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Trade Liberalization and Heterogeneous Firm Models: An Evaluation Using the Canada - US Free Trade Agreement

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Abstract
We examine the qualitative and quantitative predictions of a heterogeneous firm model à la Melitz (2003) in the context of the Canada - US Free Trade Agreement (CUSFTA) of 1989. We calibrate our model to the pre-trade liberalization stage, simulate the trade liberalization, and compute the resulting growth rates of Canadian industry productivity, exports and imports. We compare them with Trefler's (2004) estimates of the effects of CUSFTA. Our results show that our model performs well in replicating the qualitative aspects of Trefler's results. In particular, we correctly predict that US tariff cuts have smaller productivity enhancing effects than Canadian tariff reductions due to the entry of less efficient exporters. Quantitatively, the model tends to underpredict the impact of CUSFTA on growth rates of productivity, but overpredicts the increase in Canadian exports and imports. We discuss how liberalization-induced changes in the firm-level productivity distribution can reconcile the model with the evidence.

Keywords: Heterogeneous firm models, trade liberalization, CUSFTA, empirical evaluation
JEL Classifications: F12, F13, F15

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1 Introduction

Since the seminal contribution by Melitz (2003), heterogeneous firm models have become a widely used instrument in the 'toolkit' of international economists. These models were motivated by a number of stylized facts: (*i*) the existence of large productivity differences among firms within the same industry; (*ii*) the higher productivity of exporting firms as compared to non-exporting firms; (*iii*) the large levels of resource reallocations across firms within exporting industries following trade liberalization reforms; and (*iv*) the resulting gains in aggregate industry productivity. In a generalization of the Krugman (1979, 1980) model, the introduction of within-industry productivity heterogeneity and beachhead costs enables this class of models to produce equilibria and comparative statics along the lines of these facts.

While these models are thus broadly consistent with available empirical evidence, a thorough evaluation of their qualitative and quantitative predictions with regards to trade liberalization is still outstanding. This is despite the fact that the models' predictions on the link between trade liberalization and changes in aggregate productivity or trade flows are of first-order importance for economic policy and welfare analysis. In this paper, we attempt for the first time to provide such an evaluation. We go beyond the stylized facts listed above and ask to what extent heterogeneous firm models in the tradition of Melitz (2003) are able to replicate both qualitative and quantitative findings from a specific trade liberalization.

We do so in the context of the Canada - US Free Trade Agreement of 1989 (henceforth, CUSFTA). As has been argued elsewhere, CUSFTA is an ideal setting for the evaluation of trade liberalization episodes (see Trefler, (2004)). It was a 'pure' trade liberalization in the sense that it was not accompanied by any other important economic reform, nor was it a response to a macroeconomic shock. It was also largely unanticipated since its ratification by the Canadian parliament was considered highly unlikely as late as November 1988.[1] Finally, the main instrument of liberalization were tariff cuts which are easily quantifiable and as such ideally suited for an econometric analysis.

Not surprisingly then, CUSFTA has been extensively studied over the past decade (*e.g.* Trefler (2004); Head and Ries (1999) and (2001)). We take the results of these studies as our starting point, in particular Trefler (2004). Consistent with the stylized facts outlined above, Trefler finds that CUSFTA led to strong productivity increases in Canadian manufacturing which to a large extent were due to a reallocation of market shares towards high-productivity firms. He also uncovers some more subtle effects. For example, Canadian tariff cuts had a much stronger effect on Canadian productivity gains than US tariff reductions. The magnitudes of some of the effects documented by Trefler

[1] See Breinlich (2008) for a discussion of this point. Frizzell *et al.* (1989) provide a detailed account of the political context in which the agreement was signed.

are also astonishing - the third of Canadian manufacturing industries subject to the highest domestic tariff cuts saw labor productivity increase by 15% over the eight years following the implementation of CUSFTA.

The goal of our analysis is to evaluate the extent to which a version of Melitz's heterogeneous firm model can account for these facts, both qualitatively and quantitavely. We begin by constructing a Melitz-style model which captures the main features of the Canadian-US liberalization experience. In particular, we allow for asymmetries across countries in terms of size, bilateral tariffs and parameter values such as fixed costs. We then calibrate the model's parameters to the pre-liberalization period, simulate the liberalization using the actual tariff cuts, and confront the model's predictions with regards to industry productivity growth and trade flows with the empirical evidence provided by Trefler.

Our results indicate that the model performs well in replicating the qualitative features of Trefler's results. Consistent with his empirical estimates, our model predicts an asymmetric effect of Canadian and US tariff reductions on aggregate Canadian productivity, with Canadian tariff cuts having the larger impact. Our model also captures the broad qualitative patterns of the effects of tariff reductions on Canada-US trade flows. The results of a comparison of the quantitative predictions of our model with Trefler's estimates are more mixed. In our baseline specification, we only predict around a quarter of the estimated impact of liberalization on aggregate labor productivity. On the other hand, we overestimate the increase in Canadian exports and imports by a factor of at least two, and up to a factor of 30 in some simulations!

In a final step, we look at ways to reconcile the theoretical predictions with the data. We show that allowing for empirically plausible changes in within-firm productivity significantly improves the model's performance. In conclusion, it thus seems that the standard approach of abstracting from firm-level productivity gains is useful for modeling *qualitative* patterns of trade liberalizations. However, to match *quantitative* patterns as well, future work on heterogeneous firm models will have to take within-firm productivity changes more seriously.

We are not the first to calibrate models with heterogeneous firms. Eaton and Kortum (2002) use international trade flows to calibrate a Ricardian model with perfect competition and perform various counterfactual policy experiments. Bernard *et al.* (2003) use a modified version of Eaton and Kortum (2002) to explain differences between US exporting and non-exporting manufacturing firms and to analyse the effects of several trade-related policy changes. Irarrazábal and Opromolla (2005) also use the Eaton-Kortum model to study Chile's liberalization experience of the 1970s and 1980s. Del Gatto *et al.* (2006) calibrate the model by Melitz and Ottaviano (2008) on European data to evaluate the benefits of trade liberalization in the EU.

None of these contributions uses Melitz's original contribution as their modeling framework. In contrast to these papers, we are also not primarily interested in counterfactual experiments. Rather, we see our calibration exercise as a way to 'test' the fundamental predictions of models of the class of Melitz (2003).[2] The Canada-US Free Trade Agreement together with Trefler's seminal study provide an optimal setting for this endeavour. In particular, we are not obliged to compare our model's predictions to the raw moments of the data. Using Trefler's empirical techniques, we can instead isolate the effect of tariff cuts from the large number of confounding factors which also influenced productivity and trade over the period under study and which will never be fully captured by a stylized model such as ours.

We also contribute to the literature by providing a tractable extension of Melitz (2003) to an asymmetric multi-country setting. In this, our paper is related to recent contributions by Melitz and Ottaviano (2008) and Chaney (2008). Finally, our paper also relates to a number of papers which have used CUSFTA for testing trade theories. For example, Head and Ries (1999) analyze the impact of tariff cuts on the number and scale of Canadian firms in order to test competing models of imperfect competition. Head and Ries (2001) use CUSFTA to evaluate Krugman and Armington style models of international trade. Kehoe (2005), too, advocates the use of trade liberalization episodes (in his case, NAFTA) as a way to assess the empirical validity of applied general equilibrium models.

The rest of the paper is structured as follows. In section 2, we revisit Trefler's results and extend his methodology to additional variables of interest. Section 3 discusses our extension of the Melitz model. Sections 4 and 5 evaluate the model's qualitative and quantitative predictions in the light of Trefler's results. In section 6 we discuss to what extent liberalization-induced changes in the firm-level productivity distribution can reconcile the model with the evidence. Section 7 concludes.

2 Revisiting Trefler's Results for Trade and Productivity

Trefler (2004) tries to estimate the causal impact of CUSFTA-mandated reductions of Canadian and US tariffs on a set of Canadian variables such as labor productivity and trade. His identification strategy thus needs to isolate these effects from a large number of confounding factors. He starts from a difference-in-differences specification in which he regresses changes in the dependent variable (*e.g.* labor productivity growth) on changes in US and Canadian tariffs pre- and post-CUSFTA:

$$(\Delta y_{i1} - \Delta y_{i0}) = \beta_0 + \beta^{CA} \left(\Delta t_{i1}^{CA} - \Delta t_{i0}^{CA}\right) + \beta^{US} \left(\Delta t_{i1}^{US} - \Delta t_{i0}^{US}\right) + \beta_X \left(\Delta X_{i1} - \Delta X_{i0}\right) + \varepsilon_i,$$

[2] Two recent papers, Eaton *et al.* (2008) and Armenter and Koren (2009) also explore the quantitative performance of Melitz (2003), but focus their attention on the model's export features outside of the context of trade liberalization.

where $\Delta y_{i1} - \Delta y_{i0}$ is the annualized double log-difference in the dependent variable of interest in industry i. Likewise, $\Delta t_{i1}^{CA} - \Delta t_{i0}^{CA}$ and $\Delta t_{i1}^{US} - \Delta t_{i0}^{US}$ represent the double difference in Canadian and US tariffs, and $\Delta X_{i1} - \Delta X_{i0}$ is the double log-difference in additional control variables.[3]

For our purposes, it is important to note that Trefler controls for a large number of factors which also influence the dependent variable of interest and might bias the estimated impact of tariff reductions. His approach is thus close in spirit to the comparative static exercises which we will perform below. That is, Trefler estimates the impact of CUSFTA-mandated tariff changes on changes in labor productivity and trade, *holding all other factors constant*. In our view, comparing our model's results to Trefler's conditional moments is better suited for an evaluation of our model than a comparison with the raw moments of the data – in the sense that it does not place an unfairly heavy burden on a relatively stylized theory.

In table 1, we first replicate Trefler's key results on labor productivity and Canadian imports. We estimate the specification above with data provided on Daniel Trefler's website and compare the results to his baseline specifications (row 1 in his tables 2 and 3). As seen in columns 1 and 2, we are able to replicate Trefler's results almost exactly. For example, Canadian tariff cuts have a strongly significant impact on domestic labor productivity in Canada. A one-percentage point change in $\left(\Delta t_{i1}^{CA} - \Delta t_{i0}^{CA}\right)$ led, on average, to a 1.4% increase in the rate of annual labor productivity growth in 1988-1996. US tariff cuts also raised labor productivity, although the estimated effect is smaller and statisticially insignificant.

Trefler refines his results by calculating a weighted total effect on the third of Canadian industries facing the highest domestic tariff cuts ('import-competing industries') and on the third of industries which enjoyed the largest US tariff concessions ('export-oriented industries'). He also computes the total weighted impact of CUSFTA through both US and Canadian tariff cuts.[4]

Lines 5-7 of table 1 report the corresponding results. Canadian tariff reductions in the most impacted, import-competing industries caused a total labor productivity increase of 0.15 log points or approximately 15% over the period 1988-1996. The effect of US tariff concession on productivity in the most impacted, export-oriented industries was much smaller at just 5%, and the total effect of CUSFTA was a productivity increase of 6%.

[3] See Trefler (2004) for details on these additional controls and further robustness checks. Most importantly, Trefler tries to control for industry-time varying trends and general business cycle effects. He addresses the first issue by including changes in the dependent variable for the US economy as an additional regressor. He also constructs a 'business cycle control' which is in essence an industry-specific prediction of the effect of business cycle conditions on the dependent variable. He also uses instrumental variable methods but does not find evidence for significant endogeneity problems.

[4] In all three cases, Trefler weighs industry-specific tariff cuts using 1988 sectoral data on the numerator of the dependent variable (*i.e.,* value added for labor productivity and import and exports for the trade regressions). He also converts annual changes into a total effect for the period 1988-1996. See appendix B of Trefler (2004) for details.

Column 2 shows the results from estimating the above equation using Canadian imports from the US as the dependent variable. Again, Canadian tariff concessions had a large positive impact, with imports rising by 45% in the most impacted, import-competing industries and 14% overall. Surprisingly, US tariff concessions also had a positive impact on Canadian imports, although the effect is smaller and less statistically significant.

In columns 3-4, we reproduce Trefler's findings for the subset of industries which we will use in our calibration. As discussed below, data availability and theoretical considerations prevent us from using Trefler's full sample. However, columns 3-4 show that Trefler's qualitative results are not affected by the reduction in sample size. The results for Canadian tariff cuts are almost exactly identical. The impact of US tariff cuts is somewhat smaller than before, but the qualitative pattern is very similar to the one arising from the full sample.

Finally, in column 5 we extend Trefler's methodology to Canadian exports to the US. US tariff concessions had the expected positive effect on Canadian exports although the effect is statistically insignificant. In contrast, Canadian tariff cuts reduced Canadian exports but again the effect is not significant. We estimate that lower US tariffs caused an increase in Canadian exports by 16% in the most impacted, export-oriented industries. Canadian tariff cuts reduced exports by 18%, however, so that the overall effect is essentially zero.

To summarize, Canadian and US tariff concessions had strongly asymmetric effects on Canadian labor productivity. Labor productivity was strongly positively impacted by Canadian tariff cuts, and to a lesser extent by US tariff reductions. Lower Canadian import tariffs led to higher Canadian imports while lower US tariffs increased Canadian exports. These findings set the stage for the rest of this paper. We will investigate to what extent our version of Melitz (2003) can replicate these findings, both in terms of the signs of the estimated effects as well as their quantitative magnitude.

3 The Model

Our model is an extension of Melitz (2003) that is close to Helpman *et al.* (2004). We allow for many industries and asymmetries across countries. Initially we simplify the model by abstracting from its free-entry stage.[5] However, further below we also model the free-entry stage as in the original Melitz model.

[5] In this sense, our model is close to Chaney (2008).

Demand

Consumers maximize the following two-tier utility function:

$$U = \sum_{i \in I} \mu_i \ln Q_i + A, \quad (1)$$

$$Q_i = \left[\int_{\gamma \in \Gamma_i} q_i(\gamma)^{\frac{\sigma_i - 1}{\sigma_i}} d\gamma \right]^{\frac{\sigma_i}{\sigma_i - 1}}, \quad (2)$$

where Γ_i represents the (endogenous) set of available varieties in the manufacturing sector i. $\sigma_i > 1$ is the elasticity of substitution between any two goods in industry i. Choosing good A as the numéraire, utility maximization on the upper level yields demand functions $A = Y - \sum_i \mu_i$ and $Q_i = \mu_i / P_i$, where Y is total expenditure per consumer. In the manufacturing goods sector, utility maximization yields demand function $q_i(\gamma) = p_i(\gamma)^{-\sigma} P_i^{\sigma-1} \mu_i$.

Technology and Environment

There are many countries, denoted by j. All countries produce positive amounts of the numéraire good, which is freely traded; its industry operates under perfect competition and with linear production function $A = l_A$ everywhere, where l_A is labor employed in the numéraire industry. This implies $w_j = 1$ for all j.

Manufacturing goods are produced using labor as the only production factor. A firms's output q and productivity γ determine its 'variable' labor requirements $q(\gamma)/\gamma$.[6] In order to supply goods to its own domestic market, a firm must also pay a fixed cost F_{jj} in terms of the numéraire good. In order to export to country j', country-j firms must incur an additional fixed cost $F_{jj'}$, also in terms of the numéraire good.[7] International trade is also subject to the standard iceberg transport cost $\tau_{jj'} \geq 1$. We assume that domestic sales are subject to no transport costs: $\tau_{jj} = 1$ for all j.

In each country, there is a given large mass M_j of potential entrants to an industry. The productivity parameter γ is revealed to firms before they pay the fixed costs and start production. In equilibrium, only those firms that can earn non-negative profits will enter a market.

Firm-level Outcomes

Each manufacturing firm has monopoly power over the variety it produces. The pricing rule of country-j firms is

$$p_{jj'}(\gamma) = \frac{\sigma}{\sigma - 1} \frac{\tau_{jj'}}{\gamma}. \quad (3)$$

[6] In what follows, industry and country notation is suppressed for simplicity wherever unnecessary.

[7] This ensures that only firms that also produce domestically will export, which is the empirically relevant case.

The firms' associated demand levels (net of transport costs in the case of exports) are

$$q_{jj'}(\gamma) = \left(\frac{\sigma}{\sigma - 1}\frac{\tau_{jj'}}{\gamma}\right)^{-\sigma} P_{j'}^{\sigma-1}\mu_{j'}. \tag{4}$$

The firm's resulting revenues (once again, in the case of export revenues they are expressed net of transport costs) are

$$r_{jj'}(\gamma) = \left(\frac{\sigma}{\sigma - 1}\frac{\tau_{jj'}}{\gamma}\right)^{1-\sigma} P_{j'}^{\sigma-1}\mu_{j'}. \tag{5}$$

Profits are

$$\pi_{jj'}(\gamma) = \frac{r_{jj'}(\gamma)}{\sigma} - F_{jj'}. \tag{6}$$

Entry Thresholds

A firm with productivity γ will enter the domestic market if $\pi_{jj}(\gamma) \geq 0$. Hence, $\pi_{jj}(\gamma^*_{jj}) = 0$ defines the domestic entry cutoff γ^*_{jj}:[8]

$$\gamma^*_{jj} = \left[\frac{F_{jj}\sigma^\sigma}{\mu_j P_j^{\sigma-1}(\sigma-1)^{\sigma-1}}\right]^{1/(\sigma-1)}. \tag{7}$$

Similarly, a firm will enter export market j' in addition to producing domestically if $\pi_{jj'}(\gamma) \geq 0$. Hence, the export cutoff $\gamma^*_{jj'}$ is implicitly defined by $\pi_{jj'}(\gamma^*_{jj'}) = 0$. Using country-$j$ firms' export cutoff condition and country-j' firms' domestic market entry condition, $\pi_{j'j'}(\gamma^*_{j'j'}) = 0$, we can express country-j's export cutoff as a function of country-j''s entry cutoff:

$$\gamma^*_{jj'} = \left(\frac{F_{jj'}}{F_{j'j'}}\right)^{1/(\sigma-1)} \tau_{jj'}\gamma^*_{j'j'}. \tag{8}$$

The consumer price index is

$$P_j = \left[\sum_{j'}\left(\int_{\gamma^*_{j'j}}^{\infty} p_{j'j}(\gamma)^{1-\sigma} M_{j'}v_{j'}(\gamma)d\gamma\right)\right]^{\frac{1}{1-\sigma}}. \tag{9}$$

[8] As in Melitz (2003), we assume parameter values such that the marginally profitable firm will not export: $\pi_{jj}\left(\gamma^*_{jj}\right) = 0 \Longleftrightarrow r_{jj}\left(\gamma^*_{jj}\right) = \sigma F_{jj}$. For

$$\pi_{jj'}\left(\gamma^*_{jj}\right) = \tau_{jj'}^{1-\sigma}\frac{P_{j'}^{\sigma-1}\mu_{j'}}{P_j^{\sigma-1}\mu_j}\frac{r_{jj}\left(\gamma^*_{jj}\right)}{\sigma} - F_{jj'} < 0,$$

we need to impose $\tau_{jj'}^{\sigma-1}F_{jj'} > \frac{P_{j'}^{\sigma-1}\mu_{j'}}{P_j^{\sigma-1}\mu_j}F_{jj}$. The price index P_j can be expressed as a function of the model's parameters.

A common assumption in the heterogeneous firm literature is that γ is Pareto distributed (Chaney (2008); Melitz and Ottaviano (2008)).[9] That is, $v(\gamma) = ak^a\gamma^{-(a+1)}$, with $a, k > 0$ and $\gamma \geq k$. Assuming the shape parameter a is equal for all countries, (7)-(9) yield expressions for productivity cutoffs γ^*_{jj} and $\gamma^*_{jj'}$ in terms of the model's parameters, which we can summarize as

$$\gamma^*_{jj'} = \left(\frac{F_{j'j'}}{\mu_{j'}}\frac{\sigma a}{a-\sigma+1}\right)^{1/a} \tau_{jj'} \left(\frac{F_{jj'}}{F_{j'j'}}\right)^{\frac{1}{\sigma-1}} \left[\sum_{j''} M_{j''} k^a_{j''} \tau^{-a}_{j''j'} \left(\frac{F_{j''j'}}{F_{j'j'}}\right)^{\frac{\sigma-1-a}{\sigma-1}}\right]^{1/a}. \quad (10)$$

In the following, we assume that $a > \sigma$.[10] The fixed cost F_{jj} has a positive effect on the domestic entry threshold γ^*_{jj}, as a higher F_{jj} makes it harder for domestic low-productivity firms to break even. $F_{j'j}$ and $\tau_{j'j}$ affect γ^*_{jj} negatively: the higher the cost to export into the home market, the easier it is for country-j's low-productivity firms to survive. $F_{j'j'}$ has a negative effect on $\gamma^*_{jj'}$: the higher this fixed cost, the easier it is for country-j's firms to break even in country-j''s market. Higher costs to export into the foreign market ($F_{jj'}$ and $\tau_{jj'}$) raise the productivity threshold $\gamma^*_{jj'}$ for country-j's firms to break even when exporting to country j'.

Industry Aggregates

Once we have expressed the entry cutoffs as functions of the model's parameters, it is easy to do the same for all industry aggregates. We will profit from this information in two ways. First, we will calibrate the model's parameters by matching its moments to the available data. Secondly, once we have calibrated the model, we will simulate the tariff cuts implemented under CUSFTA and compare the resulting model predictions to the empirical evidence discussed in section 2.

Mass of Firms

The mass of country-j firms active in market j' is given by

$$N_{jj'} = \left[1 - V_j\left(\gamma^*_{jj'}\right)\right] M_j = M_j k^a_j \left(\gamma^*_{jj'}\right)^{-a}, \quad (11)$$

where $V(\gamma)$ denotes the distribution function of γ. Our notational convention and our assumption that all active firms operate in the domestic market implies N_{jj} is the total mass of country-j firms.

[9] See the evidence discussed in Luttmer (2002).

[10] For the n^{th}-moment of a Pareto distribution to exist, we need $a > n$. We impose $a > \sigma$ to ensure existence of the moments which are of interest for our purposes.

Trade Flows

The f.o.b. value of exports from country j' to country j is

$$X_{j'j} = \frac{a\sigma}{a-\sigma+1} M_{j'} k_{j'}^{a} F_{jj} \left(\frac{F_{j'j}}{F_{jj}} \right)^{\frac{\sigma-1-a}{\sigma-1}} \tau_{j'j}^{-a} \left(\gamma_{jj}^{*} \right)^{-a}. \tag{12}$$

Sales

Aggregate sales by industry are

$$R_j = M_j k_j^a \frac{a\sigma}{a-\sigma+1} \left[\sum_{j'} \tau_{jj'}^{1-a} \left(\frac{F_{jj'}}{F_{j'j'}} \right)^{\frac{\sigma-1-a}{\sigma-1}} F_{j'j'} \left(\gamma_{j'j'}^{*} \right)^{-a} \right]. \tag{13}$$

Employment

Industry employment is

$$L_j = M_j k_j^a \frac{a(\sigma-1)}{a-\sigma+1} \left[\sum_{j'} \tau_{jj'}^{-a} \left(\frac{F_{jj'}}{F_{j'j'}} \right)^{\frac{\sigma-1-a}{\sigma-1}} F_{j'j'} \left(\gamma_{j'j'}^{*} \right)^{-a} \right]. \tag{14}$$

Productivity

Following Melitz (2003),[11] we define an industry's aggregate productivity as

$$\tilde{\gamma}_j = \left[\sum_{j'} \frac{N_{jj'}}{\sum_{j'} N_{jj'}} \left(\tilde{\gamma}_{jj'} \right)^{\sigma-1} \right]^{\frac{1}{\sigma-1}}, \tag{15}$$

where

$$\tilde{\gamma}_{jj'} \left(\gamma_{jj'}^{*} \right) = \left[\frac{1}{1 - V_j \left(\gamma_{jj'}^{*} \right)} \int_{\gamma_{jj'}^{*}}^{\infty} (\gamma)^{\sigma-1} v_j(\gamma)\, d\gamma \right]^{\frac{1}{\sigma-1}} = \left(\frac{a}{a-\sigma+1} \right)^{\frac{1}{\sigma-1}} \gamma_{jj'}^{*}. \tag{16}$$

As further explained below, our calibration will not enable us to identify the level of $\tilde{\gamma}_j$, but only its growth rate - which is all we need to compare the model's predictions to Trefler's results.[12]

Alternatively, we will work with two more definitions of productivity. First, we simply

[11] In comparison with Melitz (2003), we do not adjust the productivity of exporters by the trade cost $\tau_{jj'}$. This spares us some ambiguities in the derivation of the theoretical results in the next section. Regarding our numerical results, discussed further below in the paper, this adjustment has negligible relevance from both a quantitative and a qualitative point of view. The corresponding results are available from the authors upon request.

[12] $\tilde{\gamma}_j$ is a harmonic average. Notice that our assumptions on parameters imply $\gamma_{jj'}^{*} > \gamma_{jj}^{*}$ (see footnote 8), which in turn yields $\tilde{\gamma}_{jj'} > \tilde{\gamma}_{jj}$.

aggregate firms' outputs linearly:

$$\frac{\tilde{Q}_j}{L_j} = \frac{1}{L_j}\left[\sum_{j'}\int_{\gamma^*_{jj'}}^{\infty}\tau_{jj'}q_{jj'}M_j v_j(\gamma)d\gamma\right] = \frac{M_j k_j^a}{L_j}\frac{a(\sigma-1)}{a-\sigma}\left[\sum_{j'}\tau_{jj'}^{1-a}\left(\frac{F_{jj'}}{F_{j'j'}}\right)^{\frac{\sigma-a}{\sigma-1}}F_{j'j'}\left(\gamma^*_{j'j'}\right)^{1-a}\right]. \tag{17}$$

Again, we will work with the growth rate rather than the level of $\tilde{Q}_j/L_j$.

Finally, we also use a measure which is most closely related to the way Trefler measures labor productivity in his paper. He uses the industry-level growth rate in deflated value added per hour worked to calculate labor productivity growth. We proxy for this with the growth rate of $(R_j/L_j)/p(\tilde{\gamma}_j)$. We think of $p(\tilde{\gamma}_j)$ as the average price charged by country j's producers (or, put differently, the price charged by the producer with a productivity level equal to the aggregate average, $\tilde{\gamma}_j$). Notice that this average price neglects the product variety component of ideal price indices based on CES functional forms. This is similar to the calculation of the deflators underlying Trefler's growth rates, which do not account for changes in product variety.[13]

As we will see when presenting our simulation results below, the growth rate of $(R_j/L_j)/p(\tilde{\gamma}_j)$ is very similar to that of $\tilde{\gamma}_j$. This suggests that deflated sales per worker is not a bad proxy after all for Melitz's aggregate productivity. The intuition for this slightly surprising result is as follows. First, the ratio R_j/L_j does not move much with changes in tariffs. This is due to the CES assumptions of the model: firm-specific f.o.b. sales $r(\gamma)$ are proportional to firm-specific employment $l(\gamma)$ which explains the almost identical expressions we obtain for R_j and L_j (see equations (13) and (14)). This leaves most of the "action" in our third productivity measure to $1/p(\tilde{\gamma}_j)$ which in turn is closely related to $\tilde{\gamma}_j$ (see the pricing equation (3)): an increase in average productivity reduces the average producer price, thus raising the value of deflated sales.

4 Model Evaluation - Qualitative Predictions

We now turn to an evaluation of the ability of our version of Melitz (2003) to replicate the qualitative and quantitative features of Trefler's results from section 2. In this section, we start by performing comparative statics exercises to check whether our model correctly predicts the signs of the effects of trade liberalization on aggregate productivity and trade flows.

In line with our notation, we denote Canadian variables by subscript j and US variables by subscript j' in the following propositions. In our model, we interpret a trade liberalization as a reduction in the iceberg transport cost τ. Since the main instrument

[13] We are grateful to Marc Melitz for pointing this out. See also Ghironi and Melitz (2005) for a related discussion. Details on the construction of Statistics Canada's price deflators can be found on at http://www.statcan.gc.ca.

of liberalization under CUSFTA were bilateral reductions in ad-valorem tariffs, this theoretical interpretation fits well with the actual liberalization experience.

Proposition 1 *Reductions of country-j import tariffs (i.e. lower $\tau_{j'j}$) raise country-j aggregate productivity $\tilde{\gamma}_j$.*

Proof. First, from (10) and (11) it is easy to see that $\partial N_j/\partial \tau_{j'j} > 0$, since $\partial \gamma^*_{jj}/\partial \tau_{j'j} < 0$. Intuitively, more domestic protection makes it easier for domestic low-productivity firms to survive. Secondly, from (15), $\tilde{\gamma}_j$ is a weighted average of $\tilde{\gamma}_{jj}$ and $\tilde{\gamma}_{jj'}$, with $\tilde{\gamma}_{jj} < \tilde{\gamma}_{jj'}$. More domestic protection reduces γ^*_{jj} and thus $\tilde{\gamma}_{jj}$; besides, N_j rises, raising the weight of $\tilde{\gamma}_{jj}$. ($\gamma^*_{jj'}$, $\tilde{\gamma}_{jj'}$ and $N_{jj'}$ remain constant.) Hence the average $\tilde{\gamma}_j$ falls with more domestic protection: $\partial\tilde{\gamma}_j/\partial\tau_{j'j} < 0$. ∎

Proposition 2 *Reductions of country-j' import tariffs (i.e. lower $\tau_{jj'}$) have an ambiguous effect on country-j aggregate productivity $\tilde{\gamma}_j$.*

Proof. More foreign protection reduces the mass of domestic exporters $N_{jj'}$: from (10) and (11), $\partial N_{jj'}/\partial\tau_{jj'} < 0$ since $\partial\gamma^*_{jj'}/\partial\tau_{jj'} > 0$. This effect has a negative impact on $\tilde{\gamma}_j$, as the weight on the larger component ($\tilde{\gamma}_{jj'}$) of average productivity falls. On the other hand, average exporter productivity $\tilde{\gamma}_{jj'}$ rises through the increase in $\gamma^*_{jj'}$. (γ^*_{jj}, $\tilde{\gamma}_{jj}$ and N_j remain constant.) Whether the overall effect is positive or negative depends on parameter values. Appendix A illustrates this issue by working out an example in which, depending on the values of transport costs, $\frac{\partial\tilde{\gamma}_j}{\partial\tau_{jj'}}$ can take positive or negative values. ∎

Our model thus correctly predicts that reductions in Canadian import tariffs raise aggregate productivity in Canada. It also predicts that the same need not hold true for reductions in US import tariffs. Intuitively, lower foreign barriers mean that existing exporters (which are the most productive firms) gain market share. However, there is also export market entry by less productive firms which also expand output. The overall effect on aggregate productivity is thus ambiguous. This is again consistent with Trefler's result of a positive but relatively small (compared to Canadian tariff concession) and statistically insignificant impact of US tariff reductions. Interestingly, one of the explanations advanced by Trefler for this finding is that US tariff cuts encouraged export market entry by less productive Canadian firms which partly offset the gains arising from market share expansions of existing exporters. This is exactly what is underlying our ambiguity result.

Proposition 3 *Reductions of country-j import tariffs raise country-j imports from country j', but have no effect on country-j exports to country j'.*

Proof. From (12), we obtain that $\partial X_{j'j}/\partial\tau_{j'j} < 0$ and $\partial X_{j'j}/\partial\tau_{jj'} = 0$. ∎

Thus, our model replicates Trefler's finding that reductions in Canadian tariffs raise imports from the US, and that US tariff concessions cause Canadian exports to the US to increase. Recall from section 2 that Trefler also finds that the impact of US tariff reductions on Canadian imports is smaller and less statistically significant than the effect of Canadian tariff reductions.[14] Similarly, the effect of US tariff concessions on Canadian exports is larger than that of Canadian reductions – the latter is actually negative albeit statistically insignificant. This is again consistent with our model's prediction on the relative importance of domestic and foreign tariff concessions on trade flows.[15]

5 Model Evaluation - Quantitative Predictions

The last section demonstrated that our version of Melitz (2003) is capable of replicating the *qualitative* results of Trefler (2004). We now raise the bar further by evaluating whether our model can also replicate Trefler's findings *quantitatively*. To this end, we calibrate the model's parameters on pre-liberalization data. We then simulate the fall in tariff barriers implied by CUSFTA, holding all other parameters equal. For this, it is useful to think of trade costs $\tau_{jj'}$ as having a 'natural' component, $\alpha_{jj'}$, and a 'policy-induced' component, $t_{jj'}$: $\tau_{jj'} = 1 + \alpha_{jj'} + t_{jj'}$. We simply let $t_{jj'}$ fall as observed in CUSFTA, and compute the resulting changes in productivity and trade flows.

To simplify this exercise, and for reasons of data availability, we start with a two-country version of our model, including Canada and the US only. Initially, we also set $\alpha_{jj'} = 0$.[16] In robustness checks reported below, we allow for a positive 'natural' component of trade costs and introduce a third country, the 'Rest of the World' (RoW), consisting of Germany, Japan and the United Kingdom.

We reduce the number of parameters to be calibrated in several ways. First, the parameters M_j and k_j^a (mass of potential entrants and the Pareto distribution parameters, respectively) cannot be identified separately but only as their product, $K_j \equiv M_j k_j^a$. Moreover, K_j itself cancels out frequently from the expressions above. Still, we can identify the ratios $K_{j'}/K_j$, with which we can compute the growth rates of productivity and bilateral trade flows.[17]

[14] This is particularly true for our smaller sample, see column 4 of table 1.

[15] The fact that we predict *no* effect of domestic tariff concessions on domestic export is of course an artifact of our abstraction from the relevant general equilibrium effects. We thus regard the comparison of *relative* effects of domestic and foreign tariff concessions as more informative. However, in section 3 we show that running Trefler's regressions on a dataset generated by our model actually *does* yield positive effects of US tariff cuts on Canadian imports. (This is because Trefler imposes a particular functional form in his regressions.)

[16] In a recent paper, Broda and Weinstein (2008) compare Canadian and US barcode data for the period 2001-2003, and find that the law of one price holds equally well for city pairs of the same country and for city pairs with cities on different sides of the Canada-US border. Since we implicitly normalize intranational trade costs to one, this result suggests that assuming no international trade costs in the post-liberalization phase is not implausible *a priori*.

[17] This discussion obviously assumes that we can treat the mass of potential entrants as a constant

Finally, we have direct proxies from the data for parameters $t_{jj'}$ (ad-valorem tariffs) and μ_j (industry-level expenditures). In the two-country model, we are thus left with 7 parameters which need to be estimated for each industry: the shape parameter of the Pareto distribution a; the elasticity of substitution σ; fixed costs F_{dd}, F_{ff}, F_{df}, and F_{fd}; and ratio K_f/K_d. (For the sake of clarity, when discussing parameter calibration issues, we depart from our standard notation of countries j, and denote Canada, the US and RoW with d, f, and w, respectively.)

Calibration Strategy

We proceed in two stages. First, we obtain estimates for a and σ from firm- and industry-level data. We then need to create a system of five parameters and five moments to calibrate the remaining parameters. For this purpose, we use the following moments: total number of firms (2), bilateral trade flows (2), and one Canadian concentration ratio. We show in appendix B that the implied system of non-linear equations can be solved for a unique set of positive parameter values. Thus, our model is able to match the pre-liberalization empirical moments exactly.[18]

Parameters a and σ

Total sales by exporting firms can be expressed as $r(\gamma) = \sum_{j'} r_{jj'}(\gamma) = \Lambda_1 \gamma^{\sigma-1}$, which is proportional to $\gamma^{\sigma-1}$ (the term Λ_1 is constant across firms). Since γ is distributed Pareto with shape parameter a, sales are distributed Pareto with shape parameter $a_r = a/(\sigma-1)$ and cutoff $k_r = \Lambda_1 k^{\sigma-1}$. Thus, we can estimate a_r and σ, and then recover a.

Obtaining a_r from Sales Data Aggregate sales for firms with sales equal or larger sales than r_x are (assuming $a_r > 1$):

$$R_{r_x} = \int_{r_x}^{\infty} rv(r)dr = \frac{a_r k_r^{a_r}}{a_r - 1} (r_x)^{1-a_r}. \tag{18}$$

Take the sales value r_x that corresponds to the x-th largest firm. The fraction n_{r_x} of firms that are bigger than or equal to this firm is $n_{r_x} = 1 - V(r_x)$. Hence, $r_x = k_r n_{r_x}^{-(1/a_r)}$. Taking the ratio to the $y-$th largest firm's sales eliminates k_r: $\frac{r_x}{r_y} = \left(\frac{n_{ry}}{n_{rx}}\right)^{1/a_r}$. We do not have data on r_x, but we know the sales volume R_{r_x} defined above (total shipments

parameter, which might be fine in the short run, but more controversial for the long run. We address this issue below by modeling free-entry as in Melitz (2003): once again, we cannot identify K_j in the post-trade liberalization steady state, but we can compute its steady-state change, which is all we need to compute the long-run growth rates of our variables of interest.

[18]We focus on an exactly identified system in the initial calibration stage, since we are primarily interested in evaluating the out-of-sample predictions of our model rather than the consistency of the model with the pre-liberalization data. Using other moments for which we have data (such as additional concentration ratios) does not alter the qualitative nature of the findings below.

times the concentration ratio):

$$\left(\frac{R_{r_x}}{R_{r_y}}\right)^{1/(1-a_r)} = \left(\frac{n_{r_y}}{n_{r_x}}\right)^{1/a_r}. \tag{19}$$

Solving for a_r,

$$a_r = \frac{\left(\ln n_{r_y} - \ln n_{r_x}\right)}{\left(\ln R_{r_x} - \ln R_{r_y}\right) + \left(\ln n_{r_y} - \ln n_{r_x}\right)}. \tag{20}$$

If firm x is larger than firm y, we have $n_{r_y} > n_{r_x}$ and $R_{r_y} > R_{r_x}$. Thus, $a_r > 1$ from above as long as $\left(\ln R_{r_x} - \ln R_{r_y}\right) + \left(\ln n_{r_y} - \ln n_{r_x}\right) > 0$, which holds by construction.

Obtaining of σ from Firm-level Data Operating profits (that is, profits net of fixed costs) are

$$\pi^o(\gamma) = \frac{r(\gamma)}{\sigma}. \tag{21}$$

Since we have data on operating profits and revenue for US and Canadian firms, we can obtain estimates of σ from the above expression separately for each firm. Our industry-specific estimate of σ is simply the median across all firms within in an industry.

Data Description

For our calibration we require sector-level data on output, trade flows, tariffs, the number of firms and concentration ratios. We also need firm-level information on operating profits and sales for the calibration of σ.

Most of our data on output, tariffs and trade flows come from Trefler (2004).[19] For the three-country version of our model, we complement these data with information on sectoral-level output for Germany, Japan and the UK from UNIDO's Industrial Statistics Database, and with information on US exports and imports from the NBER. We use gross output in Canadian, US and RoW manufacturing industries as proxies for R_d, R_f, and R_w (where w denotes RoW). As proxies for X_{df}, X_{fd}, X_{dw}, X_{wd}, X_{fw}, and X_{wf}, we use sector-level trade flows between the three countries. We also use these data to calculate μ_d, μ_f and μ_w as industry-level absorption, *e.g.* $\mu_d = R_d + (X_{fd} + X_{wd} - X_{df} - X_{dw})$.[20] Trefler also provides data on Canadian and US import tariffs which we use as proxies for t_{fd} and t_{df}.

We convert all data to the 4-digit level of the Canadian Standard Industrial Classification of 1980. Value data are expressed in 1992 Canadian dollars using the US-Canadian Dollar exchange rate and 4-digit industry price and value added deflators. To ensure

[19] These data are available on Daniel Trefler's website at http://www.rotman.utoronto.ca/~dtrefler/. Trefler's original sources are special tabulations by Statistics Canada and the NBER Manufacturing Productivity Database. See Trefler (2004) for a detailed description.

[20] For the two-country version, this simplifies to $\mu_d = R_d + (X_{fd} - X_{df})$ and $\mu_f = R_f + (X_{df} - X_{fd})$.

compatibility with our choice of numéraire, we further normalize all value data by Canadian industry-level wages, proxied by total annual earnings per worker. Data on exchange rates, deflators and wages are also from Trefler (2004).

Secondly, we use information from Statistics Canada, the US Census Bureau and UNIDO on the number of enterprises as proxies for N_{dd}, N_{ff} and N_{ww}. Statistics Canada also provides the output share accounted for by the top 4, 8, 12, 16, 20, and 50 enterprises in each 4-digit Canadian industry. Multiplying these shares with total industry output (R_d) we obtain the total output of the top 4, 8, *etc.* enterprises which we use as proxies for R_{r_x}.

Finally, the computation of σ requires data on operating profits (π^o) and sales (r) at the firm-level. We obtain these from Compustat North America and Compustat Global. We proxy π^o as operating income before depreciation and r as net sales.[21]

Parameter Estimates

Table 2 presents descriptive statistics on the parameter estimates. We estimate a different set of parameter values for each manufacturing industry in our sample. Availability of concentration ratios and trade data reduces the number of industries from 213 in Trefler to 196 in our analysis. We furthermore drop 18 additional sectors which violate parameter restrictions of our model, leaving us with 178 sectors in total.[22]

Our estimates of the elasticity of substitution σ are of the same order of magnitude as estimates at similar aggregation levels by Broda and Weinstein (2006a), (2006b). The estimates of the shape parameter of the sectoral-level sales distribution a_r are also comparable to other estimates in the literature: Chaney (2008), who measures a_r as the regression coefficient of the log of the rank on the log of sales (across US listed firms), reports estimates for a_r of around 2. Eaton *et al.* (2008), with an alternative method using the propensity of French firms to export to multiple markets, report estimates for a_r of around 1.5. This compares to a median value of 1.9 in our estimates.

For the rest of the parameters there are no easily comparable estimates from other sources, but their median values seem mostly plausible. For example, recalling that we normalized all value terms by Canadian sectoral wages, the estimates for F_{dd} and F_{ff} indicate that the median cost for Canadian and US manufacturing firms of entering their domestic market was 339,000 and 509,000 Canadian dollars in 1988, respectively.

While our model thus produces broadly reasonable parameter estimates, the minimum

[21] Information on these variables is contained in Compustat North America data items 12 (net sales) and 13 (operating income before depreciation). For Compustat Global, net sales are contained in data item 1 and operating profits are calculated as operating income plus depreciation (data items 14 plus 11).

[22] We drop sectors for which our calibration yields $a < \sigma$ or $\gamma^*_{jj} > \gamma^*_{jj'}$. We also experimented with minimizing squared deviations between theoretical and empirical moments, subject to the second constraint. Results were almost identical to the ones presented below.

and maximum values reported in table 2 indicate that there are also a number of outliers. In the robustness checks reported below, we experiment with excluding such sectors insofar as they produce extreme growth rates for productivity or exports which could drive our results.

Baseline Results

In this section we simulate the tariff cuts of CUSFTA (that is, a reduction in trade cost parameters τ_{df} and τ_{fd}, holding all other parameters constant), and compare the productivity gains and increases in trade flows predicted by the model with the estimates reported in table 1, columns 3-5.

Recall that we defined trade costs as $\tau_{jj'} = 1 + \alpha_{jj'} + t_{jj'}$, where $\alpha_{jj'}$ are natural trade costs and $t_{jj'}$ are policy-induced barriers (tariffs). For example, in 1988 the poultry products industry (SIC 1012) had Canadian and US import tariffs of 6.6% and 3.7%, respectively. For our baseline results, we also assume that $\alpha_{fd} = \alpha_{df} = 0$. We thus set $\tau_{fd,t-1} = 1.066$ and $\tau_{df,t-1} = 1.037$. Since CUSFTA was a free-trade agreement, we simulate the trade liberalization by setting $\tau_{df,t}$ and $\tau_{fd,t}$ to one.

We compute the growth rates of productivity and trade flows discussed above for each industry separately by using our calibrated parameter values, and $\tau_{fd,t-1}$, $\tau_{df,t-1}$, $\tau_{df,t}$ and $\tau_{fd,t}$. We first do so separately for each of the tariffs and then for both of them together. These simulations correspond to the three comparative statics results implicit in Trefler's regressions - the effect of Canadian tariffs (corresponding to β^{CA}), the effect of US tariffs (corresponding to β^{US}), and their joint impact.

Thus, we obtain a set of three simulation results for each of our measures of productivity growth and for import and export growth. Table 3 presents the results of these baseline simulations. For comparison with Trefler's results, we report weighted averages of our sector-specific simulation results. Specifically, we calculate a weighted average for the most impacted, import-competing third of industries when performing the simulation corresponding to a unilateral Canadian liberalization (reducing t_{fd} to zero). When simulating the reduction in t_{df} (unilateral US liberalization), we similarly use a weighted average of results for the most impacted, export-oriented third of industries. Finally, for the bilateral liberalization simulation (both t_{df} and t_{fd} set to zero), we compute a weighted average across all sectors.[23]

The first line in table 3 is thus comparable to line 5 in table 1 ('Impact on most impacted, import competing industries'). Depending on the productivity measure we use, we predict around a quarter (3.2%-4.0%) of the 14% overall increase estimated earlier.

[23] Following Trefler (2004), we use value added and trade flows by industry in 1988 to weigh our sector-specific simulation results for trade and productivity increases.(compare footnote 4). That is, we calculate $\sum_{i\epsilon I} \tilde{y}_i \varpi_i$, where $\tilde{y}_i$ is the simulation forecast for sector i and ϖ_i the share of i in total exports, imports or value added in the group of industries I (import- competing industries, export-oriented industries or all industries).

We do better on the predicted effects of US tariff reductions (line 2). In column 3 of table 1, we estimated an increase of 2%, very close to the prediction for our second productivity measure (Q/L). The other two productivity measures do essentially predict no effects, however, so that on average we underpredict the productivity impact of US tariff cuts as well.

More importantly, however, our simulation results capture the key stylized fact about the asymmetric effect of tariff reductions on productivity. Canadian tariff reductions led to a much bigger increase in aggregate productivity than US tariffs. Again, the reason why this happens in our simulation is that lower US import tariffs encourage entry by less efficient exporting firms.[24]

As mentioned before, our model matches the broad qualitative pattern of predicted changes in Canadian imports and exports from and to the US. The results in table 1 (column 4) show that Canadian imports in the most impacted, import-competing third of industries increased by 46% in response to Canadian tariff cuts, and by 17% in response to US tariff cuts in the most impacted, export-oriented industries. We predict a positive impact of Canadian tariff reductions and no effect of US tariff reductions, so the ordering of magnitudes is similar.

With regards to quantitative accuracy our model does less well. We predict an increase of 380% for the response of Canadian imports with respect to domestic tariffs which is roughly eight times larger than the 46% estimated earlier. As said, our model predicts no increase in response to US tariff reductions so we are again some way off the 17% increase estimated in section 2. In terms of the CUSFTA's total effect our model again overpredicts although not as badly as for the unilateral Canadian liberalization (we predict a 50% increase versus a 12% increase in our replication of Trefler's results for our smaller sample).

Our model also overpredicts the increase in Canadian exports to the US in response to trade liberalization (table 3, column 5). We predict a weighted average increase of 400% in response to US tariff cuts and no increase in response to Canadian tariff cuts. The corresponding estimation results from section 2 are 16% and -18%. We also overpredict the overall effect by an order of magnitude (+35% vs. no overall effect).

To summarize, our simulation results again confirm that our version of Melitz (2003) matches the qualitative findings of Trefler's analysis quite well. Our model does somewhat less well on the quantitative aspects. It systematically underestimates productivity gains and overestimates increases in trade flows. In the following sections, we investigate how robust these patterns are to variations in our simulation design.

[24] An additional reason is that US tariff cuts are on average only half as large as Canadian tariff cuts. However, this does not explain the negative growth rates we obtain for a substantial fraction of industries when we simulate a US unilateral trade liberalization (note that the weighted average impact for our deflated-sales measures is negative, too).

Robustness Checks

Outliers

For some sectors, our model can only match the pre-liberalization moments with extreme values for parameters (see table 2). This is a source of concern insofar as it might generate outliers in predicted trade flow and productivity changes.

Table 4 thus presents results for the same simulations as in table 3, but excludes sectors with either very low or very high growth rates for each of our five variables of interest. Variable by variable, we first exclude the top and bottom 1% of sectors and then the top and bottom 5%.

Removing outliers does indeed reduce the predicted increase in trade flows by up to half, but this still leaves us considerably above Trefler's estimates. At the same time, the predicted productivity increases drop as well, taking us even further away from the results in table 1.

Regression-based Approach

Trefler estimates the reported effects of CUSFTA on trade and productivity assuming a specific functional form for the impact of tariffs reductions (his estimates are semi-elasticities). In this section, we ask how his results would look like if we estimated a specification motivated by Trefler's regression equation on our simulated data. Of course, our model abstracts from both pre-CUSFTA trends in the data and other factors which Trefler tries to control for through differencing and the inclusion of control variables. We thus estimate a reduced version of Trefler's specification:

$$\Delta y_i = \ln y_{i1} - \ln y_{i0} = \beta_0 + \beta_{alt}^{CA} \Delta t_i^{CA} + \beta_{alt}^{US} \Delta t_i^{US}, \qquad (22)$$

where Δy_i is the prediction of our model for growth rates of productivity and trade flows, respectively, and $\Delta t_i^{CA} = t_{i1}^{CA} - t_{i0}^{CA}$ and $\Delta t_i^{US} = t_{i1}^{US} - t_{i0}^{US}$ are the CUSFTA-mandated tariff cuts which we used in our simulations.

Since Trefler's data were of course generated by a bilateral trade liberalization, we also generate the data for the estimation of (22) by setting both US and Canadian tariffs to zero in our simulations. Once we have obtained estimates of β_{alt}^{CA} and β_{alt}^{US}, we calculate the same magnitudes reported in table 1, using the same approach as Trefler (*i.e.*, the impact on the most-impacted, import-competing industries, the impact on the most-impacted, export-oriented industries, and the total impact of CUSFTA).

As shown in table 5, using this alternative approach brings our results closer to Trefler's estimates along some dimensions but not along others. The effect of Canadian reductions on aggregate productivity is qualitatively comparable to our baseline, albeit slighly weaker. On the other hand, we now do better on the predictions on trade flows.

We predict a 106% increase in Canadian exports in response to US tariff reductions and a 137% increase in Canadian imports in response to Canadian tariff cuts (compared to 16% and 46% in our estimations reported in table 1, respectively). We also do quite well in replicating US tariff cut-induced productivity gains, in particular for our productivity measure Q_d/L_d.

Long-run Results

So far we have abstracted from firm entry by holding fixed the mass of potential entrants, M_d and M_f, during our simulation of CUSFTA. Our results up to now are thus best thought of as a short-run response to trade liberalization. We think that this corresponds best to Trefler's study, which covers a period of eight years after CUSFTA. However, since any definition of short *vs.* long run is somewhat arbitrary, we also analyse the long-run responses predicted by our model.

To do so, we first extend our theoretical framework to include free entry and then repeat the same simulations as above. Consider thus the following free-entry condition for country j:

$$\left[1 - V\left(\gamma_{jj}^{*}\right)\right] \frac{\Pi_j}{N_{jj}} = \delta_j F_j, \tag{23}$$

where Π_j denotes country-j industry's aggregate profits; δ_j is country j's discount rate; and F_j is the fixed cost (in terms of the numéraire) that a firm has to pay to pick a draw from the productivity distribution.[25] Appendix C demonstrates how (23) can be used to solve for long-run changes in the parameters K_j and calculates the corresponding long-run growth rates of trade and productivity. Table 6 presents the corresponding results.

The key change in the long run is that the mass of potential entrants, M_j, adjusts.[26] Specifically, a unilateral Canadian liberalization reduces M_d as operating profits are reduced through the effect of stronger import competition on the price level. At the same time, lower Canadian tariffs increase M_f as US exporters can now make additional profits on the Canadian market. These changes lead to similar adjustments in the number of exporters in each country, and explain why we now observe a stronger increase in US exports than in the short-run, and a *decrease* in Canadian exports in response to lower Canadian tariffs. Exit by Canadian firms in the long-run also implies a lower cutoff on the domestic market, and thus lower productivity gains.[27]

A unilateral US liberalization has the opposite effects on M_d and M_f – more Canadian and less US entrants. Accordingly, the effect on trade flows mirrors the one of Canadian

[25] This free-entry condition can be generated as in Melitz (2003), and is consistent with the rest of our model's setup. We omit a detailed discussion of the corresponding assumptions for the sake of brevity.

[26] More precisely, we only identify changes in $K_j = M_j k_j^a$. Assuming that k_j^a stays constant, changes in K_j capture changes in the mass of entrants.

[27] Note that the average long-run effect of a unilateral liberalization on the liberalizing country's productivity cutoff is positive in our simulations. This stands in contrast with the results in Melitz and Ottaviano (2008), where the short-run increase in the cutoff is wiped out completely in the long run.

tariff reductions. For productivity, however, the observed increases are much stronger than in the short run. The productivity-decreasing entry of less efficient exporters still takes place. But now this is accompanied by an increase in the domestic productivity cutoff γ^*_{dd} due to increased entry. This effect is also the main driver of the additional productivity gains of bilateral liberalization in the long run over and above its short-run impact (now predicted to be between 1.4-3.3% rather than -0.2-2.1% as in the short run).

Despite these changes, however, the overall picture remains broadly the same. While our long-run results yield higher productivity increases, they remain well below Trefler's estimates in the case of unilateral Canadian tariff cuts. The predictions for exports and imports are also still much higher than what Trefler finds. We now do very well on the results for productivity gains induced by a unilateral US liberalization, however. All three productivity measures are close to the 2% increase we estimated in section 2 for our smaller sample, and the average across measures is 2.1%.

Three Countries

We also extend our baseline model in two additional ways. First, we calibrate a three-country version but still stick to our earlier assumption of no natural trade barriers. We then allow for positive natural trade barriers calibrated on the pre-liberalization stage of our model. These changes require a recalibration of our model to obtain values for the various additional parameters. Appendix B describes this procedure in more detail. Here, we focus on a discussion of our results.

Table 7 shows predictions for the three-country model without natural trade barriers. The predicted productivity gains are now smaller than in our baseline simulations. Intuitively, the existence of a third country with which Canada does not liberalize trade implies that the change relative to the initial situation is less dramatic. On the other hand, trade increases by more as standard trade diversion effects compound the trade creation effect from the two-country model. That is, Canada and the US now obtain a larger fraction of their overall imports from each other, rather than from the rest of the world.

Allowing for multiple countries thus makes it more difficult to reconcile our simulation results with Trefler's findings. This is also true when we allow for natural variable trade barriers (table 8). Again, the predicted productivity increases are smaller than what Trefler estimated, while predicted trade growth is too high.

General Equilibrium

We conclude our robustness checks by discussing a number of general equilibrium issues that we have ignored so far. The assumptions of quasi-linear preferences (which eliminate income effects) and of a freely traded numéraire good (which fixes the wage and enables us to ignore the balanced trade condition) shut down the possibility of general-equilibrium effects that might enhance the effects of trade liberalization. In the original Melitz model, for example, a symmetric trade liberalization leads to an increase in the real wage, thus raising the industry's productivity cutoff and reinforcing the effect of tariff cuts on aggregate productivity.

Modeling these general equilibrium effects is a challenging task, as the choices one has to make are not obvious at all. At the same time, we have reasons to believe these effects might not be that strong after all. First, whether workers (or a large fraction of them) are freely mobile across industries or sector specific is a key question. The former assumption would lead to minor effects, given the relative size of the manufacturing sector in Canada and the US. The latter might lead to outcomes in different directions across industries, given the asymmetry of CUSFTA. Secondly, the balanced trade condition does not hold between Canada and the US. In fact, since CUSFTA is likely to have lead to different aggregate gains in productivity for the two countries over time, the liberalization itself is likely to have had an effect on the trade balance. Once again, obviously, the size of the manufacturing sector relative to GDP qualifies the importance of this type of effects.

Rather than focusing our attention on these "macro" issues, below we consider a "micro" issue that is likely to be much more relevant from a quantitative (and empirical) point of view.

6 Reconciling Theory and Evidence

At this point, it is worth taking stock of our results so far. While our model did well at replicating the qualitative aspects of Trefler's results, it was much less successful in terms of its quantitative predictions. This is especially true for the two trade flows and the productivity gains induced by Canadian tariff reductions. In contrast, we came quite close to productivity gains induced by US tariff reductions in some of the robustness checks (e.g., when allowing for long-run entry). In the following, we will thus mainly look at ways of reconciling theory and evidence for the fomer three measures. However, the solution we propose below also addresses remaining shortcomings in productivity gains driven by US tariff cuts.

At first sight, the fact that our model underpredicts productivity growth but overpredicts trade growth suggests that the task of reconciling theory and evidence is not that easy. This is because productivity and trade are closely linked. Intuitively, any change to the model which increases aggregate productivity will also raise aggregate sales and thus exports, improving the model's performance on one dimension but making it worse on another.

As we explain in the next section, however, the diverging behavior of our two variables of interest has a common root. We first outline this argument and then discuss ways to correct the model's quantitative performance.

Understanding the Model's Performance

For the following, it is helpful to write the model's predictions in elasticity form.[28] The elasticity of $\tilde{\gamma}_j$ with respect to $\tau_{j'j}$ is

$$\frac{d\tilde{\gamma}_j}{d\tau_{j'j}}\frac{\tau_{j'j}}{\tilde{\gamma}_j} = \frac{N_{jj}}{\sum_{j'} N_{jj'}}\left[\left[1 - \frac{\left(\tilde{\gamma}_{jj}\right)^{\sigma-1}}{\left(\tilde{\gamma}_j\right)^{\sigma-1}}\right]\frac{a}{\sigma-1} + \frac{\left(\tilde{\gamma}_{jj}\right)^{\sigma-1}}{\left(\tilde{\gamma}_j\right)^{\sigma-1}}\right]\frac{d\gamma^*_{jj}}{d\tau_{j'j}}\frac{\tau_{j'j}}{\gamma^*_{jj}} < 0, \qquad (24)$$

where $N_{jj}/\sum_{j'} N_{jj'}$, $\left(\tilde{\gamma}_{jj}\right)^{\sigma-1}/\left(\tilde{\gamma}_j\right)^{\sigma-1} \in (0,1)$, and $a/(\sigma-1) > 1$. Given our parameter estimates, the fraction of purely domestic firms to all Canadian firms ($N_{jj}/\sum_{j'} N_{jj'}$) and the term in squared brackets in (24) are both close to unity. That is, the magnitude of the productivity reaction depends mainly on the elasticity of the domestic cutoff. Figure 1 visualizes this by plotting the absolute values of the two elasticities against each other for all 178 sectors. From figure 1, it is also evident that the cutoff elasticity is small in most industries (the median value is -0.12). As a result, average aggregate productivity gains are small.

The elasticity of Canadian trade flows with respect to tariff reductions also depends on the domestic cutoff elasticity:

$$\frac{dX_{j'j}}{d\tau_{j'j}}\frac{\tau_{j'j}}{X_{j'j}} = -a\left(1 + \frac{d\gamma^*_{jj}}{d\tau_{j'j}}\frac{\tau_{j'j}}{\gamma^*_{jj}}\right) < 0. \qquad (25)$$

This time, however, a higher cutoff elasticity implies a lower trade flow elasticity. Intuitively, a higher cutoff elasticity implies a stronger increase in aggregate productivitiy (see (24)) which lowers the Canadian price index and makes exporting to Canada less profitable. (*Vice versa*, a stronger productivity reaction in the US will reduce Canadian exports.)

The second determinant of the magnitude of the trade elasticity is the Pareto distribution's shape parameter, a. Its role in determining the responsiveness of trade flows to tariff cuts has already being discussed by Chaney (2008): the higher a, the more homogeneous the industry in terms of the distribution of firm productivities. In this case, large productive firms represent a smaller fraction of firms. The export cutoff moves in a region where most of the mass of firms lies. Therefore in those industries aggregate exports are sensitive to changes in transport costs because many firms exit and enter when the former vary.[29]

[28] Trefler's estimates are semi-elasticities but working with elasticities conveys the intutition underlying our results more easily. None of the following conclusions hinges on this simplification.

[29] The attentive reader may wonder why our elasticity of exports with respect to transport costs does not depend exclusively on the shape parameter a, as in Chaney (2008). This is due to the fact that we are not making the simplifying assumptions Chaney makes. In earlier working paper versions, Chaney

With our parameter estimates, this second effect quantitatively dominates the offsetting effect working through changes in the domestic cutoff. Since the median value of a is 16 whereas the median value of the cutoff elasticity is only -0.12, it is not surprising that we obtain very large increases in trade flows. Put differently, the productivity enhancing reallocation effect in Canada is not strong enough to offset the direct effect on US exports working through lower Canadian tariffs. Thus, the strong response of trade flows and the small increase in productivity are in fact two sides of the same coin.[30]

Firm-level Productivity Growth

The fact that low productivity gains are also responsible for the overprediction of trade flow increases suggests that a promising avenue for reconciling theory and evidence is to look for additional sources of productivity gains.

One simple and empirically plausible way of doing so is to allow for within-firm productivity gains. Indeed, Trefler (2004) estimates that CUSFTA had a substantial impact on firm-level productivity growth as well. That is, aggregate productivity increased not only through a reallocation of market shares, but also because individual firms became more productive. The most natural way to capture such changes in our model is to allow the parameters governing the productivity distributions of potential entrants (a, k_d and k_f) to vary with trade liberalization. As it turns out, incorporating this simple and empirically relevant change goes a long way in reconciling theory and evidence.

We proceed in two steps. We first show that changes in the parameters governing the productivity distribution of potential entrants can be chosen to exactly match aggregate changes in productivity and trade. We then verify how reasonable our estimates are by analyzing the implied changes in the productivity distribution of *active* firms - which is observable.

In practice, it is easier to work with functions of a, k_d and k_f. Specifically, we calibrate changes in a, K_f/K_d and $K_d^{1/a}$ to match changes in aggregate productivity and trade flows.[31] Technically, this is a system of three non-linear equations in three unknowns. Appendix D shows that this system has a unique solution and that we can thus match

himself works out a more general case (Proposition 3) that yields an expression akin to (25).

[30] The reason why the domestic cutoff and price index move so little is the high ratio of exporting to domestic fixed costs (see table 2). This implies that the part of the domestic cutoff which varies with import tariffs obtains a very low weight (see (10)). This issue is reminiscent of the problem faced by Armenter and Koren (2009, AK henceforth) in matching the share and size advantage of US exporters. Similar to AK, our model predicts that exporters are very large and thus cannot be numerous if we want to match aggregate trade flows, which in turn requires large exporting fixed costs. An alternative to the solution proposed below would thus be to weaken the link between producitivity, size and export status similar to AK. The problem this approach faces in our context is that we do not have data on the share and size of exporting firms by sector. It is also unclear how to interpret the additional heterogeneity in the export decision of firms introduced by AK in terms of observable economic variables.

[31] Recall that $K_j = M_j k_j^a$. Assuming a constant M_j, changes in a, K_f/K_d and $K_d^{1/a}$ are uniquely determined by changes in a, k_d and k_f.

aggregate trade and productivity growth rates exactly.

Table 9 reports the resulting parameter values for changes in a, K_f/K_d and $K_d^{1/a}$. As results for our theory-based productivity measure ($\tilde{\gamma}^j$) are almost identical to the results for our deflated sales measure ($\left(R_j/L_j\right)/p\left(\tilde{\gamma}_j\right)$), we omit the latter for the sake of brevity (results available from the authors upon request).

As we can see, $K_d^{1/a}$ increased for the majority of industries, with a median increase of 0.3-5.3%, depending on the type of liberalization and the productivity measure we try to fit. Since $K_d = M_d k_d^a$, this is best interpreted as approximating the average increase in the productivity cutoff of potential entrants (k_d), keeping their mass (M_d) fixed.[32] Not surprisingly then, matching aggregate productivity gains requires potential entrants to become more productive.

But what about trade flows? First recall that a higher k_d also implies less imports as domestic firms get more productive and the domestic price index declines. Secondly, looking across the columns of table 9, we see that the change in a is also positive for the majority of sectors. A higher a implies a larger mass of low-productivity potential entrants. Since low-productivity firms are less likely to be exporters, this tends to decrease exports from both Canada and the United States.[33] Finally, the ratio of K_f/K_d increases in the case of the unilateral US liberalization, and decreases for the unilateral Canadian liberalization. A lower K_f/K_d can be interpreted as a stronger increase in the productivity cutoff of potential entrants on the Canadian side than on the US side (and similarly, a higher K_f/K_d implies a stronger increase on the US side). The effect of these changes is to further lower US exports (in the case of lower K_f/K_d) or Canadian exports (higher K_f/K_d).

One way to read these results is to interpret them as residuals. That is, table 9 tells us what changes in firm-level productivity are needed to match aggregate variables exactly. However, we think that these parameter changes are also empirically plausible. In support, we provide two pieces of evidence based on the implied changes in the productivity distribution of *active* firms - which is observable. First, we ask whether there is evidence for the qualitative pattern of these changes. Second, we ask what firm-level productivity gains our model predicts and compare them to Trefler's estimates.

We start by noting that the productivity distribution of active firms in country j is given by:

$$f_j(\gamma) \equiv \frac{v_j(\gamma)}{1 - V_j(\gamma_{jj}^*)} = \frac{a k_j^a \gamma^{-(a+1)}}{k_j^a \left(\gamma_{jj}^*\right)^{-a}} = a\gamma^{-(a+1)} \left(\gamma_{jj}^*\right)^a$$

[32]Note that changes in $K_d^{1/a} = M_d^{1/a} k_d$ capture increases in a as well, even with M_d unchanged. In unreported results, we show that a increased for the vast majority of sectors, as well as on average and for the median sector (which is reported in table 9). Thus, in most cases the reported figure for $K_d^{1/a}$ is a lower bound for the increase in k_d.

[33]Formally, exports will decline if $k_j < \tau_{jj'} \left(F_{jj'}/F_{j'j'}\right)^{1/(\sigma-1)}$, *i.e.* if trade costs are high relative to the minimum level of productivity of potential entrants.

That is, the productivity of active firms is also distributed Pareto, with shape parameter a and cutoff γ_{jj}^*. Further note that γ_{dd}^* and γ_{ff}^* can be written as:

$$\gamma_{dd}^* = K_d^{1/a}\left(\frac{F_{dd}}{\mu_d}\frac{\sigma a}{a-\sigma+1}\right)^{1/a}\left[1+\frac{K_f}{K_d}\tau_{fd}^{-a}\left(\frac{F_{fd}}{F_{dd}}\right)^{\frac{\sigma-1-a}{\sigma-1}}\right]^{1/a} \quad (26)$$

$$\gamma_{ff}^* = K_d^{1/a}\left(\frac{F_{ff}}{\mu_f}\frac{\sigma a}{a-\sigma+1}\right)^{1/a}\left[\frac{K_f}{K_d}+\tau_{df}^{-a}\left(\frac{F_{df}}{F_{ff}}\right)^{\frac{\sigma-1-a}{\sigma-1}}\right]^{1/a} \quad (27)$$

Changes in a, K_f/K_d and $K_d^{1/a}$ thus directly map into changes in the shape parameter and cutoff of the distribution of active Canadian and US firms. Specifically, higher values of $K_d^{1/a}$ and K_f/K_d raise the cutoff which can be interpreted as a proportional increase in productivity across all initial levels of γ. A higher a, in contrast, is consistent with increases in the productivity of firms with initially low productivity, relative to those with initially high productivity. From table 9, both effects are present in all three liberalization scenarios. This again clarifies how increases in firm-level productivity can produce both higher aggregate productivity growth *and* lower growth in exports and imports. Having more productive firms in both markets implies lower domestic price indices and thus higher domestic cutoffs, higher export cutoffs and thus lower exports from both countries. Together with the increase in the dispersion parameter a, this effect outweighs the increase in exports triggered by the higher productivity of the remaining exporting firms.[34]

How realistic are these changes? There is of course a sizable empirical literature predating Trefler (2004) that documents within-firm productivity gains after trade liberalization (see Tybout (2003) for a survey). Direct evidence on changes in the shape of the productivity distribution after trade liberalization is much rarer, however. A recent paper which is supportive of an increase in the shape parameter a is Nocke and Yeaple (2006). These authors report estimates that show a flattening of the firm-level rank-size distribution with lower trade costs.[35] More generally, our findings are consistent with a more pronounced catch-up of low-productivity firms which manage to survive a liberalization of import tariffs. Since there is more scope for productivity enhancing measures at such firms, this strikes us as *a priori* not implausible.

What about the magnitude of the shift in the productivity distribution of active firms? Here we are on firmer ground as we can use Trefler's estimates of average within-

[34] In unreported results, we plotted changes in the firm productivity distribution resulting from changing the cutoffs and the shape parameter separately. For the median sector, the rightward shift in the distribution implied by changes in γ_{dd}^* clearly dominated the overall change in the distribution, with higher values of a only playing a minor role.

[35] With Pareto, the productivity γ associated with rank ρ_γ is $\gamma = kr_\gamma^{-1/a}$. Differentiation shows that $\partial\gamma/\partial r < 0$ and $\partial^2\gamma/(\partial r\partial a) > 0$. Thus, given that sales are a monotonic function of productivity in our model, a flattening of the rank-size distribution is consistent with an increase in a.

firm productivity growth to judge the reasonableness of our estimates. Theoretically, the increase in the average productivity of active firms is given by:[36]

$$\frac{E\left(\gamma_t|\gamma_t > \gamma^*_{dd,t}\right)}{E\left(\gamma_{t-1}|\gamma_{t-1} > \gamma^*_{dd,t-1}\right)} = \frac{a_t\left(a_t - 1\right)^{-1}\gamma^*_{dd,t}}{a_{t-1}\left(a_{t-1} - 1\right)^{-1}\gamma^*_{dd,t-1}}. \tag{28}$$

Table 10 reports the implied average productivity increase among active firms for our three liberalization scenarios and compares them to Trefler's estimates (shown in brackets underneath the implied productivity gains).[37] Depending on the productivity measure we are trying to match, we are quite close to Trefler's estimates for all three liberalization experiments (unilateral Canadian, unilateral US and bilateral liberalization). Of course, there are still some discrepancies but these are an order of magnitude smaller than the substantial deviations reported in the earlier sections of this paper.

7 Concluding Remarks

Models with heterogeneous firms à la Melitz (2003) have become a widely applied tool in the International Trade literature. In this paper, we examined the qualitative and quantitative predictions of a model of this class in the context of the Canada - US Free Trade Agreement (CUSFTA) of 1989.

We began by constructing a Melitz-style model which captured the main features of the Canadian-US liberalization experience (in particular, asymmetries in terms of country size, bilateral tariffs and parameter values such as fixed costs). We then calibrated the model's parameters to the pre-liberalization period, simulated the liberalization using the actual tariff cuts, and compared them with Trefler's (2004) estimates of the effects of CUSFTA.

Our results show that our model performs well in replicating the qualitative aspects of Trefler's results. In particular, we correctly predict that US tariff cuts have smaller productivity enhancing effects than Canadian tariff reductions due to the entry of less efficient exporters. Quantitatively, the model does somewhat less well. It tends to underpredict the impact of CUSFTA on growth rates of productivity, but overpredicts the increase in Canadian exports and imports.

In a final step, we allowed for changes in within-firm productivity as a way of rec-

[36] Trefler estimates within-firm productivity gains for continuing establishments. There is no clear theoretical counterpart to this in our model, because we do not observe individual firms but only productivity distributions.

[37] We adjust Trefler's estimates to take into account that the aggregate effects are slightly different for our smaller sample (see table 1). We do so by assuming that the contribution of within-firm productivity gains to total gains remains constant as we move to our smaller sample. For example, Trefler reports an aggregate productivity effect of Canadian tariff reductions on the most import-competing industries of 0.15 and a within-firm effect of 0.08 (lines 1 and 10 of his table 2, p.880). In our smaller sample, we estimate an aggregate effect of 0.14 and thus adjust the within-firm effect to $0.08 \times (0.14/0.15) = 0.075$.

onciling theory and evidence. We showed that allowing for such changes allows us to match aggregate productivity gains and trade flow changes exactly. We also provided evidence that the required changes in the parameters governing the underlying firm-level productivity distribution were empirically plausible.

In conclusion, it thus seems that the standard approach in the literature of abstracting from firm-level productivity gains is useful for modeling the *qualitative* patterns of trade liberalizations. To match *quantitative* patterns as well, however, within-firm improvements are needed. In this paper, we have outlined the broad pattern of changes in the firm-level productivity distribution required to match conditional aggregate trade and productivity moments. Directly incorporating these changes into heterogeneous firm models, *e.g.* by allowing for endogenous reactions of the productivity parameters to increased trade, seems a very promising venue for future research.

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A Comparative Statics - Productivity

This section shows that $\frac{\partial \tilde{\gamma}_j}{\partial \tau_{jj'}}$ has got an ambiguous sign. Let us simplify by assuming two countries and some symmetry: $F_{jj} = F_{j'j'} = F_{jj'} = F_{j'j}$, $K_j = K_{j'}$, and $\mu_j = \mu_{j'}$. Thus,

$$\tilde{\gamma}_j \propto \left[\frac{\left(1+\tau_{j'j}^{-a}\right)^{\frac{\sigma-1-a}{a}} + \left(1+\tau_{jj'}^{a}\right)^{\frac{\sigma-1-a}{a}}}{\left(1+\tau_{j'j}^{-a}\right)^{-1} + \left(1+\tau_{jj'}^{a}\right)^{-1}} \right]^{\frac{1}{\sigma-1}} . \tag{29}$$

One can show that

$$sign\left\{\frac{\partial \tilde{\gamma}_j}{\partial \tau_{jj'}}\right\} = sign\left\{ \frac{\sigma-1}{a} - \frac{1-\left(\frac{1+\tau_{j'j}^{-a}}{1+\tau_{jj'}^{-a}}\right)^{\frac{\sigma-1}{a}}}{1+\left(\frac{1+\tau_{j'j}^{-a}}{1+\tau_{jj'}^{a}}\right)} \right\} \tag{30}$$

can be positive or negative, depending on the values of a, σ, $\tau_{jj'}$ and $\tau_{j'j}$. For example, fix a and σ, and consider different values of τ: when both $\tau_{jj'}$ and $\tau_{j'j}$ tend to one, $sign\left\{\frac{\partial \tilde{\gamma}_j}{\partial \tau_{jj'}}\right\} > 0$; when both $\tau_{jj'}$ and $\tau_{j'j}$ tend to infinite, $sign\left\{\frac{\partial \tilde{\gamma}_j}{\partial \tau_{jj'}}\right\} < 0$.

B Calibration

Two-country Model

We demonstrate below that with given values for a and σ, our model can be solved for a set of positive parameter values F_{dd}, F_{ff}, F_{df}/F_{ff}, F_{fd}/F_{dd} and K_d/K_f. First, using the model's equilibrium outcomes for N_{dd} and X_{fd}, we can solve for F_{dd} as a function of a, σ, and 'data':

$$F_{dd} = \frac{\tau_{fd}\mu_d - X_{fd}}{\tau_{fd}N_{dd}} \frac{a-\sigma+1}{a\sigma}. \tag{31}$$

By symmetry, from the model's equilibrium outcomes for N_{ff} and X_{df},

$$F_{ff} = \frac{\tau_{df}\mu_f - X_{df}}{\tau_{df}N_{ff}} \frac{a-\sigma+1}{a\sigma}. \tag{32}$$

From the model's equilibrium outcomes for N_{dd} and N_{ff} and from (31) and (32),

$$\frac{F_{df}}{F_{ff}} = \left[\frac{\left(\tau_{fd}\mu_d - X_{fd}\right)\left(\tau_{df}\mu_f - X_{df}\right)}{\left(\tau_{fd}\right)^a \left(\tau_{df}\right)^a X_{fd}X_{df}} \right]^{-\frac{\sigma-1}{\sigma-a-1}} \left(\frac{F_{fd}}{F_{dd}}\right)^{-1}. \tag{33}$$

From (gammadxstar2), (11), and (31),

$$\frac{K_d}{K_f} = \frac{\tau_{fd}\mu_d - X_{fd}}{\left(\tau_{fd}\right)^a X_{fd}} \left(\frac{F_{fd}}{F_{dd}}\right)^{\frac{\sigma-a-1}{\sigma-1}} . \tag{34}$$

Notice that F_{df}/F_{ff} and K_d/K_f are functions of F_{fd}/F_{dd} and known parameters/data. Hence, all we need to do in order to complete our calibration is to solve for F_{fd}/F_{dd}. Define $\gamma_j^T > \gamma_{jj}^*$ as the productivity level above which the productivity lies for the mass N_j^T of most productive (and therefore largest) firms:

$$N_j^T = \left[1 - V_j\left(\gamma_j^T\right)\right] M_j = M_j k_j^a \left(\gamma_j^T\right)^{-a}. \tag{35}$$

Hence, $\gamma_j^T = \left(N_j^T/N_{jj}\right)^{-1/a} \gamma_{jj}^*$. Assuming $\gamma_j^T > \gamma_{jj'}^*$, the industry's revenue accounted for by the top firms is

$$R_j^T = M_j k_j^a \frac{a\sigma}{a-\sigma+1} \left(\frac{N_j^T}{N_{jj}}\right)^{-\frac{\sigma-a-1}{a}} \left[\sum_{j'} \tau_{jj'}^{2-\sigma} F_{j'j'} \left(\gamma_{j'j'}^*\right)^{1-\sigma} \left(\gamma_{jj}^*\right)^{\sigma-1-a}\right]. \tag{36}$$

After some algebraic manipulations, we obtain R_d^T as:

$$R_d^T = \frac{a\sigma}{a-\sigma+1} \left(\frac{N_d^T}{N_{dd}}\right)^{-\frac{\sigma-a-1}{a}} N_{dd} \cdot$$
$$\cdot \left[F_{dd} + \tau_{df}^{2-\sigma} \tau_{fd}^{1-\sigma} F_{ff} \left(\frac{N_{dd}}{N_{ff}}\right)^{\frac{1-\sigma}{a}} \left(\frac{\tau_{fd}\mu_d - X_{fd}}{X_{fd}}\right)^{\frac{\sigma-1}{a}} \left(\frac{F_{fd}}{F_{dd}}\right)^{\frac{\sigma^2-2\sigma-a\sigma+a+1}{(\sigma-1)a}}\right]. \tag{37}$$

This is a non-linear equation in F_{fd}/F_{dd} with a unique positive solution. Once we obtain F_{fd}/F_{dd}, we can find values for F_{df}/F_{ff} and K_d/K_f from equations (33) and (34), respectively.

Three-country Model - No Natural Trade Barriers

The three-country version of our model requires additional parameters to be calibrated. Initially, we assume that $\alpha_{jj'} = 0$ and that $\tau_{jj'}$ is thus a function of (known) tariffs only. We further make the simplifying assumption that export fixed costs are destination-specific only and do not vary by exporter. Thus, we now need values for a, σ, F_{dd}, F_{ff}, F_{ww}, $F_{df} = F_{wf}$, $F_{fd} = F_{wd}$, $F_{dw} = F_{fw}$, K_f/K_d, and K_w/K_d. We calibrate a and σ as in the two-country model, leaving us with eight parameters. We use functions of the now six bilateral trade flows and the number of firms in Canada, the US and the RoW for our calibration.

Again, we can show that these moments can be exactly solved for a set of positive parameter values. To see this, we start from the expressions for the number of active firms and for bilateral trade flows to obtain,

$$F_{dd} = \frac{\mu_d - \tau_{fd}^{-1} X_{fd} - \tau_{wd}^{-1} X_{wd}}{N_{dd}} \frac{a - \sigma + 1}{a\sigma}, \tag{38}$$

$$F_{ff} = \frac{\mu_f - \tau_{df}^{-1} X_{df} - \tau_{wf}^{-1} X_{wf}}{N_{ff}} \frac{a - \sigma + 1}{a\sigma}, \tag{39}$$

$$F_{ww} = \frac{\mu_w - \tau_{dw}^{-1} X_{dw} - \tau_{fw}^{-1} X_{fw}}{N_{ww}} \frac{a - \sigma + 1}{a\sigma}. \tag{40}$$

Dividing X_{dw} by X_{fw},

$$\frac{X_{dw}}{X_{fw}} = \frac{K_d}{K_f} \left(\frac{\tau_{dw}}{\tau_{fw}} \right)^{1-a}. \tag{41}$$

Hence,

$$\frac{K_f}{K_d} = \frac{X_{fw}}{X_{dw}} \left(\frac{\tau_{dw}}{\tau_{fw}} \right)^{1-a}. \tag{42}$$

Similarly,

$$\frac{K_w}{K_d} = \frac{X_{wf}}{X_{df}} \left(\frac{\tau_{df}}{\tau_{wf}} \right)^{1-a}. \tag{43}$$

Again from the expressions for bilateral trade flows, we can obtain

$$\frac{F_{fd}}{F_{dd}} = \left[X_{fd} \frac{K_d}{K_f} N_{dd}^{-1} \tau_{fd}^{a-1} F_{dd}^{-1} \left(\frac{a - \sigma + 1}{\sigma a} \right) \right]^{\frac{\sigma-1}{\sigma-a-1}}, \tag{44}$$

$$\frac{F_{df}}{F_{ff}} = \left[X_{df} \frac{K_f}{K_d} N_{ff}^{-1} \tau_{df}^{a-1} F_{ff}^{-1} \left(\frac{a - \sigma + 1}{\sigma a} \right) \right]^{\frac{\sigma-1}{\sigma-a-1}}, \tag{45}$$

$$\frac{F_{dw}}{F_{ww}} = \left[X_{dw} \frac{K_w}{K_d} N_{ww}^{-1} \tau_{dw}^{a-1} F_{ww}^{-1} \left(\frac{a - \sigma + 1}{\sigma a} \right) \right]^{\frac{\sigma-1}{\sigma-a-1}}. \tag{46}$$

Three-country Model - Natural Trade Barriers

Once we allow for natural trade costs, we require additional parameter values for the $\alpha_{jj'}$. To reduce the number of parameters, we make the simplifying assumption that bilateral trade costs are symmetric, *i.e.* $\alpha_{df} = \alpha_{fd}$, $\alpha_{dw} = \alpha_{wd}$ and $\alpha_{fw} = \alpha_{wf}$. This choice still requires three additional moments as compared to the three-country model without natural trade costs, yielding a total of eleven parameters in addition to a and σ. As moments, we again use bilateral trade flows (6), the number of firms (3) as well as two concentration ratios.

The implied system of non-linear equations cannot be solved explicitly this time. Instead, we calibrate our parameters via the minimization of a quadratic form in the deviations between moments and data. Formally, denote m the vector of data, $\hat{m}(\theta)$ the moments, and θ the parameter vector (all vectors are 11×1). Thus,

$$\theta = \arg\min_{\theta} \ \ (m - \hat{m}(\theta))' I(11) (m - \hat{m}(\theta)). \tag{47}$$

where $I(11)$ is the 11×11 identity matrix.

C The Long Run

We start by restating the free entry conditions (23) for each country:

$$\left[1 - V\left(\gamma_{jj}^*\right)\right] \frac{\Pi_j}{N_{jj}} = \delta_j F_j, \tag{48}$$

These conditions can be rewritten as

$$\frac{\sigma - 1}{a - \sigma + 1} \left[\sum_{j'} \left(\frac{F_{jj'}}{F_{j'j'}} \right)^{\frac{\sigma-1-a}{\sigma-1}} F_{j'j'} \tau_{jj'}^{-a} \left(\gamma_{j'j'}^*\right)^{-a} \right] = \delta_j F_j k_j^{-a}. \tag{49}$$

Notice that the right-hand side of this condition consists of parameters only, whereas the terms on the left-hand side are functions of K_j. The left-hand side evaluated at the pre-liberalization steady state and post-liberalization steady state must match. Assuming that prior to the trade liberalization we had a steady state, we have a system of as many equations as countries that can be expressed in terms of unknowns K_j'/K_j and $K_{j'}'/K_j'$, where a prime distinguishes the new steady state from the old steady state. Notice we can express the long-run growth rates of relevant variables (*e.g.*, productivity) in terms of K_j'/K_j, $K_{j'}'/K_j'$ and the rest of calibrated parameters. For the two-country version we obtain

$$\frac{\tilde{\gamma}_{d,t}'}{\tilde{\gamma}_{d,t-1}} = \left(\frac{K_d'}{K_d}\right)^{1/a} \frac{\left[\frac{N_{dd,t}'}{N_{dd,t}'+N_{df,t}'} \left[\theta_{dd}\left(K_d', t\right)\right]^{\sigma-1} + \frac{N_{df,t}'}{N_{dd,t}'+N_{df,t}'} \left[\theta_{df}\left(K_d', t\right)\right]^{\sigma-1}\right]^{\frac{1}{\sigma-1}}}{\left[\frac{N_{dd,t-1}}{N_{dd,t-1}+N_{df,t-1}} \left[\theta_{dd}\left(K_d, t-1\right)\right]^{\sigma-1} + \frac{N_{df,t-1}}{N_{dd,t-1}+N_{df,t-1}} \left[\theta_{df}\left(K_d, t-1\right)\right]^{\sigma-1}\right]^{\frac{1}{\sigma-1}}} \tag{50}$$

for our theory-based productivity measure, where

$$\theta_{dd}(K_d) \equiv \gamma_{dd}^*/K_d^{1/a} = \left[\frac{F_{dd}}{\mu_d} \frac{\sigma a}{a - \sigma + 1}\right]^{1/a} \left[1 + \frac{K_f}{K_d} \tau_{fd}^{-a} \left(\frac{F_{fd}}{F_{dd}}\right)^{\frac{\sigma-a-1}{\sigma-1}}\right]^{1/a}, \tag{51}$$

$$\theta_{ff}(K_d) \equiv \gamma_{ff}^*/K_d^{1/a} = \left[\frac{F_{ff}}{\mu_f} \frac{\sigma a}{a - \sigma + 1}\right]^{1/a} \left[\frac{K_f}{K_d} + \tau_{df}^{-a} \left(\frac{F_{df}}{F_{ff}}\right)^{\frac{\sigma-a-1}{\sigma-1}}\right]^{1/a}. \tag{52}$$

For our empirical measure, Q_d/L_d, we have:

$$d\left(Q_d/L_d\right)_{LR} = \frac{\tilde{Q}'_{d,t}/L_{d,t}}{\tilde{Q}_{d,t-1}/L_{d,t-1}} \tag{53}$$

where

$$\frac{\tilde{Q}'_{d,t}}{\tilde{Q}_{d,t-1}} = \left(\frac{K'_d}{K_d}\right)^{1/a} \frac{F_{dd}\left[\theta_{dd}\left(K'_d,t\right)\right]^{1-a} + \left(\frac{F_{df}}{F_{ff}}\right)^{\frac{\sigma-a}{\sigma-1}} F_{ff} \frac{\left[\theta_{ff}\left(K'_d,t\right)\right]^{1-a}}{\tau_{df,t}^{a-1}}}{F_{dd}\left[\theta_{dd}\left(K_d,t-1\right)\right]^{1-a} + \left(\frac{F_{df}}{F_{ff}}\right)^{\frac{\sigma-a}{\sigma-1}} F_{ff} \frac{\left[\theta_{ff}\left(K_d,t-1\right)\right]^{1-a}}{\tau_{df,t-1}^{a-1}}}, \tag{54}$$

and

$$\frac{L'_{d,t}}{L_{d,t-1}} = \frac{F_{dd}\left[\theta_{dd}\left(K'_d,t\right)\right]^{-a} + \left(\frac{F_{df}}{F_{ff}}\right)^{\frac{\sigma-a-1}{\sigma-1}} F_{ff} \frac{\left[\theta_{ff}\left(K'_d,t\right)\right]^{-a}}{\tau_{df,t}^{a}}}{F_{dd}\left[\theta_{dd}\left(K_d,t-1\right)\right]^{-a} + \left(\frac{F_{df}}{F_{ff}}\right)^{\frac{\sigma-a-1}{\sigma-1}} F_{ff} \frac{\left[\theta_{ff}\left(K_d,t-1\right)\right]^{-a}}{\tau_{df,t-1}^{a}}}. \tag{55}$$

Finally, the long-run changes in trade flows are:

$$\frac{X'_{df,t}}{X_{df,t-1}} = \left[\frac{\tau_{df,t}^{1-a}\mu_f\left(\frac{F_{df}}{F_{ff}}\right)^{\frac{\sigma-a-1}{\sigma-1}}}{\frac{K'_f}{K'_d} + \tau_{df,t}^{-a}\left(\frac{F_{df}}{F_{ff}}\right)^{\frac{\sigma-a-1}{\sigma-1}}}\right]\left[\frac{\frac{K_f}{K_d} + \tau_{df,t-1}^{-a}\left(\frac{F_{df}}{F_{ff}}\right)^{\frac{\sigma-a-1}{\sigma-1}}}{\tau_{df,t-1}^{1-a}\mu_f\left(\frac{F_{df}}{F_{ff}}\right)^{\frac{\sigma-a-1}{\sigma-1}}}\right], \tag{56}$$

and

$$\frac{X'_{fd,t}}{X_{fd,t-1}} = \left[\frac{\tau_{fd,t}^{1-a}\mu_d\left(\frac{F_{fd}}{F_{dd}}\right)^{\frac{\sigma-a-1}{\sigma-1}}}{\frac{K'_d}{K'_f} + \tau_{fd,t}^{-a}\left(\frac{F_{fd}}{F_{dd}}\right)^{\frac{\sigma-a-1}{\sigma-1}}}\right]\left[\frac{\frac{K_d}{K_f} + \tau_{fd,t-1}^{-a}\left(\frac{F_{fd}}{F_{dd}}\right)^{\frac{\sigma-a-1}{\sigma-1}}}{\tau_{fd,t-1}^{1-a}\mu_d\left(\frac{F_{fd}}{F_{dd}}\right)^{\frac{\sigma-a-1}{\sigma-1}}}\right]. \tag{57}$$

D Matching Productivity and Trade Growth

In this appendix we show that we can choose changes in the parameters a, K_f/K_d and $K_d^{1/a}$ to exactly match the growth rates of aggregate productivity and exports and imports. First note that it is notationally less cumbersome to match the predicted post-liberalization values of trade flows which are implicitly defined by the growth rates estimated by Trefler. Thus, define $\hat{X}_{jj',t} = X_{jj',t-1} \times d\hat{X}_{jj'}$, where $d\hat{X}_{jj'}$ is the predicted sectorial level growth rates of exports or imports. Denoting all post-liberalization variables by subscript t, we can then solve for K_{ft}/K_{dt} as a function of $\hat{X}_{df,t}$ and a_t (see expression (12)):

$$\frac{K_{f,t}}{K_{d,t}} = \frac{\mu_f - \hat{X}_{df,t}}{\hat{X}_{df,t}\tau_{df,t}^{a_t}\left(\frac{F_{df}}{F_{ff}}\right)^{-\frac{\sigma-1-a_t}{\sigma-1}}}. \tag{58}$$

Next, using K_{ft}/K_{dt} in the expression for $\hat{X}_{fd,t}$, we can solve for a_t as

$$a_t = \frac{(\sigma-1)\left[\ln\left(\mu_d - X_{fd,t}\right) + \ln\frac{\mu_f - X_{df,t}}{X_{fd,t}X_{df,t}} + \ln\left(\frac{F_{df}}{F_{ff}}\frac{F_{fd}}{F_{dd}}\right)\right]}{(\sigma-1)\ln\left(\tau_{df,t}\tau_{fd,t}\right) + \ln\left(\frac{F_{df}}{F_{ff}}\frac{F_{fd}}{F_{dd}}\right)}. \quad (59)$$

Lastly, we need to match productivity growth. Recall that we focused on two alternative measures only in this section ($\tilde{\gamma}_{j,t}$ and Q_j/L_j). Solving the growth rate $\tilde{\gamma}_{d,t}/\tilde{\gamma}_{d,t-1}$ for $K_{d,t}^{-\frac{1}{a_t}}K_{d,t-1}^{\frac{1}{a_{t-1}}}$, we obtain:

$$K_{d,t}^{-\frac{1}{a_t}}K_{d,t-1}^{\frac{1}{a_{t-1}}} = \frac{\left[\left(\frac{a_t}{a_t-\sigma+1}\right)\frac{\left(\gamma^*_{dd,t}\right)^{\sigma-1-a_t}+\left(\gamma^*_{df,t}\right)^{\sigma-1-a_t}}{\left(\gamma^*_{dd,t}\right)^{-a_t}+\left(\gamma^*_{df,t}\right)^{-a_t}}\right]^{1/(\sigma-1)}}{\left[\left(\frac{a_{t-1}}{a_{t-1}-\sigma+1}\right)\frac{\left(\gamma^*_{dd,t-1}\right)^{\sigma-1-a_{t-1}}+\left(\gamma^*_{df,t-1}\right)^{\sigma-1-a_{t-1}}}{\left(\gamma^*_{dd,t-1}\right)^{-a_{t-1}}+\left(\gamma^*_{df,t-1}\right)^{-a_{t-1}}}\right]^{1/(\sigma-1)}}\left(d\hat{\gamma}_t^d\right)^{-1}, \quad (60)$$

where $d\hat{\gamma}_t^d$ is the growth rate in sectorial productivity estimated by Trefler. Using Q_j/L_j instead, we obtain:

$$K_{d,t}^{-\frac{1}{a_t}}K_{d,t-1}^{\frac{1}{a_{t-1}}} = \frac{\frac{a_t-\sigma}{a_t-\sigma+1}}{\frac{a_{t-1}-\sigma}{a_{t-1}-\sigma+1}}\frac{\frac{\left[F_{dd}\left[\gamma^*_{dd,t}\right]^{1-a_t}+\tau_{df,t}^{1-a_t}\left(\frac{F_{df}}{F_{ff}}\right)^{\frac{\sigma-a_t}{\sigma-1}}F_{ff}\left[\gamma^*_{df,t}\right]^{1-a_t}\right]}{F_{dd}\left[\gamma^*_{dd,t}\right]^{-a_t}+\tau_{df,t}^{-a_t}\left(\frac{F_{df}}{F_{ff}}\right)^{\frac{\sigma-a_t-1}{\sigma-1}}F_{ff}\left[\gamma^*_{df,t}\right]^{-a_t}}}{\frac{\left[F_{dd}\left[\gamma^*_{dd,t-1}\right]^{1-a_{t-1}}+\tau_{df,t-1}^{1-a_{t-1}}\left(\frac{F_{df}}{F_{ff}}\right)^{\frac{\sigma-a_{t-1}}{\sigma-1}}F_{ff}\left[\gamma^*_{df,t-1}\right]^{1-a_{t-1}}\right]}{F_{dd}\left[\gamma^*_{dd,t-1}\right]^{-a_{t-1}}+\tau_{df,t-1}^{-a_{t-1}}\left(\frac{F_{df}}{F_{ff}}\right)^{\frac{\sigma-a_{t-1}-1}{\sigma-1}}F_{ff}\left[\gamma^*_{df,t-1}\right]^{-a_{t-1}}}}\left(d\hat{\gamma}_t^d\right)^{-1}, \quad (61)$$

where again, $d\hat{\gamma}_t^d$ is the growth rate in sectorial productivity derived from Trefler's estimates. Together with the pre-liberalization estimates for a and K_f/K_d, the above estimates can be used to calculate the growth rates in a, K_f/K_d and $K_{d,t}^{1/a}$ reported in section 6. Note that the number of observations decreases from 178 to 175 in tables 9 and 10. This arises from changes in a which lead to violations of the condition $a > \sigma$ needed for the existence of all relevant moments.

Table 1: Trefler's Results

Tariff cuts	Trefler's Sample (1) Labour Productivity	Trefler's Sample (2) Canadian imports from the U.S.	Our sample (3) Labour Productivity	Our sample (4) Canadian imports from the U.S.	Our sample (5) Canadian exports to the U.S.
Canadian tariffs	-1.420	-5.365	-1.593	-5.412	2.106
	(-3.11)	(-4.67)	(-3.12)	(-4.36)	(1.26)
U.S. tariffs	-1.113	-5.289	-0.522	-3.431	-3.518
	(-1.14)	(-2.16)	(-1.51)	(-1.39)	(-1.07)
Business conditions	0.253	0.216	0.248	0.258	0.137
	(8.30)	(5.10)	(7.58)	(5.83)	(2.73)
U.S. control	0.159		0.131		
	(1.99)		(1.37)		
Impact on most impacted, import competing industries	0.15	0.45	0.14	0.46	-0.18
Impact on most impacted, export-oriented industries	0.05	0.25	0.02	0.17	0.16
Total impact of CUSFTA (t-stat)	0.06	0.14	0.06	0.12	0.00
	(3.84)	(6.10)	(3.29)	(5.18)	(0.26)
Adj. R-squared	0.31	0.24	0.30	0.28	0.03
Observations	211	210	178	178	178

Notes: Table displays coefficient estimates and t-statistics for OLS regressions based on specification (1). 'Impact on most impacted, import competing industries' is the weighted average impact on the 1/3 of Canadian industries exposed to the highest Canadian import tariff cuts (expressed in log points). 'Impact on most impacted, export-oriented industries' is the weighted average impact on the 1/3 of Canadian industries exposed to the highest US import tariff cuts. 'Total impact' is the combined average impact on all Candian industries of both U.S. and Canadian tariff cuts.

Table 2: Calibrated parameter values

Parameter	Observations	Median	Min	Max
σ	178	9.01	5.16	17.41
a	178	15.98	6.31	45.21
a_r	178	1.94	1.13	4.88
F_{dd}	178	11.34	1.43	590.70
F_{ff}	178	15.98	0.46	3269.36
F_{fd}/F_{dd}	178	19.58	0.04	7.14E+18
F_{df}/F_{ff}	178	7.60	0.05	135794.50
K_d/ K_f	178	0.14	0.00	28384.08

Table 3: Baseline simulation results

Simulation	(1) Productivity Measure 1 – Melitz	(2) Productivity Measure 2 – Qd/Ld	(3) Productivity Measure 3 – Deflated Sales	(4) Canadian imports from the US	(5) Canadian exports to the US
Unilateral Canadian Liberalization (τ_{fd}=1), weighted average effect on most impacted, import-competing industries	3.2%	3.9%	4.0%	379.7%	0.0%
Unilateral US Liberalization (τ_{df}=1), weighted average effect on most impacted, export-oriented industries	0.3%	2.1%	-0.2%	0.0%	400.8%
Bilateral Liberalization (τ_{fd}=τ_{df}=1), weighted average effect across all industries	1.4%	2.3%	1.1%	50.4%	35.0%
Number of industries	178	178	178	178	178

Notes: Table presents simulation results for productivity and trade volume changes after the parameter changes indicated in the first column. We report weighted averages for the most impacted, import competing third of industries (row 1), the most impacted, export oriented third of industries (row 2), and for all industries (row 3). For productivity, we use the share of value added of an industry in 1988 in the total value added of the respective groups of industries as weights. For trade flows, we use the share of exports or imports of an industry in 1988 in the total value added of the respective groups of industries as weights.

Table 4: Baseline simulation results, outliers removed

Simulation	Excluded sectors	(1) Prod. – Melitz	(2) Prod. – Qd/Ld	(3) Prod. Deflated sales	(4) Canadian imports from the US	(5) Canadian exports to the US
Unilateral Canadian Liberalization (τ_{fd}=1), weighted average effect on most impacted, import-competing industries	Top and bottom 1%	3.0%	3.7%	3.7%	370.5%	0.0%
	Top and bottom 5%	2.3%	2.8%	2.6%	295.1%	0.0%
Unilateral US Liberalization (τ_{df}=1), weighted average effect on most impacted, export-oriented industries	Top and bottom 1%	0.3%	2.0%	-0.1%	0.0%	350.6%
	Top and bottom 5%	0.3%	1.6%	-0.1%	0.0%	181.7%
Bilateral Liberalization (τ_{fd}=τ_{df}=1), weighted average effect across all industries	Top and bottom 1%	1.4%	2.3%	1.1%	49.9%	31.9%
	Top and bottom 5%	1.2%	2.1%	1.0%	45.3%	21.3%

Notes: Table presents simulation results for productivity and trade volume changes after the parameter changes indicated in the first column and the removal of outliers. For each of the five measures reported along the first line of the table, we remove the top and bottom 1% or 5% of sectors with the highest and lowest growth rates. See table 3 and text for details.

Table 5: Simulation results, regression-based approach

Simulation	(1) Productivity Measure 1 – Melitz	(2) Productivity Measure 2 – Qd/Ld	(3) Productivity Measure 3 – Deflated Sales	(4) Canadian imports from the US	(5) Canadian exports to the US
Unilateral Canadian Liberalization (τ_{fd}=1), weighted average effect on most impacted, import-competing industries	2.4%	3.2%	2.3%	137.1%	64.0%
Unilateral US Liberalization (τ_{df}=1), weighted average effect on most impacted, export-oriented industries	1.0%	1.9%	0.6%	55.7%	105.5%
Bilateral Liberalization (τ_{fd}=τ_{df}=1), weighted average effect across all industries	1.2%	1.7%	1.0%	31.8%	19.1%
Number of industries	178	178	178	178	178

Notes: Table presents simulation results for changes in productivity and trade flows after the parameter changes indicated in the first column. See table 3 and text for details.

Table 6: Simulation results, long-run

Simulation	(1) Productivity Measure 1 – Melitz	(2) Productivity Measure 2 – Qd/Ld	(3) Productivity Measure 3 – Deflated Sales	(4) Canadian imports from the US	(5) Canadian exports to the US
Unilateral Canadian Liberalization (τ_{fd}=1), weighted average effect on most impacted, import-competing industries	3.1%	3.8%	3.7%	405.3%	-10.9%
Unilateral US Liberalization (τ_{df}=1), weighted average effect on most impacted, export-oriented industries	1.4%	3.3%	1.6%	-19.6%	505.1%
Bilateral Liberalization (τ_{fd}=τ_{df}=1), weighted average effect across all industries	4.2%	2.8%	4.3%	41.9%	48.8%
Number of industries	178	178	178	178	178

Notes: Table presents long-run simulation results for productivity and trade volume changes after the parameter changes indicated in the first column. See table 3 and text for details.

Table 7: Simulation results, three countries, no natural trade costs

Simulation	(1) Productivity Measure 1 – Melitz	(2) Productivity Measure 2 – Qd/Ld	(3) Productivity Measure 3 – Deflated Sales	(4) Canadian imports from the US	(5) Canadian exports to the US
Unilateral Canadian Liberalization (τ_{fd}=1), weighted average effect on most impacted, import-competing industries	3.0%	3.6%	3.9%	409.1%	0.0%
Unilateral US Liberalization (τ_{df}=1), weighted average effect on most impacted, export-oriented industries	-0.2%	0.9%	-0.7%	0.0%	402.7%
Bilateral Liberalization (τ_{fd}=τ_{df}=1), weighted average effect across all industries	0.9%	1.7%	0.6%	54.6%	35.2%
Number of industries	178	178	178	178	178

Notes: Table presents simulation results for productivity and trade volume changes after the parameter changes indicated in the first row. See table 3 and text for details.

Table 8: Simulation results, three countries, natural trade costs

Simulation	(1) Productivity Measure 1 – Melitz	(2) Productivity Measure 2 – Qd/Ld	(3) Productivity Measure 3 – Deflated Sales	(4) Canadian imports from the US	(5) Canadian exports to the US
Unilateral Canadian Liberalization (t_{fd}=1), weighted average effect on most impacted, import-competing industries	1.6%	1.9%	2.2%	467.6%	0.0%
Unilateral US Liberalization (t_{df}=1), weighted average effect on most impacted, export-oriented industries	-0.1%	0.6%	0.3%	0.0%	305.3%
Bilateral Liberalization (t_{fd}=t_{df}=1), weighted average effect across all industries	0.6%	1.0%	0.9%	56.3%	27.4%
Number of industries	178	178	178	178	178

Notes: Table presents simulation results for productivity and trade volume changes after the parameter changes indicated in the first row. See table 3 and text for details.

Table 9: Parameter changes needed to exactly match aggregate trade and productivity increases (median values across industries)

Simulation	Unilateral Canadian Liberalization (τ_{fd}=1)	Unilateral US Liberalization (τ_{df}=1)	Bilateral Liberalization (τ_{fd}=τ_{df}=1)
Change in $K_d^{1/a}$ - prod. measure 1 (Melitz)	3.5%	1.2%	5.3%
Change in $K_d^{1/a}$ -prod. measure 2 (Qd/Ld)	0.3%	0.4%	0.3%
Change in a	6.8%	1.4%	8.7%
Change in K_f/K_d	-24.1%	25.6%	-1.3%
Number of industries	175	175	175

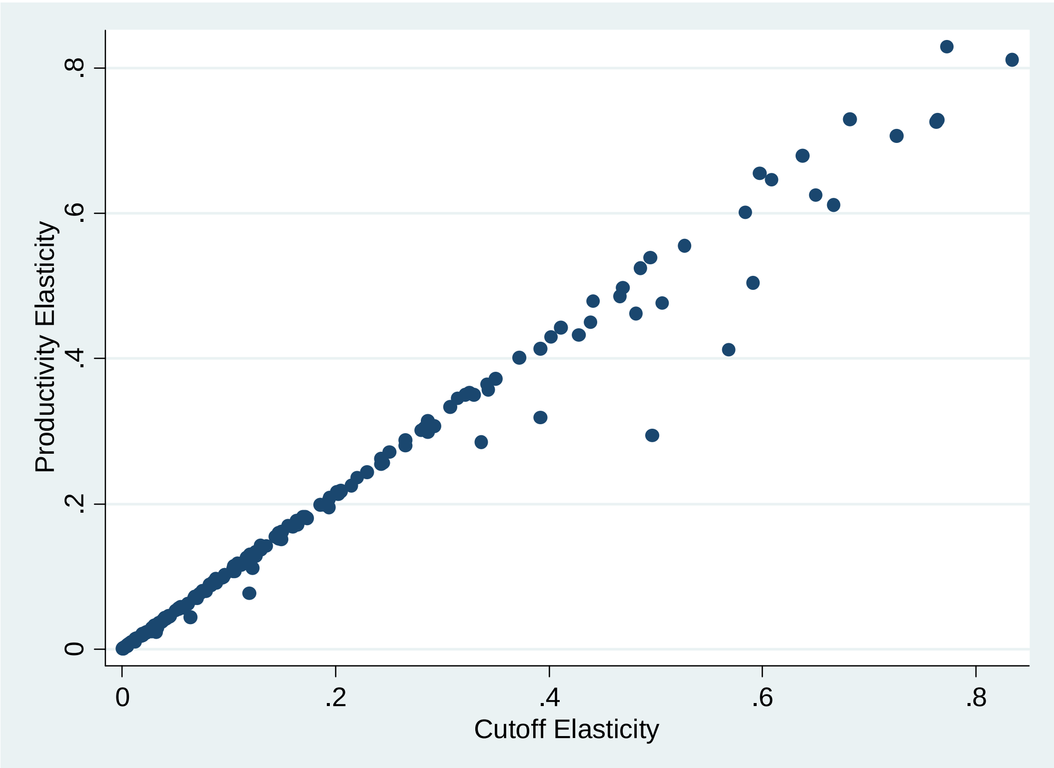
Notes: The table shows changes in parameter combinations governing the distribution of potential entrants. We show the changes needed to match aggregate changes in productivity and trade flows following the liberalization experiments indicated in the first row. See text for details.

Table 10: Implied average productivity gains at the firm-level

	Moments matched	
Simulation	Prod. measure 1 (Melitz) and trade flows	Prod. Measure 2 (Qd/Ld) and trade flows
Unilateral Canadian Liberalization (τ_{fd}=1), weighted average effect on most impacted, import-competing industries	13.4% (7.5%)	9.0% (7.5%)
Unilateral US Liberalization (τ_{df}=1), weighted average effect on most impacted, export-oriented industries	5.2% (5.6%)	3.7% (5.6%)
Bilateral Liberalization (τ_{fd}=τ_{df}=1), weighted average effect across all industries	6.3% (7.4%)	4.3% (7.4%)
Weights	Trefler	Trefler
Number of industries	175	175

Notes: The table shows the changes in average within-firm productivity implied by the parameter changes from table 9. For comparison, we report estimates based on Trefler (2004) in brackets underneath each change. See text for details.

Figure 1: Elasticity of Productivity and the Domestic Cutoff with respect to Canadian Import Tariffs



Notes: Figure shows the plot of the absolute values of the elasticity of aggregate Canadian productivity (measure 1 – Melitz) with respect to the Canadian import tariff against the absolute values of the elasticity of the domestic Canadian cutoff with respect to the same tariff. Each dot in the graph represents one of the 178 sectors of our analysis.

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