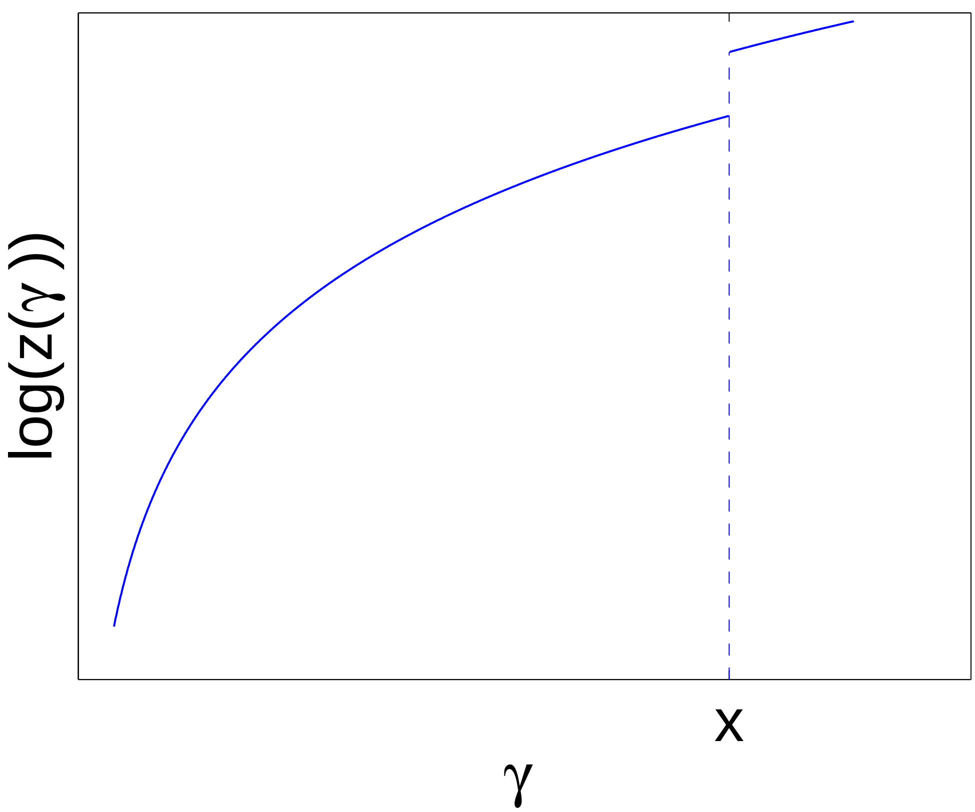

Figure 4: Innovation as a function of firm type ($z(\gamma)$). The figure shows that innovation is an increasing function of firm type. It is continuous except when firms switch from being non exporters ($\gamma \leq x$), to exporters ($\gamma > x$). At the export threshold, the function makes a discontinuous jump.

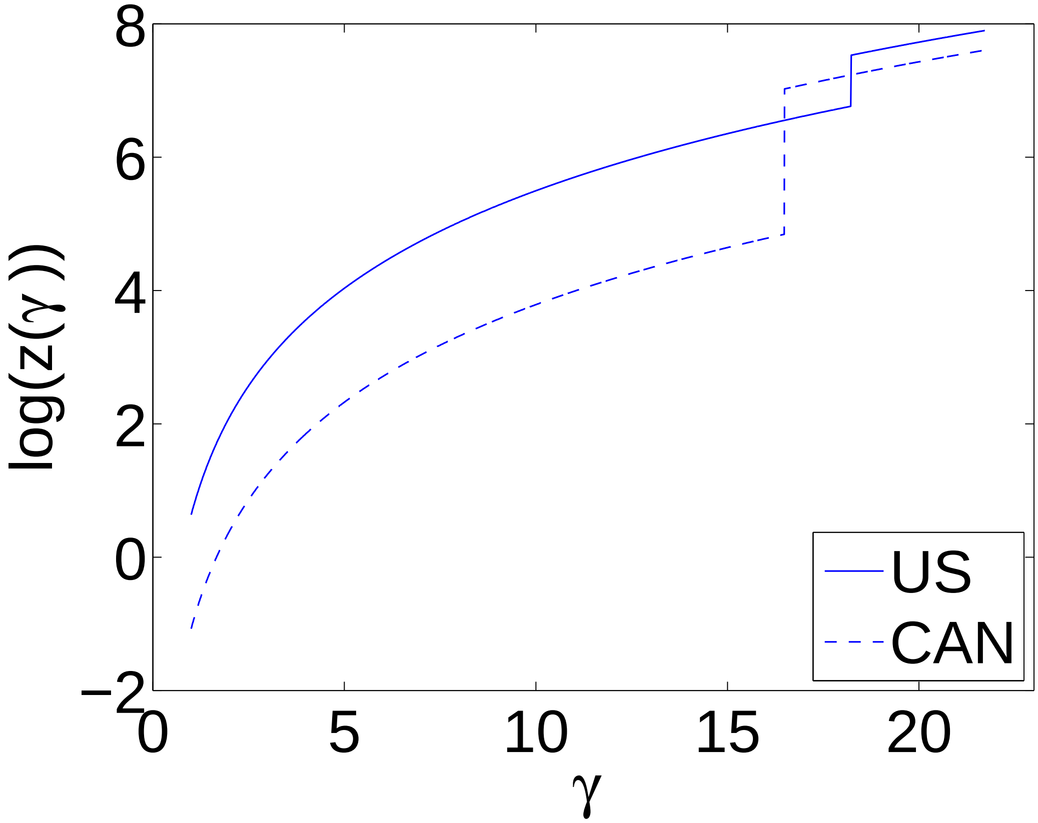

Figure 5: Innovation Before Tariff Drops. Graph shows the log of innovation levels ($\log(z(\gamma))$) for different firm types (γ) in the United States (solid line) and Canada (dashed line) before the tariff reduction in the Free Trade Agreement. Innovation levels are the outcome of the equilibrium in the model.

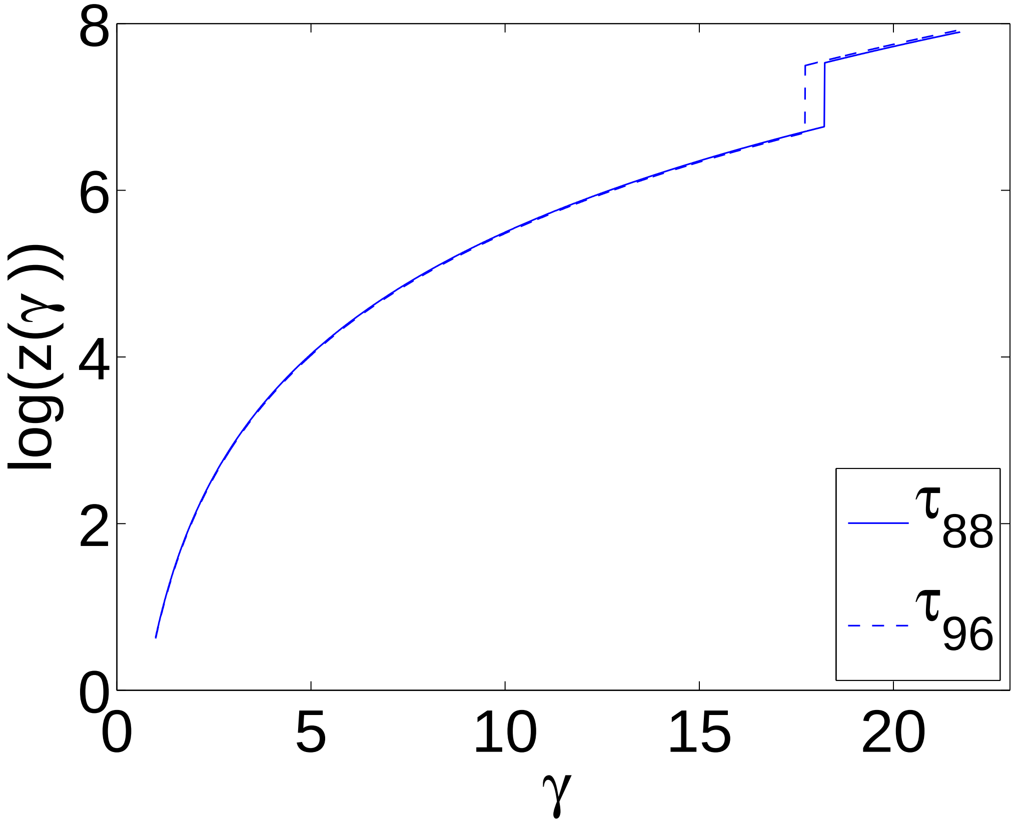

Figure 6: Innovation in the United States. Graph shows the log of innovation levels ($\log(z(\gamma))$) before (solid line) and after (dashed line) the tariff drops in the United States. Innovation levels are the outcome of the equilibrium in the model.

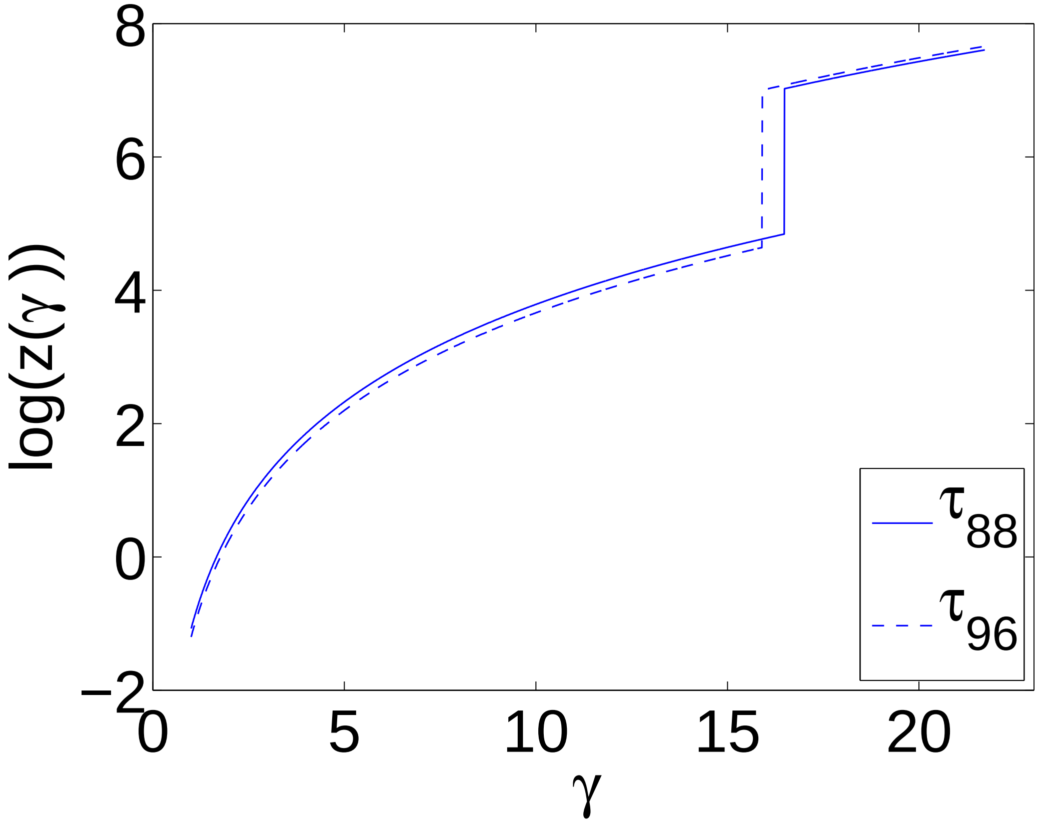

Figure 7: Innovation in Canada. Graph shows the log of innovation levels ($\log(z(\gamma))$) before (solid line) and after (dashed line) the tariff drops in Canada. Innovation levels are the outcome of the equilibrium in the model.