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ABSTRACT

Tariffs, Trade and Productivity: A Quantitative Evaluation of Heterogeneous Firm Models*

We examine the quantitative predictions of heterogeneous firm models à la Melitz (2003) in the context of the Canada - US Free Trade Agreement (CUSFTA) of 1989. We compute predicted increases in trade flows and measured productivity across a range of standard models and compare them to the post-CUSFTA increases observed in the data. Our results point to a fundamental problem which most models we analyse face: predicted increases in measured productivity are too low by an order of magnitude relative to predicted increases in trade flows. Thus, most models are inherently incapable of simultaneously matching trade and productivity reactions to freer trade, raising doubts about the accuracy of the quantitative predictions of a large number of work-horse models in the literature. Using a multi-product firm extension of our baseline model as an example, we show that allowing for within-firm productivity increases has the potential to reconcile model predictions with the data.

JEL Classification: C54, F12, F14 and F17
Keywords: gmm estimation, heterogeneous firm models, international trade, out-of-sample predictions and quantitative evaluation

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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 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 quantitative predictions with regards to trade liberalization is still at an early stage. 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 to provide such an evaluation. We go beyond the stylized facts listed above and ask to what extent a range of heterogeneous firm models in the tradition of Melitz (2003) are able to quantitatively replicate the changes in trade flows and productivity associated with a specific trade liberalization episode.

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)). First, 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. Second, it was also largely unanticipated since its ratification by the Canadian parliament was considered to be uncertain as late as November 1988.[1] Third, the main instrument of liberalization were tariff cuts which are easily quantifiable and have a direct theoretical counterpart in all the models we analyse. Finally, there is a substantial amount of reduced-form evidence that CUSFTA has had a significant causal impact on both trade flows and productivity in the Canadian manufacturing sector (*e.g.* Trefler (2004); Head and Ries (1999) and (2001)).

The goal of our analysis is to evaluate to which extent different versions and extensions of Melitz's heterogeneous firm model can replicate the magnitude of trade flow and productivity increases we observe in Canada in the post-CUSFTA period (1988-1996). The baseline model we use for our analysis is a version of Chaney (2008), who extends Melitz (2003) to multiple asymmetric countries and industries as well as asymmetric trade barri-

[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.

ers between countries. We write the model's equilibrium conditions in changes following Dekle, Eaton and Kortum (2008). This allows us to express predicted increases in trade flows and measured productivity as functions of initial trade shares, the actual observed tariff cuts as well as a small number of additional parameters. We compute these predictions for around 200 Canadian manufacturing sectors and compare means, variances and covariances of these increases across sectors to the trade flow and productivity increases observed in the data. Throughout, we pay close attention to construct model predictions which are directly comparable to the data. We do so by mimicking the procedures used by Statistics Canada in computing measured trade and productivity growth as closely as possible in the construction of our theoretical moments.[2]

Our central result is that our benchmark model is inherently incapable of matching both trade and productivity increases. This is true when we use sectoral parameter estimates obtained from other data sources, or when we choose parameters to minimize deviations between theoretical and empirical moments via a simple GMM procedure. Intuitively, the predicted increase in trade flows for a given change in tariffs is much too large relative to the predicted increase in measured productivity. Put differently, if we choose parameters to match trade flows, the model substantially underpredicts the growth in measured productivity we observe in the data.

We explore the robustness of our results in a number of ways, such as using different approaches to computing measured productivity growth or modeling tariff cuts in the model. We also experiment with removing a number of sources of variation from the data which are arguably absent from our highly stylized baseline model and might render a direct comparison uninformative. For example, we first-difference the data to remove time-invariant trends in productivity and trade flow increases. We also project the data on sectoral-level tariff cuts as in Trefler (2004) and use the predicted values for a comparison to our model's predictions (thus only using variation in the data correlated with tariff cuts).[3] These procedures lead to a slightly better fit of the model to the data, but the overall discrepancies remain very large.

Having established the inability of our baseline model to simultaneously match trade and productivity increases, we ask which variations in modeling features bring the model's predictions closer to the data. We experiment with versions of our baseline model allowing for free entry, tradable intermediate inputs, general equilibrium effects operating through wages, and endogenous firm-level productivity through adjustments in product scope as

[2]Section 3 and Appendix A discuss in detail how measured real productivity growth arises in our modeling frameworks despite the presence of fixed markups. Also see Burstein and Cravino (2012) for a related discussion. We note, however, that there are important considerations which arise when working at a fine level of sectoral disaggregation (as we do). These considerations lead to additional sources of measured productivity gains absent from Burstein and Cravino (see Section 3 and Appendix A for details).

[3]We always perform the same transformation on the actual and the model-generated data to preserve comparability. We explain this approach in more detail in Section 4.

in Bernard, Redding and Schott (2011). We find that free entry and general equilibrium effects do not markedly improve the model's performance. Introducing tradable intermediates helps somewhat, but formal over-identification tests in our GMM framework still reject this model variant. The only model that is capable of providing a good fit to the data and of passing our over-identification tests is the multiproduct firm extension. We interpret these results as evidence for the need to explicitly model within-firm productivity increases when constructing quantitative trade models capable of explaining first-order features of trade liberalization episodes.[4]

Our research contributes to two related strands in the literature. The first are papers concerned with the design and testing of a new generation of computable general equilibrium (CGE) models (e.g., Balistreri et al. (2011), Corcos et al. (2012), Caliendo and Parro (2012)). This new generation of CGE models tries to improve the predictive performance of earlier CGE models by explicitly modeling firm-level heterogeneity.[5] Our paper highlights a fundamental problem many of these models face when trying to predict the effects of a reduction of trade barriers – the inability to match both trade and productivity increases, the two variables which have been the focus of most existing theoretical and empirical analyses of trade liberalization episodes. We also contribute to this literature by performing a comparative evaluation of a wide range of popular trade models, rather than focusing on the performance of one particular version. Finally, we look at both within- and out-of-sample predictions and employ formal statistical tests to evaluate model performance, rather than only comparing the model predictions and data in a relatively ad-hoc fashion.[6]

Secondly, we contribute to the rapidly growing literature on quantitative trade models (e.g., Eaton and Kortum (2002), Alvarez and Lucas (2007), Hsieh and Ossa (2011), Levchenko and Zhang (2011), Ossa (2012), Arkolakis, Costinot and Rodríguez-Clare (2012); see Costinot and Rodríguez-Clare (2013) for a recent overview). One of the key purposes of these papers is to compute the gains from trade in different gravity-type models and to relate the magnitude of the predicted gains to specific model features. Obviously, the usefulness of these exercises depends crucially on the empirical validity of the underlying modeling frameworks in terms of their quantitative (rather than just qual-

[4]Given that the number of free parameters in the above models varies, we also look at the out-of-sample predictions of our models. That is, we estimate parameters on the pre-liberalization period (1980-1988) and compare the models' predictions for the post-liberalization (1988-2006) period, thus controlling for potential problems of overfitting. Still, we find that the multiproduct extension of our baseline model performs best.

[5]See Kehoe (2005) for an evaluation of the (poor) quantitative performance of some of these earlier models.

[6]Two recent papers, Eaton *et al.* (2011) 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. Fieler (2011) tests and rejects the ability of the Eaton-Kortum (2002) model to predict cross-sectional non-OECD trade flows, and proposes an extension based on nonhomothetic preferences.

itative) predictions. We point out that a class of widely used quantitative trade models has difficulties matching basic adjustment patterns to freer trade, and show which model modifications provide a better fit to the data.

The rest of the paper is structured as follows. In Section 2, we provide background information on CUSFTA and take a first look at the increases in trade flows and measured productivity we observe in the data. Section 3 discusses our baseline model and how we compute our theoretical predictions. Section 4 evaluates this model's quantitative predictions and shows why the model is inherently incapable of matching our empirical moments. In Section 5 we discuss different extensions of our baseline model and show that allowing for endogenous firm-level productivity is one way of reconciling models of the class of Melitz (2003) with the evidence. Section 6 concludes.

2 Empirical Setting

Negotiations for CUSFTA started in May 1986, were finalized in October 1987 and the treaty was signed in early 1988. The agreement came into effect on 1 January 1989, which was also the date of the first round of tariff cuts. Tariffs were then phased out over a period of up to ten years with some industries opting for a swifter phase-out.

While average Canadian manufacturing tariffs against the United States were already relatively low in 1988 (around 8%), this average hides a substantial amount of sectoral heterogeneity. As discussed in Trefler (2004), more than a quarter of Canadian industries were protected by tariffs in excess of 10%. These industries also tended to be characterised by low initial profit margins, implying potentially strong selection effects of CUSFTA. Similarly, the import tariffs faced by Canadian firms exporting the United States also showed a strong variation across sectors, although the average intial tariff whas somewhat lower at approximately 4%.

Figure 1 shows that the tariff reductions were indeed accompanied by strong increases in trade flows (Canadian imports plus exports) and measured labor productivity.[7] The average Canadian trade flow increase over the period 1988 to 1996 was 118%, while the increase in labor productivity was 30%. This compares to growth rates of only 44% (trade) and 17% (labor productivity) for the pre-liberalization period, 1980-1988. Figure 1 also displays a high degree of heterogeneity in trade flow and productivity changes across the 203 sectors in our data in the post-liberalization period. For example, industries at the 5th percentile of the distribution of productivity changes observed a decrease of close to -12% over the 1988-1996 period, or -1.5% per year. In contrast, industries at the 95%

[7] We use data for 203 Canadian manufacturing sectors from Trefler (2004), who uses Statistics Canada as his original data source. We compute growth rates from data expressed in 1992 Canadian dollars using 4-digit industry price and value added deflators and the 1992 US-Canadian Dollar exchange rate. Labor productivity is calculated as value added in production activities divided by total hours worked by production workers. See section 4 for additional details on data construction.

percentile saw productivity increase by over 80% in total or 7.7% per year. Likewise, trade flow changes range from -14% (-1.9% p.a.) at the 5th percentile to over +400% (22% p.a.) at the 95th percentile. Using differences-in-differences estimation and instrumental variables techniques, Trefler (2004) demonstrates a causal link between these changes and the extent of tariff cuts across sectors.

In the light of this evidence, we focus on model predictions regarding average changes in trade and productivity and their dispersion across sectors. Table 2 summarizes our empirical moments. Besides the mean and the variance of trade flow and productivity increases, we also look at the covariance between these increases across sectors. That is, we will be comparing the first and second moments of these variables to their theoretical counterparts in our models.

3 Description of Baseline Model

In this section, we outline our baseline model, which is a version of Chaney (2008). We describe the model setup and how we derive our equilibrium conditions in changes. We then discuss how to construct theoretical predictions from the model which are comparable to the empirical moments we observe in the data (see Table 2).[8]

Model Setup and Equilibrium Conditions

There are many countries. Each country admits a representative agent, with quasi-linear preferences

$$U = \sum_{i \in I} m_i \ln Q_i + A,$$

where $m_i > 0$. A denotes consumption of a homogeneous final good. Q_i denotes a Dixit-Stiglitz aggregate (manufacturing) final good i:[9]

$$Q_i^c = \left[\int_{\gamma \in \Gamma_i} q_i(\gamma)^{\rho_i} d\gamma \right]^{\frac{1}{\rho_i}},$$

where $\rho \in (0,1)$ and $\sigma \equiv 1/(1-\rho)$ denotes the elasticity of substitution between any two varieties. Choosing good A as the numéraire, utility maximization on the upper level yields demand functions $A = Y - \sum_i m_i$ and $E_i \equiv P_i Q_i = m_i$, where Y is total expenditure per consumer. In the manufacturing goods sector, utility maximization yields demand function $q_i(\gamma) = p_i(\gamma)^{-\sigma} P_i^{\sigma-1} m_i$.

[8]Given that this model is a straightforward extension of Chaney (2008), we keep the description of the model set up to a minimum and devote more space to the construction of the theoretical moment. Further details about the model are contained in the Online Appendix to this paper (available at http://privatewww.essex.ac.uk/~hbrein/TheAppendix_20130717.pdf).

[9]Wherever possible, we dispense with industry index i and with country indexes.

The homogeneous good is made with labor l and a linear technology $A = l_A$ identical across countries. Manufacturing varieties are made with the production function $q_i(\gamma) = \gamma l_i(\gamma)$, where γ denotes (firm-specific) productivity. γ is iid across firms within an industry. For tractability purposes, we assume γ to be distributed Pareto with shape parameter a_γ and location parameter k_γ. We assume the same shape parameter for an industry across countries, but allow it to vary across industries. The location parameter is allowed to vary across industries and countries. Producers of the homogeneous good and the final goods Q operate in a perfectly competitive environment. Producers of varieties in the manufacturing industry have instead monopoly power over their own varieties.

The homogeneous good is traded freely; supplying it to any market involves no costs. We consider equilibria in which all countries produce positive amounts of this good, thus leading to the equalization of wages across countries. (We normalize wages to one.) The final goods Q are not traded; supplying them involves no costs either. For the varieties produced by the manufacturing industries, we assume iceberg trade costs, which take the form $\tau_{hj} = (1 + c_{hj})(1 + t_{hj})$ for $j \neq h$ and $\tau_{jj} = 1$. (h and j denote the exporting and importing country, respectively.) c_{hj} denotes "natural" transport costs, and t_{hj} denotes policy-induced trade barriers. We can safely ignore tariff revenue for now, given the quasi-linear utility assumption above. A manufacturing industry-i firm based in country h faces a fixed cost F_{hj} of supplying country j. Fixed costs are in terms of the destination country's labor. We assume these labor services are provided by a "services sector" that operates under perfect competition and with a linear technology that turns one unit of labor into one unit of the fixed cost.[10] Fixed and variable trade costs are allowed to vary across industries. We assume there is no free entry in the manufacturing sectors: there is a given mass of firms M_h that pick a draw from the distribution of γ prior to any decision. The labor market is perfectly competitive.

We now proceed to the formal treatment of the model, which consists of three steps:[11] (i) First we show how to express the model's industry equilibrium outcomes of interest as functions of the model's parameters and of the "productivity thresholds" typical of the Melitz model. (ii) We then express the growth rates of these industry outcomes in terms of the changes in parameter values (the change in transport costs τ_{hj}), the resulting growth rates of the productivity thresholds, a few of the model's parameters (e.g., a_γ and σ), and the levels of bilateral trade volumes (which subsume the rest of the model's parameters). (iii) Finally, we show how to manipulate the growth rates of the model's equilibrium conditions so as to obtain changes in the productivity thresholds as a function of changes in τ_{hj}, which will proxy for the trade liberalization, the shape parameter a_γ, and the levels of bilateral trade volumes.

[10] Most of the activities associated with entering foreign markets are best described as service activities, such as conducting market studies or setting up distribution networks.

[11] We thank Ralf Ossa for helpful comments and suggestions on this part of the model.

The pricing decision over the variety produced by a country-h firm with productivity γ is the usual mark-up over marginal cost. Well-known manipulation of firm revenue and profit functions yields the following expression for the threshold value of productivity γ^*_{hj} that leads country-h firms to select into market j:

$$\gamma^*_{hj} = \frac{\sigma}{\sigma-1}\frac{\tau_{hj}}{P_j}\left(\frac{\sigma F_{hj}}{m_j}\right)^{\frac{1}{\sigma-1}}. \tag{1}$$

The expected revenue and expected profit that a country-h firm obtains in country j, conditional upon selecting into that market, are respectively

$$\begin{aligned} E\left[r_{hj}(\gamma)\middle|\,\gamma > \gamma^*_{hj}\right] &= \frac{a_\gamma \sigma}{a_\gamma - \sigma + 1}F_{hj}, \\ E\left[\pi_{hj}(\gamma)\middle|\,\gamma > \gamma^*_{hj}\right] &= \frac{\sigma - 1}{a_\gamma - \sigma + 1}F_{hj}. \end{aligned}$$

The mass of country-h firms that select into market j is given by $N_{hj} = \left(k_h/\gamma^*_{hj}\right)^{a_\gamma} M_h$. Country-$h$ exports to country j can be expressed as $X_{hj} = N_{hj}E\left[r_{hj}(\gamma)\middle|\,\gamma > \gamma^*_{hj}\right]$. The industry's aggregate sales are $R_h = \sum_j X_{hj}$. Industry employment can be easily shown to be $L_h = \frac{\sigma-1}{\sigma}R_h$.[12] The price level P_j is given by

$$P_j = \left[\frac{a_\gamma}{a_\gamma - \sigma + 1}\sum_h N_{hj}\left(\frac{\sigma}{\sigma-1}\frac{\tau_{hj}}{\gamma^*_{hj}}\right)^{1-\sigma}\right]^{\frac{1}{1-\sigma}}.$$

Melitz (2003) defines industry productivity as

$$\tilde{\gamma}_h = \left[\sum_j \frac{N_{hj}}{\sum_j N_{hj}}\left(\tilde{\gamma}_{hj}\right)^{\sigma-1}\right]^{\frac{1}{\sigma-1}}, \tag{2}$$

where

$$\tilde{\gamma}_{hj} = \frac{1}{1-G_{ih}\left(\gamma^*_{hj}\right)}\int_{\gamma^*_{hj}}^{\infty}\gamma^{\sigma-1}g_{ih}(\gamma) = \left(\frac{a_\gamma}{a_\gamma-\sigma+1}\right)^{\frac{1}{\sigma-1}}\gamma^*_{hj}. \tag{3}$$

$G(\gamma)$ denotes the distribution function of γ.

Define $\hat{x} \equiv x'/x$ as a gross growth rate, where x and x' denote, respectively, the values

[12] Implicit here is the assumption that the labor necessary to provide the fixed costs F_{hj} is not part of the manufacturing industry's employment. We think of the fixed cost as services being provided by some other sector that operates under perfectly competitive conditions. As discussed, examples include conducting market studies or setting up distribution networks in foreign markets.

of a variable before and after the trade liberalization:

$$\hat{X}_{hj} = \hat{N}_{hj} = \left(\hat{\gamma}^*_{hj}\right)^{-a_\gamma}, \quad (4)$$

$$\hat{R}_h = \hat{L}_h = \sum_j \frac{X_{hj}}{\sum_j X_{hj}} \hat{X}_{hj}, \quad (5)$$

$$\hat{P}_j = \left[\sum_h \frac{X_{hj}}{\sum_h X_{hj}} \hat{N}_{hj} \left(\hat{\tau}_{hj}\right)^{1-\sigma} \left(\hat{\gamma}^*_{hj}\right)^{\sigma-1}\right]^{\frac{1}{1-\sigma}}.$$

Substituting out terms in the price index equation leads to

$$\hat{P}_j = \left[\sum_h \frac{X_{hj}}{\sum_h X_{hj}} \hat{\tau}_{hj}^{-a_\gamma}\right]^{-1/a_\gamma}. \quad (6)$$

We can use the system (6) to solve for the growth rates of the price levels $\hat{P}_j$ as a function of the changes in transport costs $\hat{\tau}_{hj}$. From equation (1), we can solve for $\hat{\gamma}^*_{hj}$ as a function of $\hat{P}_j$ and $\hat{\tau}_{hj}$,

$$\hat{\gamma}^*_{hj} = \hat{\tau}_{hj}/\hat{P}_j, \quad (7)$$

and thereafter generate predictions for the industry aggregates of interest.

In this model, a decrease in country j's own import tariffs triggers an increase in imports and a reduction in country j's price level, thereby reducing the revenues (and profits) obtained by country j's firms in their domestic market. This crowds out some low-productivity firms, thus raising average industry productivity, (2). A reduction in the trade barriers that country j's firms face in their export markets has an ambiguous effect on (2). On the one hand, firms that were not exporting previously (thus with productivity lower than that of old exporters) become exporters. This reduces the average productivity of country j's exporters. On the other hand, the relative mass of exporters over non-exporters rises; since the former are on average more productive than the latter, this effect contributes positively to industry productivity.

Notice that this model minimizes the number of channels for the transmission of changes in trade barriers to changes in industry productivity. In comparison with Melitz (2003), for example, the no-free-entry assumption shuts down the possibility of any effects via changes in M_{ji}. The quasi-linear preferences eliminate general-equilibrium effects via changes in the relative demands of manufacturing goods; and the assumption that the homogeneous good is produced by all countries in equilibrium shuts down any effects via the labor market, as it leads to $w_j = 1$ for all j. (We allow for these additional channels below.)

Finally, we note that expression (2) measures theoretical productivity, which is conceptually different from the measured productivity we observe in the data and on which our descriptive statistics and empirical moments from Section 2 are based. As we will see next, however, theoretical and measured productivity growth are very similar in practice, so that the intuition just provided will continue to hold once we move to measured productivity and trade flows.

Construction of Theoretical Moments

We now construct theoretical counterparts of our empirical moments (mean, variances and covariance of industry-level real growth rates of trade flows and productivity). We try to stay as close as possible to the procedures used by Statistics Canada to assure comparability between theoretical and empirical moments.

We compute real growth rates of measured labor productivity growth by deflating value added per worker with a suitable producer price index (PPI). Note that in our baseline model, value added growth equals revenue growth because there are no intermediate inputs. Thus, measured productivity growth is equal to:

$$MPG_{ih} = \frac{\widehat{R_{ih}/L_{ih}}}{\widehat{PPI}_{ih}} = \left(\widehat{PPI}_{ih}\right)^{-1} \tag{8}$$

Note that in this basic productivity measure, any measured productivity growth will come from changes in the PPI, as the variations in revenue and employment exactly offset each other. In our robustness checks below, we will look at additional sources of (measured) productivity gains and will find them to be unimportant relative to changes in the PPI.

Similarly, real growth in bilateral trade flows between countries h and j is defined as:

$$MTG_{ihj} = \frac{\hat{X}_{ihj}}{\widehat{PPI}_{ih}} \frac{X_{ihj}}{X_{ihj} + X_{ijh}} + \frac{\hat{X}_{ijh}}{\widehat{PPI}_{ij}} \frac{X_{ijh}}{X_{ihj} + X_{ijh}}. \tag{9}$$

Note that we follow Statistics Canada's approach to use PPIs to deflate export sales.[13]

Both growth rates require a suitable PPI deflator. In Appendix A, we provide a more detailed description of how Statistics Canada calculates PPIs at the sectoral level and how their procedure can be replicated in our model. But in essence, Statistics Canada's PPIs are based on sample surveys of currently active firms and give more weight to larger producers. They also use so-called factory gate prices which exclude any costs associated with transport, distribution, subsidies, taxes or tariffs.[14] We compute a theoretical PPI

[13] See Statistics Canada (2001). For a few sectors, export price indices are used but for the vast majority of sectors in our data, Statistics Canada relied on PPIs during our sample period. Also note that exports in our data are valued at free-on-board prices which exclude charges for shipping services incurred abroad, but might include other parts of the overall trade costs such as information or regulatory compliance costs (also see Burstein and Cravino, 2012). Here, we use the value of trade flows inclusive of trade costs, although we will also present results excluding them in our robustness checks.

[14] There are some important differences between our implementation of Statistics Canada's procedures and Burstein and Cravino's (2012) analysis of the construction of the National Income and Product Accounts (NIPA) by the Bureau of Labor Analysis in the United States. We discuss these differences in more detail in Appendix A and explain why we think that our procedure best describes the data

which captures these features while preserving a tight link to theoretical productivity. Specifically, we use the factory-gate price charged by the firm with average productivity, $p\left(\tilde{\gamma}_{ih}\right)=\frac{\sigma}{\sigma-1}\frac{w}{\tilde{\gamma}_{ih}}$, where

$$\tilde{\gamma}_{ih}=\left[\sum_{j}\frac{N_{ihj}}{\sum_{j}N_{ihj}}\left(\tilde{\gamma}_{ihj}\right)^{\sigma-1}\right]^{\frac{1}{\sigma-1}} \tag{10}$$

and

$$\tilde{\gamma}_{ihj}=\frac{1}{1-G_{ih}\left(\gamma_{ihj}^{*}\right)}\int_{\gamma_{ihj}^{*}}^{\infty}\gamma^{\sigma-1}g_{ih}\left(\gamma\right)d\gamma=\left(\frac{a_{\gamma}}{a_{\gamma}-\sigma+1}\right)^{\frac{1}{\sigma-1}}\gamma_{ihj}^{*}. \tag{11}$$

As noted by Melitz (2003), $\tilde{\gamma}_{ihj}$ can be interpreted as a weighted average of firm productivities, where the weights reflect the relative output shares of firms. Also note that $\tilde{\gamma}_{ihj}$ is calculated as an average across active firms, reflecting the sampling procedure of Statistics Canada explained in Appendix A. We thus obtain our theoretical PPI as:

$$\widehat{PPI}_{ih}=\hat{p}\left(\tilde{\gamma}_{h}\right)=\frac{p'\left(\tilde{\gamma}_{h}'\right)}{p\left(\tilde{\gamma}_{h}\right)}=\left(\frac{\tilde{\gamma}_{ih}'}{\tilde{\gamma}_{ih}}\right)^{-1} \tag{12}$$

where the growth rate $\tilde{\gamma}_{ih}'/\tilde{\gamma}_{ih}$ can be written as

$$\frac{\tilde{\gamma}_{ih}'}{\tilde{\gamma}_{ih}}=\left[\left(\sum_{j}\left(\frac{N_{ihj}'}{N_{ihj}}\frac{N_{ihj}}{\sum_{j'}N_{ihj'}}\right)\right)^{-1}\sum_{j}\left[\frac{N_{ihj}'}{N_{ihj}}\left(\frac{\tilde{\gamma}_{ihj}'}{\tilde{\gamma}_{ihj}}\right)^{\sigma-1}\frac{N_{ihj}\left(\tilde{\gamma}_{ihj}\right)^{\sigma-1}}{\sum_{j'}N_{ihj'}\left(\tilde{\gamma}_{ihj'}\right)^{\sigma-1}}\right]\right]^{\frac{1}{\sigma-1}}. \tag{13}$$

Expression (13) requires the number of exporters from country h to country j in sector i, which we do not observe in our data. We show in Appendix A that bilateral sector specific exports (X_{ihj}) can be used as a proxy for N_{ihj} under the additional assumption that the fixed market entry costs (F_{ihj}) are proportional to some observable destination-specific factor that is exogenous to our model.[15]

From (8), (9) and (13), we compute MPG_{ih} and MTG_{ihj} for all sectors in our data as a function of changes in tariffs ($\hat{\tau}_i$), initial trade flows ($X_{i.}$) and the remaining parameters $\theta_i=\left\{a_{\gamma}^{i},\sigma_i\right\}$. We then calculate our theoretical moments as means, variances and covariances across sectors.[16]

Regarding the choice of θ_i, we pursue two alternative approaches. We first use sector-specific estimates of θ_i derived from data not used in the calibration of our model. For our baseline model, we derive estimates for σ from the ratio of revenues to operating profits using firm-level data from Compustat North America. Estimates for a_γ are ob-

construction at the fine level of sectoral disaggregation at which we are working.

[15]We use sector-destination absorption (m_{ij}) in the calibration of our baseline model, although in practice almost identical results are obtained if we use destination market population size or GDP.

[16]For example, mean trade growth is calculated as $m_{1,model}\left(\theta\right)=\frac{1}{I}\sum_{i=1}^{I}MTG_{ihj}$

tained in two steps. First, we estimate the Pareto shape parameter of the industry *sales* distribution (a_r) using industry-specific concentration ratios. We then use the fact that in our model $a_\gamma = a_r \times (\sigma - 1)$ to obtain estimates for a_γ. For more details on these estimation procedures, see Appendix B.

Our second approach is to choose θ_i so as to match our empirical moments via GMM estimation. In order for this exercise to be meaningful, we restrict parameters to be equal across sectors ($\theta_i = \theta$). Given that our benchmark model has two remaining parameters and we have five empirical moments, this overidentifies the model and allows us to test the validity of our moment restrictions. Formally, the GMM estimator of θ is given by

$$\hat{\theta}_{gmm} = \arg\min_{\theta} g(\theta) = \arg\min_{\theta} \left\{ \mathbf{m}(\theta)' W_n \mathbf{m}(\theta) \right\} \tag{14}$$

where $\mathbf{m}(\theta) = [m_1(\theta) ... m_K(\theta)]'$ and $m_k(\theta) = m_{k,data} - m_{k,model}(\theta)$ are the individual moments. W_n is a (positive definite) weighting matrix to be estimated in a first step. We compute a first step estimate $\hat{\theta}_0$ by setting $W_n = W_n^0 = I$. We then use $\hat{\theta}_0$ to compute the optimal weighting matrix

$$W_n^{opt} = \left[\frac{1}{I} \frac{1}{I-1} \sum\nolimits_{i=1}^{I} \mathbf{m}_n \left(\hat{\theta}_0 \right) \mathbf{m}_n' \left(\hat{\theta}_0 \right) \right]^{-1}$$

and obtain $\hat{\theta}_{gmm}$ by setting $W_n = W_n^{opt}$ in (14). The best way to understand our GMM estimation approach is as a test of the model's basic ability to match the empirical moments of interest. As we will see, all but one of our models will fail even this most basic test.

4 Evaluation of Baseline Model

We now evaluate our baseline model's quantitative predictions and show that the model is inherently incapable of matching our empirical moments.

Data

Our baseline analysis requires sectoral level data for trade flows, production, labor productivity per worker and tariffs for the period 1988 to 1996. In our robustness checks, we will also use data for the pre-liberalization period (1980 to 1988). Note that production data is needed to calculate internal trade flows as the value of production minus exports (see Wei, 1996).

All Canadian data are from Statistics Canada as prepared by Trefler (2004).[17] We also require comparable data for the United States and a third country ('Rest of the World',

[17] These data are available from Daniel Trefler's homepage at http://www-2.rotman.utoronto.ca/~dtrefler/files/Data.htm.

or RoW). We define RoW here as Japan, the United Kingdom and (West) Germany, Canada's three largest trading partners after the United States in 1988. Data for the United States and RoW are from Trefler (2004), the U.S. Census Bureau (see Schott, 2010) and UNIDO's Industrial Statistics Database.

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 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).

Results

Table 2 reports results for the theoretical moments computed for our baseline model. For comparison, the first row restates the empirical moments from Table 1 which we are trying to match.

In row (2), we present the model's predictions when we use estimates for a_γ and σ estimated on external data sources. We report the mean and standard deviation of these parameter estimates further down in the table (panel 'Parameters (SE)', 'Data (mean, sd)'). Our parameter estimates for σ are comparable to other estimates in the literature. For example, Broda and Weinstein (2006) estimate an average of $\sigma = 4.0$ across 256 SITC-3 goods between 1990 and 2001. Likewise, the mean across our estimates for the shape parameter of industry sales distributions is $a_r = 2.1$. Using Compustat data on the sales of US listed firms, Chaney (2008) estimates $a_r = 2.0$.

However, the model's predictions are substantially out of line with what we observe in the data. The model does not generate strong enough increases in either trade or productivity, with the predictions for productivity being particularly far off. For example, the model predicts a mean productivity increase over the period 1988-1996 of just 1.4%, whereas the true increase in the data is 30.4%. For comparison, we predict about a quarter (30.9%) of the actual 118% average increase in trade flows.

In row (4), we choose parameters to minimize (weighted) deviations between theoretical and empirical moments, following the GMM approach outlined above.[18] As expected, the model does better in this case but there is still a substantial shortfall in the mean and variance of productivity increases across sectors (we do better for trade flows now). Also note that the optimization procedure pushes the parameter values up to $a_\gamma = 14.2$ and

[18] In row (3), we also report predictions based on our first-step estimates (using the identity matrix as our weighting matrix). These give equal weight to all moments and ignore the moment covariance structure. As such, these predictions are more directly comparable to the ones presented in row (2) and show to what extent the optimal choice of parameters improves upon predictions based on externally estimated parameters. (Although we note that the externally estimated parameters vary by sector and could, in principle, lead to more accurate predictions.)

$\sigma = 8.5$. The shape parameter (a_γ) is precisely estimated, but the same is not true for the estimated elasticity of substitution (σ). Finally, the last two rows of Table 2 report the value of the GMM objective function at its minimum ($g\left(\hat{\theta}_{gmm}\right)$).[19] Given that our baseline model is over-identified (five moments and two parameters), we can also use $g\left(\hat{\theta}_{gmm}\right)$ as the basis for a test of overidentifying restrictions (see Greene, 2000). Under the null that $\hat{\theta}_{gmm} = \theta_{true}$, the GMM objective function follows a $\varkappa^2$-distribution with three degrees of freedom. The corresponding p-value (reported underneath the GMM objective) indicates that we can reject this null at the 1%-level.

What explains the inability of the model to simultaneously match trade and productivity moments? From equations (8) and (12), measured productivity growth is inversely related to the change in the price of the (active) firm with average productivity ($\tilde{\gamma}_{ih}$) in an industry. From (11), changes in $\tilde{\gamma}_{ih}$ are in turn directly proportional to changes in the productivity thresholds, γ^*_{ihj}. In contrast, we can see from (4) that export and import growth are a power function of the changes in export productivity thresholds, with the corresponding trade elasticity being governed by the Pareto shape parameter a_γ.[20]

As discussed, trade liberalization will increase the productivity threshold in the domestic Canadian market ($\gamma^*_{ihh} = 1/\hat{P}_{ih}$) and lower export thresholds for both Canadian and US firms ($\gamma^*_{ihj} = \hat{\tau}_{ihj}/\hat{P}_{ij}$ and $\gamma^*_{ijh} = \hat{\tau}_{ijh}/\hat{P}_{ih}$). From (7), the export threshold for foreign exporters will fall by more than the entry threshold for domestic firms. In addition, the elasticity of trade growth with respect to changes in export threshold is larger than the elasticity of average firm productivity with respect to domestic thresholds (as long as $a_\gamma > 1$, which is the case for our parameter estimates). Thus, any changes in productivity thresholds triggered by the lowering of tariffs will tend to increase trade flows by more than measured industry productivity.

Next, note that a higher a_γ enhances the effects of tariff cuts on the growth of both trade and measured productivity, but increases the former much more than the latter, as is evident from (6), (7) and (4). Thus, if we try to match productivity growth by increasing a_γ, we will necessarily predict trade flows increases which are too high. Measured trade and productivity growth are of course also influenced by σ, which enters the PPI used to deflate both measures. But in practice changes in σ are quantitatively unimportant in the sense that they do not move the GMM objective function by much.[21] Figure 2

[19] Note that the GMM optimisation takes into account the full moment variance-covariance matrix (W_n^{opt}). Thus, it contains more information than the simple comparison of moments in lines (1)-(3). This also explains why the theoretical moments can all be smaller than the empirical moments at the optimized parameter values.

[20] This is a well-known result in the literature, going back to Chaney (2008). Our case is slightly more complicated, because we deflate trade flows by the theoretical PPI, which also depends on σ. In practice, however, the role of σ in the determination of trade flow growth is quantitatively unimportant (see below).

[21] This also explains why σ is estimated with little precision, as can be seen from the high standard error reported in Table 2.

illustrates this point by plotting deviations of the first empirical and theoretical moments (mean productivity and trade growth) against a_γ and σ.

Robustness Checks

Tables 3-8 show results for a number of robustness checks. We begin by moving back to predictions based on externally estimated parameter values (which vary by sector), but change sector-level σs by a factor of 1.5 and 2, respectively. Note that because a_γ is calculated as $a_\gamma = a_r \times (\sigma - 1)$, this also leads to a corresponding variation in the shape parameter of the productivity distribution. As expected from the discussion in the last subsection, increasing both σ and a_γ leads to slightly higher productivity gains, but increases the mean and variance of trade flows by much more. As a results, at $\sigma_{new} = 1.5 \times \sigma_{old}$, the model predicts about 60% of the observed mean increase in trade flows, but already overpredicts the trade flow variance by 25%. At $\sigma_{new} = 2 \times \sigma_{old}$, we overpredict mean trade increases by around 15% and the variance by a factor of 10, but still only obtain a predicted mean increase in productivity of 1.7% and a variance of 0.0002 (or $1/500th$ of the actual variance).

We next examine the sensitivity of our results to outliers, by dropping all sectors which fall within the top or bottom 5% of the trade or productivity growth distributions. This drops 42 sectors, leaving us with 161 observations. Panel A of Table 4 show how this changes the empirical and theoretical moments. (Note that we now only compute theoretical moments based on 161 sectors.) Dropping outliers reduces mean increases in trade flows and productivity and, in particular, the variance of trade flow increases. Still, the model is only able to match a fraction of the variation observed in the data, and does again particularly poorly with regards to productivity. In Panel B, we only drop the 5% of sectors with the highest trade and productivity growth (21 sectors, leaving 182 observations). This does of course work in favor of the model, but its predictive performance remains poor.

Another concern with our results so far is that we might be too demanding of our model, in the sense that it intentionally abstracts from a number of factors present in the data. Thus, we should not be surprised by a poor predictive performance. In Table 5, we undertake two additional robustness checks trying to address this concern. First, we take first differences in growth rates between the post- and pre-liberalization period (1980-1988 and 1988-1996, respectively). We do this for both the actual observed data, and for the data generated by our model. For the latter, we calculate predictions for the pre-liberalization period in the same way as described above, but using initial trade flows for 1980 and observed tariff cuts between 1980 and 1988. (The remaining parameters, a_γ and σ, are assumed to stay constant over time.) The purpose of this exercise is to eliminate time-invariant factors from the data which are absent from our model, such as technological progress leading to ongoing productivity growth.

Secondly, we implement a difference-in-differences strategy similar to Trefler (2004). We regress first differences of trade and productivity growth (as calculated above) on first differences in tariff cuts, and compute predicted values from these two regressions. We then use the model to generate data for both the pre-and post-liberalization period and run the same regressions on the generated data. We again compute predicted values and compare them to the predicted values from the regressions on the actual data.[22] The purpose of this approach is to only use variation which is explained by tariff cuts. Since this is the driving factor in the model's data generating process, we would expect the model to perform much better when focusing on this source of variation only.

Table 5 presents results for first differences, Table 6 for the difference-in-differences approach. First-differencing the data reduces the magnitude of all moments with the exception of the variance of (first-differenced) productivity growth rates. However, the first-differenced theoretical moments are also smaller, leaving the overall percentage difference to the empirical moment basically unchanged. This is true when we use externally estimated data (row 2) and when we choose parameters to match the empirical moments (rows 3-4). The lack of improvement is also reflected in the GMM objective function value which is basically unchanged compared to the baseline results in Table 2.

The difference-in-differences approach fares slightly better. We now get much closer to observed trade flow changes even when using externally estimated parameters (we match 75% of the mean increase and 50% of the variance). We also do better for mean productivity increases (we match 30% of the observed increase). However, we are still an order of magnitude below the actual variance of productivity increases and the covariance between trade and productivity increases. The better ability of the model in matching the 'cleaned' data is also reflected in a lower GMM objective function value, although we still reject the null that the moment restrictions implied by our model are valid at the 1% level.

In the next robustness check, we modify the computation of our theoretical moments in a way that leads to larger productivity gains. So far, we have valued firm revenue at destination-specific rather than factory gate prices. We now follow Statistics Canada's procedures yet more closely and compute both revenue and trade growth at factory-gate prices, i.e., excluding trade costs.[23] This leads to the following expressions for measured

[22] To be precise, we use the model's theoretical predictions to run exactly the same regressions, and compare the predicted values from the regressions based on these theoretical predictions with those based on actual data.

[23] Strictly speaking, exports in our data are valued at free-on-board prices which exclude charges for shipping services incured abroad, but might include other parts of the overall trade costs such as information or regulatory compliance costs (see Burstein and Cravino, 2012). In our case, we are interested in the implications of changes in tariffs, which are part of the costs not taken into account in f.o.b. prices. Thus, the relevant change in f.o.b. and ex-factory gate prices is identical.

trade and productivity growth:

$$MPG_{ih}^{FG} = \frac{\hat{R}_{ih}^{m}/\hat{L}_{ih}}{\widehat{PPI}_{ih}} = \left(\widehat{PPI}_{ih}\right)^{-1} \left(\sum_{j} \frac{X_{ihj}/\tau_{ihj}}{\sum_{j} X_{ihj}/\tau_{ihj}} \frac{\hat{X}_{ihj}}{\hat{\tau}_{ihj}}\right) \left(\sum_{j} \frac{X_{ihj}}{\sum_{j} X_{ihj}} \hat{X}_{ihj}\right)^{-1}$$

$$MTG_{ihj}^{FG} = \frac{\hat{X}_{ihj}^{m}}{\widehat{PPI}_{ih}} \frac{X_{ihj}^{m}}{X_{ihj}^{m} + X_{ijh}^{m}} + \frac{\hat{X}_{ijh}^{m}}{\widehat{PPI}_{ij}} \frac{X_{ijh}^{m}}{X_{ihj}^{m} + X_{ijh}^{m}}.$$

where $\hat{R}_{ih}^{m}$ denotes measured revenue growth which is now different from $\hat{R}_{ih}$ as it is valued at factory gate prices. Likewise, we have $\hat{X}_{ihj}^{m} = (\hat{\tau}_{ihj})^{-1} \hat{X}_{ihj}$ and $X_{ijh}^{m} = (\tau_{ijh})^{-1} X_{ijh}$. Note that any reduction in tariffs will now automatically lead to an increase in measured revenue and trade growth in the data.

Table 7 presents results for this alternative measurement approach. Compared to Table 2, the differences are only minor. As expected, we achieve higher productivity growth. But we are still an order of magnitude below the actually observed growth rates. In addition, the new approach also leads to higher trade flow increases which makes it more difficult to simultaneously match both trade and productivity moment. This is evident from the results for the internally optimized parameter values, where we obtain a GMM objective function value very close to the baseline results.

Our final robustness check uses a different modeling of tariffs. So far, we have followed the approach in most of the literature of treating tariffs as being isomorphic to physical transportation costs in our formulation of overall trade costs (see Section 3.1). We now explicitly model tariffs as a payment deducted from the firm' s revenue. This brings about a number of changes to the equilibrium conditions of our model. We briefly outline the most important ones here and refer the reader to Appendix C for a full exposition of the modified model.

Most importantly, the firm's market-specific profit function can now be written as:

$$\pi_{ij} = \frac{p_{ij}}{1+t} q_{ij}\left(p_{ij}\right) - \tau_{ij} q_{ij}\left(p_{ij}\right) \frac{1}{\gamma} - f_{ij}$$

where p_{ij} denotes the price paid by the consumers of the importing country. This modification leads to the following equilibrium conditions for price indices and productivity cut-offs (expressed in changes):

$$\hat{P}_{j} = \left[\sum_{h} \frac{T_{hj} X_{hj}}{\sum_{h} T_{hj} X_{hj}} \left(\hat{T}_{hj}\right)^{1-\frac{\sigma}{\sigma-1} a_{\gamma}}\right]^{-1/a_{\gamma}}. \tag{15}$$

$$\hat{\gamma}_{hj}^{*} = \frac{\left(\hat{T}_{hj}\right)^{\frac{\sigma}{\sigma-1}}}{\hat{P}_{j}}. \tag{16}$$

where $T_{hj} \equiv 1 + t_{hj}$. Similar to before, we can use (15) to solve for price index changes as a function of tariff changes. Using (16) we can then solve for changes in the productivity cut-offs. These are sufficient to calculate changes in trade flows and industry revenues:

$$\begin{aligned}\hat{X}_{hj} &= \hat{N}_{hj} = \left(\hat{\gamma}^*_{hj}\right)^{-a_\gamma}, \\ \hat{R}_h &= \hat{\Pi}_h = \hat{L}_h = \sum_j \frac{X_{hj}}{\sum_j X_{hj}} \hat{X}_{hj}.\end{aligned}$$

Note that for the purpose of our estimation, the key change is that the parameter σ now enters the price index and productivity cut-off equilibrium conditions. Given that we noted before that the impact of variations in σ on the theoretical moments was quantitatively unimportant in our baseline model, this modification should, in principle, allow the model to match the data better. This is because σ now directly enters the productivity cut-offs (and thus nominal trade flow increases), rather than only entering measured trade and productivity growth through the theoretical PPI.

In practice, however, this additional impact channel only leads to minor improvements in the model's predictive performance, as is evident from Table 8. The reason for this is that a_γ and $1/\sigma$ tend to move our moments in the same directions. Thus, the increased impact σ now has is not useful in matching the data. Figure 3 illustrates this by plotting deviations of theoretical from empirical moments against a_γ and σ, as Figure 2 did for our baseline model. We note that the tendency to move theoretical moments in similar ways also explains the reduction in the precision with which the parameter a_γ is now estimated (although σ is now of course estimated with a lower standard error).[24]

5 Model Extensions

We now move on to a number of more major modifications of our basic modeling framework. The goal of this section is to explore which extensions are most promising in terms of improving the baseline model's predictive performance. As all the extensions we consider are well known in the literature, we focus on an exposition of the most important modifications. We also outline how our main equilibrium conditions and our trade and productivity measures change, and explain the economic intuition behind these changes. A detailed exposition of the different models is available in the paper's online appendix.[25]

[24] In an additional robustness check (not reported), we also constructed a PPI deflator by giving equal weight to all active firms, rather than overweighting larger firms (see Appendix A for details). This yielded very similar results to the one in Table 2, with a GMM objective function value of 91.9835 compared to 91.7885 for the baseline model.

[25] Available at: http://privatewww.essex.ac.uk/~hbrein/TheAppendix_20130717.pdf. Also see Redding and Melitz (2013) and Costinot and Rodriguez-Clare (2013) for recent surveys of a number of heterogeneous firm models.

Free Entry

The "free-entry model" is identical to the "baseline model" but for the assumption of a given mass of potential entrants, M_j. We now allow for firms to decide whether to enter the market at the fixed cost F_j (before they pick a draw of γ from its distribution). This adds a free-entry condition to the model which sets expected firm profits equal to the fixed entry cost F_j. As a consequence, we also obtain an additional set of equations when we express the equilibrium conditions in changes:

$$\begin{aligned} 1 &= \sum_j \frac{X_{hj}}{\sum_n X_{hn}} \hat{\tau}_{hj}^{-a_\gamma} \hat{P}_j^{a_\gamma}, \\ \hat{P}_j^{-a_\gamma} &= \sum_h \frac{X_{hj}}{\sum_h X_{hj}} \hat{M}_h \hat{\tau}_{hj}^{-a_\gamma}. \end{aligned}$$

The first equation above is the free-entry condition in growth rates; the second equation is the price index equation in growth rates. In comparison with (6), the growth in the mass of firms $\hat{M}_h$ is now an argument in the determination of price indices. These equations can be solved for $\hat{P}_j$ and $\hat{M}_j$, which in turn can then be used to generate the model's predictions for all other variables of interest.

Adding free entry implies an additional effect of trade liberalization on industry productivity and trade flows, as the mass M_j reacts to changes in tariff barriers, with a decrease if import barriers fall and an increase if export barriers fall. Other things equal, an increase in M_j leads to higher average productivity as low-productivity entrants decide not to produce. Similarly, an increase (decrease) in M_j increases (decreases) the number of exporters and leads, ceteris paribus, to more (less) exports.

Thus, allowing for free entry has an a priori ambiguous effect on trade flows, as well as on theoretical and (through changes in the PPI) measured productivity. Whether we observe an overall increase depends on whether the effect of lower US import tariffs (which raise M_{CAN}) outweighs the effect of lower Canadian import tariffs (which lower M_{CAN}). This ambiguity is reflected in the results in Table 9, where we actually observe a slightly lower increase in average Canadian productivity when using externally estimated parameter values (row 2). Thus, allowing for free entry does not help with improving the model's predictive performance with regards to productivity. We do predict slightly higher trade flow increases, but remain far off our target of 118%.[26]

The fact that allowing for free entry only marginally affects model predictions also explains that the free-entry model is not noticeably better than the baseline model at matching our empirical moments when we can choose parameter values optimally (rows 3-4). Indeed, the GMM objective function value is only slighly lower than the one reported

[26] Note that changes in trade flows are influenced by changes in both M_{US} and M_{Canada} Thus, trade and productivity growth need not move in the same direction as compared to the baseline model.

in Table 2 (83.30 compared to 91.79).

General Equilibrium

In our second model extension, we replace the quasi-linear utility function of the baseline model with a Cobb-Douglas utility function

$$U_j = \prod_{i \in I} (Q_{ji})^{\mu_{ji}} , \tag{17}$$

where $\mu_{ji} > 0$, $\sum_i \mu_{ji} = 1$. We also assume free entry and remove the numéraire sector.[27]

In analytical terms, the most important changes implied by this model are (i) the presence of wages both as unknowns and as a relevant variable in many of the equations that pin down industry outcomes; (ii) the presence of labor market clearing within the equilibrium conditions. For the sake of brevity, we omit a detailed description of the equilibrium conditions in growths rates here. In the Online Appendix we show that we can obtain predictions for all growth rates of interest by manipulating the growth rates of the price index, the free-entry condition and the labor market claring condition.

In this general equilibrium version of our model, the effects of trade liberalization now also operate via changes in the demand for labor and its subsequent effect on wages. A lowering of US import tariffs leads to a higher demand for Canadian exports, which in turn raises Canadian labor demand and (with a fixed labor supply) wages. Ceteris paribus, this increases production costs, dampening the overall increase in Canadian exports but also driving some of the less productive Canadian firms out of the market. A reduction in Canadian import tariffs has the opposite effect through a reduction in domestic demand for Canadian producers. Compared to the baseline model, this lowers wages and production costs, dampening the productivity increasing effect of tougher import competition from the US.

Note that these wage effects operate in addition to the free-entry effects described in the last subsection, but also modify them. For example, a reduction in Canadian wages in response to lower Canadian import tariffs will also dampen the decline in the number of potential entrants (M_j). Thus, Canadian exports will decline by less compared to a situation without a wage response, and productivity will drop by less.

A priori, the expected change in our model predictions is thus again ambiguous compared to both the baseline and the free-entry version of our model. Table 10 shows that trade and productivity growth are indeed very similar to the free-entry version when we use externally estimated parameter values (row 2). The same is true when we choose

[27] Allowing for free entry and Cobb-Douglas preferences while keeping the numéraire sector (that is, fixing all wages to 1) yields results identical to those of our "free entry" model. This is due to the fact that, besides labor income being the same across the two models, the free-entry conditions in both models lead to the same price levels.

parameter values to match our empirical moments. Our key statistic, the GMM objective function value is practically identical to the one for the free entry version. We conclude that allowing for general equilibrium wage effects is quantitatively unimportant in matching the data.

Intermediate Inputs

In the third extension of our model, we assume that the production of manufacturing varieties requires both labor and intermediate inputs:

$$q_{ji}(\gamma) = \gamma \left[\frac{Q_{ji}^{input}(\gamma)}{\alpha} \right]^{\alpha} \left[\frac{l(\gamma)}{1-\alpha} \right]^{1-\alpha},$$

where Q_{ji}^{input} denotes the amount of the aggregate manufacturing good used as an intermediate input, and $\alpha \in [0,1)$.[28]

In this case, the price and expenditure equations in changes can be rewritten as

$$\begin{aligned} \hat{P}_j^{\frac{a_\gamma}{\sigma-1}} &= \left(\hat{E}_j\right)^{\frac{\sigma-a_\gamma-1}{(1-\sigma)^2}} \left[\sum_h \frac{X_{hj}}{\sum_m X_{mj}} \hat{\tau}_{hj}^{-a_\gamma} \frac{1}{\hat{P}_h^{\alpha a_\gamma}} \right]^{\frac{1}{1-\sigma}}, \\ \hat{E}_j &= \frac{1}{E_j} \left[m_j + P_j Q_j^{input} \hat{P}_j^{-a_\gamma \alpha} \left(\sum_h \frac{X_{jh}}{\sum_h X_{jh}} \hat{\tau}_{jh}^{-a_\gamma} \hat{P}_h^{a_\gamma} \hat{E}_h^{\frac{a_\gamma}{\sigma-1}} \right) \right]. \end{aligned} \tag{18}$$

This yields a system of non-linear equations in $\hat{P}_j$ and $\hat{E}_j$. Once we solve for $\hat{P}$ and $\hat{E}$, we can solve for the growth rates of the variables of interest. The expression for expenditure is more elaborate now because it now also encompasses purchases of intermediates (i.e., $E_j = m_j + P_j Q_j^{input}$).

Labor productivity is now value added per worker

$$\frac{VA_j}{L_j} = \frac{R_j - P_j Q_j^v}{L_j},$$

and its measured growth rate is

$$MPG_{ih}^{int} = \frac{\widehat{VA_{ih}/L_{ih}}}{\widehat{PPI}_{ih}} = \left(\hat{P}_j\right)^{-\alpha} \left(\tilde{\gamma}_h'/\tilde{\gamma}_h\right) \tag{19}$$

A comparison with expressions (8) and (12) reveals that allowing for intermediate inputs adds $\left(\hat{P}_j\right)^{-\alpha}$ as an additional source of measured productivity growth. Intuitively, the availability of cheaper (imported) intermediate inputs leads to a stronger decrease in

[28] For simplicity we abstract from interindustry input-output linkages. Note that in order to isolate the effect of allowing for intermediates, we have also switched back to the no free-entry, no general equilibrium case.

the domestic PPI for a given change in the productivity of the 'average' firm ($\tilde{\gamma}'_h/\tilde{\gamma}_h$), and thus to stronger increases in measured productivity. Note, however, that increases in $\tilde{\gamma}'_h/\tilde{\gamma}_h$ will tend to be lower than in the baseline model. This is because lower input costs mean that some of the less productive firms can stay in the market, ceteris paribus.

Table 10 shows that the overall impact on productivity is positive. When we use externally estimated parameter values (row 2), we more than double predicted productivity growth as compared to the baseline model. However, a large gap between predicted and actual productivity gains remains (2.95% vs. 30.41%). The results also reveal that allowing for intermediates increases predicted trade flows as intermediates make up a growing proportion of international trade. (See also Caliendo and Parro (2012).) Thus, while the presence of intermediate inputs allows us to obtain larger productivity increases, it also leads to stronger trade growth. This again makes it difficult for the model to simultaneously match trade and productivity growth and explains why our GMM approach is still unsuccessful in matching the empirical moments (rows 3 and 4). While the GMM objective function is 50% lower than in the baseline model, the overidentification test still rejects at the 1%-level.[29]

Multi-product Firms

The final extension we consider is to introduce multi-product firm features as modeled in Bernard, Redding and Schott (2011) into the baseline model.[30] As in Bernard, Redding and Schott (2011), we introduce an additional layer into our utility function by modeling final goods (Q_i) as a continuum of products which are imperfect substitutes in demand. Within each product, firms supply horizontally differentiated varieties. While firms produce one variety of each product, they can supply a range of products. In addition to productivity (γ), firms now also draw 'product attributes' (λ) for the continuum of products which act as demand shifters. We assume that λ is Pareto distributed with location parameter k_λ and shape parameter a_λ. Firms observe their γ and λ and decide whether to pay the additional fixed costs associated with entering different markets and products. As we explain in the Online Appendix, the derivation of our equilibrium conditions and productivity measures is similar to the baseline model. The main difference is that they now contain a third parameter (a_λ) which governs productivity and trade growth rates in addition to a_γ and χ.[31]

Intuitively, the "multi-product model" reinforces the between-firm reallocation effect

[29] Note that the model with intermediates has one additional parameter (α), so that we lose one degree of freedom as compared to the baseline model. This is taken into account in the reported p-value which in any case is substantially below the 1% level.

[30] Apart from the multi-product firm features described below, we thus switch back to the assumptions of the benchmark model. That is, we assume a given mass M_j, impose $\alpha = 0$ for all sectors, and assume quasilinear preferences and the presence of a numéraire good.

[31] χ governs the substitutability of product varieties and is the equivalent of σ in our baseline model in terms of its role in the estimation procedure.

on productivity with a within-firm reallocation effect as a response to trade liberalization. Firms reallocate resources from product-varieties with (now loss-making) low attributes to product-varieties with (more profitable) high attributes, thus leading to higher firm-level productivity. As we show in the Online Appendix, this leads to a stronger decrease in the industry PPI and thus a more pronounced increase in industry productivity. At the same time, the additional within-firm productivity effect also reduces the increase in imports as domestic firms become more productive relative to foreign exporters.

As seen in Table 12, this combination of effects makes the multi-product firm model quite successful in matching the observed data. We are now able to simultaneously match productivity and trade flow increases by choosing the appropriate model parameters.[32] Indeed, our overidentification test is now unable to reject the model at conventional levels of statistical significance. We see this as an indication that sources of within-firm productivity increases need to be added to our baseline model in order to solve the problem of simultaneously matching trade and productivity growth rates in the wake of CUS-FTA. While we have used the multi-product firm model of Bernard, Redding and Schott (2011) to achieve these within-firm productivity gains, our conjecture is that other modeling frameworks will yield similar results. For example, within-firm productivity gains could also be achieved through technological upgrading in response to trade liberalization (see Bustos (2011)).

One concern with the multiproduct extension is that we have now one more parameter at our disposition. This will make it easier to match our empirical moments within a given sample, but might not necessarily lead to the best out-of-sample predictions (this is the classic 'overfitting' problem).

In order to evaluate whether this is an issue in the present context, we also perform the following out-of-sample test of our baseline model and the four extensions discussed above. We first estimate the model parameters on the pre-liberalization period (1980-1988). We then use these estimates to obtain trade and productivity growth predictions for the post-liberalization period (1988-1996) and recompute the GMM objective function with these new predictions.[33] If overfitting were a problem, we would expect a higher value for the multiproduct firm model than for the other extensions. Table 13 shows that this is not the case - the multiproduct firm model continues to outperform all other extensions.

[32]Note that we do not have estimates for our parameters obtained from external sources. This would require firm-level data similar to the data available to Bernard, Redding and Schott (2011). Unfortunately, we do not have access to such data for Canada or the US.

[33]To ensure comparability, we use the same weighting matrix as in the original (post-liberalization) GMM estimation.

6 Conclusions

In this paper, we examined the quantitative predictions of heterogeneous firm models à la Melitz (2003) in the context of the Canada - US Free Trade Agreement (CUSFTA) of 1989. We computed predicted increases in trade flows and measured productivity across a range of standard models and compared them to the post-CUSFTA increases observed in the data.

Starting from a version of Chaney (2008), we found that this model was not able to simultaneously match both trade and productivity increases. This was true when we used sectoral parameter estimates obtained from other data sources, or when we chose parameters to minimize deviations between theoretical and empirical moments via a simple GMM procedure. Our basic result also seem robust to different ways of computing predicted productivity and trade growth, and to comparing model predictions and data in ways which eliminate a number of unmodeled determinants of trade and productivity increases. In each case, the fundamental problem remained that predicted increases in trade flows for a given change in tariffs are much too large relative to the predicted increase in measured productivity.

We also considered different extensions of our basic framework by allowing for free entry, tradable intermediate inputs, general equilibrium effects operating through wages, and endogenous firm-level productivity through adjustments in product scope as in Bernard, Redding and Schott (2011). Free entry and general equilibrium effects did not markedly improve the model's performance. Introducing tradable intermediates helped somewhat, but formal over-identification tests in our GMM framework still rejected this model variant. The only model that is capable of providing a good fit to the data and of passing our over-identification tests was the multiproduct firm extension. We interpret these results as evidence for the need to explicitly model within-firm productivity increases when constructing quantitative trade models capable of explaining first-order features of trade liberalization episodes.

References

[1] Alvarez, F. and R. Lucas (2007), "General equilibrium analysis of the Eaton–Kortum model of international trade," *Journal of Monetary Economics*, 54, 1726–1768.

[2] Arkolakis, C., Costinot, A. and A. Rodríguez-Clare (2012), "New Trade Models, Same Old Gains?," *American Economic Review*, 102(1), 94–130.

[3] Armenter, R. and M. Koren (2009), "Economies of Scale and the Size of Exporters," manuscript, C.E.U.

[4] Balistreri, E., Hillberry, R. and T. Rutherford (2011), "Structural estimation and solution of international trade models with heterogeneous firms," *Journal of International Economics*, 83, 95–108.

[5] Bernard, A.B., J. Eaton, J.B. Jensen, and S. Kortum (2003): "Plants and Productivity in International Trade," *American Economic Review*, 93(4), pp. 1268-1290.

[6] Bernard, A., Redding, S. and P. Schott (2011), "Multiproduct Firms and Trade Liberalization," *Quarterly Journal of Economics*, 126(3), 1271-1318.

[7] Breinlich, H. (2008): "Trade Liberalization and Industrial Restructuring through Mergers and Acquisitions," *Journal of International Economics*, December 2008.

[8] Broda, C. and D.E. Weinstein (2006): "Globalization and the Gains from Variety," *Quarterly Journal of Economics*, 121(2), 541-585.

[9] Burstein, A. and J. Cravino (2012), "Measured Aggregate Gains from International Trade," NBER Working Paper 17767.

[10] Bustos, P (2011), "Trade Liberalization, Exports, and Technology Upgrading: Evidence on the Impact of MERCOSUR on Argentinian Firms," *American Economic Review*, 101(1), 304–340.

[11] Caliendo, L. and F. Parro (2012), "Estimates of the Trade and Welfare Effects of NAFTA," NBER Working Paper 18508.

[12] Chaney, T. (2008): "Distorted Gravity: The Intensive and Extensive Margins of International Trade," *American Economic Review*, Vol. 98, No. 4, September.

[13] Corcos, G., del Gatto, M., G. Mion, and G.I. Ottaviano (201): "Productivity and firm selection: quantifying the "new" gains from trade," *The Economic Journal*, Vol. 122 (561), pp 754-798

[14] Costinot, A. and A. Rodríguez-Clare (2013), "Trade Theory with Numbers: Quantifying the Consequences of Globalization," forthcoming, Handbook of International Economics, Vol. 4, eds. Gopinah, Helpman and Rogoff.

[15] Dekle, R., Eaton, J. and S. Kortum (2008), "Global Rebalancing with Gravity: Measuring the Burden of Adjustment", NBER Working Paper 13846.

[16] Eaton, J. and S. Kortum (2002): "Technology, Geography, and Trade," *Econometrica*, Vol. 70, September, pp. 1741-1779.

[17] Eaton, J., S. Kortum and F. Kramarz (2011): "An Anatomy of International Trade: Evidence from French Firms," *Econometrica*.

[18] Fieler, A.C. (2011), "Non-homotheticity and bilateral trade: evidence and a quantitative explanation," *Econometrica* 79 (4), 1069–1101.

[19] Frizzell, A., J. Pammett, and A Westell (1989): *The Canadian General Election of 1988*, Carleton University Press, Ottawa, Canada.

[20] Greene, W. (2000), "Econometric Analysis," 4th edition, Prentice Hall International.

[21] Head, K. and J. Ries (1999), "Rationalization Effects of Tariff Reductions," *Journal of International Economics*, Vol. 47, pp. 295-320.

[22] Head, K. and J. Ries (2001), "Increasing Returns Versus National Product Differentiation as an Explanation for the Pattern of US-Canada Trade,", *American Economic Review*, Vol. 91, no. 4, pp. 858-876.

[23] Hsieh, C.-T. and R. Ossa (2011), "A Global View of Productivity Growth in China and India," NBER Working Paper 16778.

[24] Kehoe, T.J. (2005): "An Evaluation of the Performance of Applied General Equilibrium Models of the Impact of NAFTA," in T.J. Kehoe, T.N. Srinivasan, and J. Whalley (eds.): *Frontiers in Applied General Equilibrium Modeling: Essays in Honor of Herbert Scarf*, Cambridge University Press.

[25] Krugman, P.R. (1979): "Increasing Returns, Monopolistic Competition, and International Trade," *Journal of International Economics*, November 9 (4), pp. 469-479.

[26] Krugman, P.R. (1980): "Scale Economies, Product Differentiation, and the Pattern of Trade," *American Economic Review* 70, pp. 950-959.

[27] Levchenko, A. and J. Zhang (2011), "The Evolution of Comparative Advantage: Measurement and Welfare Implications," mimeo University of Michigan."

[28] Melitz, M.J. (2003): "The Impact of Trade on Intra-industry Reallocations and Aggregate Industry Productivity," *Econometrica*, Vol. 71, November, pp. 1695-1725.

[29] Ossa, R. (2012), "Why Trade Matters After All," NBER Working Paper 18113.

[30] Schott, P. (2010), "U.S. Manufacturing Exports and Imports by SIC or NAICS Category and Partner Country, 1972 to 2005," mimeo, Yale University.

[31] Statistics Canada (2001), "A Guide to Deflating the Input-Output Accounts: Sources and Methods," Statistics Canada, catalogue no. 15F0077GIE.

[32] Statistics Canada (2012a), "The Industrial Product Price Index (IPPI)," available at: www.statcan.gc.ca

[33] Statistics Canada (2012b), "Industry Price Indexes," Statistics Canada, Catalogue no. 62-011-X.

[34] Trefler, D. (2004): "The Long and Short of the Canada-U.S. Free Trade Agreement," *American Economic Review*, Vol. 94, September, pp. 870-895.

[35] Wei, S.J. (1996), "Intra-national versus international trade: how stubborn are nations in global integration?," NBER Working Paper 5531.

[36] Redding, S. and M. Melitz (2013), "Heterogeneous Firms and Trade," in: vol. 4 of Handbook of International Economics. Elsevier.

A Appendix A - PPI Deflators

In the following, we describe how Statistics Canada calculates producer price indices (PPIs), which are used to convert current to constant prices entries in our data. We then outline how we apply that procedure to the computation of theoretical moments in our setting.[34]

For our sample period, Statistics Canada computes current price entries for 243 industries of which 211 industries are in the manufacturing sector. For manufacturing, there is also a more disaggregated commodity level, the so-called Principal Commodity Group Aggregation (PCGA), for which prices and shipment values are available. There are 1057 PCGAs in total which serve as the starting point for constructing deflators.

In a first step, Statistics Canada computes PCGA price indices via the following sampling procedure. Each month, Statistics Canada contacts important producers plus a random sample of smaller producers of a given PCGA manufacturing product. For each PCGA, 3 to 15 price quotes are obtained from which an average price is calculated. Price quotes are always based on so-called factory gate prices which exclude any costs associated with transport, distribution, subsidies, taxes or tariffs. The particular weights used in computing the average across price quotes varies from PCGA to PCGA, but generally more weight is given to producers accounting for a larger market share. Yearly average prices are then computed as arithmetic averages over the 12 monthly average prices. The sample of firms used for obtaining price quotes is updated every December. That is, Statistics Canada will draw a new sample of smaller producers from the currently active firms. If any producer goes out of business or drops a product, Statistics Canada chooses a still active producer/product as a replacement. By construction (and by necessity), the sample from which price quotes are obtained is thus based on the set of currently active firms.

In a second step, Statistics Canada combines PCGA price indices into industry level PPIs using current shipment values as weights.[35] The number of PCGAs indices used as inputs varies across industries but is generally low, at around 4-5 PCGAs per industry.

The choice of an appropriate deflator in the computation of our theoretical moments depends on what we consider the most appropriate counterpart in the data to the 'industries' in the model. In the data, an industry at the level of aggregation we are working at comprises on average only 4-5 PCGAs. In contrast, there were around 40,000 establishments in Canadian manufacturing in 1988, or around 200 per industry. This means that each PCGA product will be produced by dozens or even hundreds of producers. Thus, it seems appropriate to associate product varieties in our model with varieties of PCGA products in the data (with each firm producing one variety of a PCGA product). The alternative would be to associate a product variety (firm) in our model with a PCGA product. But this seems implausible given the large number of firms and the small number of PCGAs per industry. It would also sit uneasily with the maintained assumption of monopolistic competition in our model. Finally, note that for the multi-product firm version of our model, it would seem natural to associate products with PCGAs and product varieties with PCGA varieties. This is a crucial difference to Burstein and Cravino (2012) who implicitly associate one product variety (firm) with the US equivalent of PCGAs,

[34] The following is based on Statistics Canada (2001; 2012a; 2012b).

[35] Technically, the PPIs are thus Paasche indices. However, the underlying PCGA price indices are usually of a fixed-weight or base-weight (i.e., Laspeyres) type. So what we get in practice is a mixture of Paasche, Laspeyres and fixed-weight deflators (see Statistics Canada, 2001).

rather than with the underlying price components of each PCGAs.[36] While this might be appropriate in their context (they are concerned with GDP at an economy-wide level), it clearly is not in the present context of disaggregated industry-level data, for the reasons just outlined.

Hence, if we associate model varieties with PCGA product varieties, our theoretical PPI should be calculated following the random sampling procedure outlined above. That is, we calculate an average price in each period based on a set of active domestic producers in the period. As discussed, the way in which individual price quotes are weighted varies by PCGA, but generally gives more weight to producers with larger market shares.

Thus, we compute a theoretical PPI which captures these features while preserving a tight link to theoretical productivity. Specifically, we use the factory gate price charged by the firm with average productivity, $p(\tilde{\gamma}_{ih}) = \frac{\sigma}{\sigma-1}\frac{w}{\tilde{\gamma}_{ih}}$, where

$$\tilde{\gamma}_{ih} = \left[\sum_j \frac{N_{ihj}}{\sum_j N_{ihj}} (\tilde{\gamma}_{ihj})^{\sigma-1}\right]^{\frac{1}{\sigma-1}}$$

and

$$\tilde{\gamma}_{ihj} = \frac{1}{1-G\left(\gamma^*_{hj}\right)}\int_{\gamma^*_{hj}}^{\infty} \gamma^{\sigma-1} g_{ih}(\gamma)\, d\gamma = \left(\frac{a_\gamma}{a_\gamma - \sigma + 1}\right)^{\frac{1}{\sigma-1}} \gamma^*_{hj}.$$

As noted by Melitz (2003), $\tilde{\gamma}_{ihj}$ can be interpreted as a weighted average of firm productivities, where the weights reflect the relative output shares of firms. Also note that $\tilde{\gamma}_{ihj}$ is calculated as an average across active firms, reflecting the sampling procedure of Statistics Canada. Thus,

$$p'/p = \frac{p(\tilde{\gamma}_h)}{p(\tilde{\gamma}'_h)} = \frac{\tilde{\gamma}'_h}{\tilde{\gamma}_h},$$

where

$$\frac{\tilde{\gamma}'_h}{\tilde{\gamma}_h} = \left[\left(\sum_j \left(\frac{N'_{hj}}{N_{hj}}\frac{N_{hj}}{\sum_{j'} N_{hj'}}\right)\right)^{-1} \sum_j \left[\frac{N'_{hj}}{N_{hj}}\left(\frac{\tilde{\gamma}'_{hj}}{\tilde{\gamma}_{hj}}\right)^{\sigma-1} \frac{N_{hj}\left(\tilde{\gamma}_{hj}\right)^{\sigma-1}}{\sum_{j'} N_{hj'}\left(\tilde{\gamma}_{hj'}\right)^{\sigma-1}}\right]\right]^{\frac{1}{\sigma-1}}.$$

We do not have data for N_{hj}, but under the assumption that entry costs are proportional to some observable destination-specific factor that is exogenous to the model (such as m_j in our baseline model):

$$\frac{N_{hj}}{\sum_j N_{hj}} = \frac{X_{hj}/\left(\frac{a_\gamma\sigma}{a_\gamma-\sigma+1}\right)F_{hj}}{\sum_j X_{hj}/\left(\frac{a_\gamma\sigma}{a_\gamma-\sigma+1}\right)F_{hj}} = \frac{X_{hj}/m_j}{\sum_j X_{hj}/m_j}.$$

From (3) and $N_{hj} = \left(k_h/\gamma^*_{hj}\right)^{a_\gamma} M_h$,

$$\tilde{\gamma}_{hj} = \left(\frac{a_\gamma}{a_\gamma - \sigma + 1}\right)^{\frac{1}{\sigma-1}} \gamma^*_{hj} = \left(\frac{a_\gamma}{a_\gamma - \sigma + 1}\right)^{\frac{1}{\sigma-1}} k_h (M_h)^{\frac{1}{a_\gamma}} N_{hj}^{-\frac{1}{a_\gamma}}.$$

[36] See Section 4 of Burstein and Cravino (2012), in particular.

We can approximate

$$\frac{N_{hj}\left(\tilde{\gamma}_{hj}\right)^{\sigma-1}}{\sum_{j'} N_{hj'}\left(\tilde{\gamma}_{hj'}\right)^{\sigma-1}} = \frac{\left(X_{hj}/m_j\right)^{\frac{1-\sigma+a_\gamma}{a_\gamma}}}{\sum_{j'}\left(X_{hj'}/m_{j'}\right)^{\frac{1-\sigma+a_\gamma}{a_\gamma}}}.$$

In an (unreported) robustness check, we also experimented with giving equal weight to the prices charged by active firms. This yielded a PPI of:[37]

$$p_h^m = \frac{1}{1-G\left(\gamma_{hh}^*\right)}\int_{\gamma_{hh}^*}^{\infty} p_h\left(\gamma\right) dG\left(\gamma\right) = \frac{\sigma}{\sigma-1}\left(\frac{k_\gamma}{\gamma_{hh}^*}\right)^{-a_\gamma}\int_{\gamma_{hh}^*}^{\infty}\gamma^{-1} dG\left(\gamma\right) = \frac{\sigma}{\sigma-1}\frac{a_\gamma}{a_\gamma+1}\left(\gamma_{hh}^*\right)^{-1},$$

with growth rate

$$\hat{p}_h^m = \left(\hat{\gamma}_{hh}^*\right)^{-1}.$$

In practice, this alternative approach to constructing the PPI yielded very similar results to the ones in Table 2, with a GMM objective function value of 91.9835 compared to 91.7885 for the baseline model.

B Appendix B: Estimation Procedure for a_γ and σ

This appendix describes how we obtain estimates for the elasticity of substitution (σ) and the shape parameter of the Pareto distribution of productivities (a_γ) from data sources not used in the model calibration.

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

Obtaining of σ from Firm-level Data In our baseline model, operating profits (that is, profits net of fixed costs) are

$$\pi^o\left(\gamma\right) = \frac{r(\gamma)}{\sigma}. \tag{20}$$

We use data on operating profits (π^o) and revenue (r) for US and Canadian firms from Compustat North America and Compustat Global. We proxy π^o as operating income before depreciation and r as net sales.[38] From (20) we can obtain estimates of σ for each firm in our data. Industry-specific estimates of σ are calculated as the median across all firms within each of our 203 manufacturing industries.

[37] We are assuming here that (*i*) the prices used to compute this average price index are also measured at factory gates, and (*ii*) all firms are sampled with the same probability (hence the lower limit γ_{hh}^* in the integral sign and the lack of firm-specific weights on individual firm-specific prices).

[38] Information on these variables is contained in Compustat North America data items 12 (net sales) and 13 and 189 (operating income before depreciation and administrative expenses; note that we do not include the latter in the computation of costs). For Compustat Global, net sales are contained in data item 1 and operating profits are calculated as operating income plus depreciation plus administrative expenses (data items 14 plus 11 plus 189).

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

$$R_{r_x} = \int_{r_x}^{\infty} rv(r)dr = \frac{a_r k_r^{a_r}}{a_r - 1} (r_x)^{1-a_r}. \tag{21}$$

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: $\frac{r_x}{r_y} = \left(\frac{n_{r_y}}{n_{r_x}}\right)^{1/a_r}$. We do not have data on r_x, but we know the sales volume R_{r_x} defined above (total shipments times the appropriate concentration ratio):

$$\left(\frac{R_{r_x}}{R_{r_y}}\right)^{1/(1-a_r)} = \left(\frac{n_{r_y}}{n_{r_x}}\right)^{1/a_r}. \tag{22}$$

Solving for a_r,

$$a_r = \frac{\left(\ln n_{r_y} - \ln n_{r_x}\right)}{\left(\ln R_{r_x} - \ln R_{r_y}\right) + \left(\ln n_{r_y} - \ln n_{r_x}\right)}. \tag{23}$$

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.

We use information from Statistics Canada on the output share accounted for by the top 4 and 8 enterprises in each Canadian manufacturing industry in our data. Multiplying these shares with total industry output (R_d) we obtain the total output of the top 4 and top 8 enterprises which we use as proxies for R_{r_x}. Note that using comparable data for the US yields qualitatively similar results to the ones reported in Table 2. (Recall that we are imposing a common shape parameter across countries, so that either of these two data sources can be used.)

C Appendix C - Alternative Modeling of Tariffs

Our assumptions about preferences, technology, market power, labor markets and entry are the same as in our baseline model (see Section 3). As before, we also assume that homogeneous good is traded freely; supplying it to any market and entering the market involves no costs. The final goods Q are still not traded and supplying them or entering the (domestic) market involves no costs either. A manufacturing industry-i firm based in country h faces the same fixed cost F_{hj} of supplying country j as in the baseline model.

The key difference to the baseline model is that we now assume that for the varieties produced by the manufacturing industries, iceberg trade costs take the form $\tau_{hj} = (1 + c_{hj})$ for $j \neq h$ and $\tau_{jj} = 1$. As before, h and j denote the exporting and importing country, respectively and $c_{hj} > 0$ denotes "natural" transport costs. Note that iceberg trade costs now exclude policy-induced trade barriers. We model be separately in the form of ad-valorem tariffs $t_{hj} > 0$ (with $T_{hj} \equiv 1 + t_{hj}$).

This changes the firm's profit maximisation problem to problem to

$$\max \pi_{ij} = \frac{p_{ij}}{1+t_{ij}} q_{ij}(p_{ij}) - \tau_{ij} q_{ij}(p_{ij}) \frac{1}{\gamma} - f_{ij} = \frac{1}{1+t_{ij}} p_{ij}^{1-\sigma} P_j^{\sigma-1} E_j - \tau_{ij} p_{ij}^{-\sigma} P_j^{\sigma-1} E_j \frac{1}{\gamma} - F_{ij},$$

where p_{ij} denotes the price paid by the consumers of the importing country. The first order condition yields

$$p_{ij} = \frac{\sigma}{\sigma - 1} \tau_{ij} T_{ij} \frac{1}{\gamma}. \tag{24}$$

The resulting expression for the threshold value of productivity γ^*_{hj} that leads country-h firms to select into market j is:

$$\gamma^*_{hj} = \frac{\sigma}{\sigma - 1} \frac{\tau_{hj}}{P_j} \left(\frac{\sigma F_{hj}}{m_j} \right)^{\frac{1}{\sigma - 1}} T_{ij}^{\frac{\sigma}{\sigma - 1}}. \tag{25}$$

The average productivity of country-h firms exporting to market j, defined as in Melitz (2003), can be expressed as

$$\tilde{\gamma}_{hj} = \left(\frac{a_\gamma}{a_\gamma - \sigma + 1} \right)^{\frac{1}{\sigma - 1}} \gamma^*_{hj}.$$

The expected revenue and expected profit that a country-h firm obtains in country j, conditional upon selecting into that market, are respectively

$$\begin{aligned} E\left[r_{hj}(\gamma) \middle| \gamma > \gamma^*_{hj} \right] &= r_{hj}\left(\tilde{\gamma}_{hj}\right) = \frac{a_\gamma T_{hj}^{-\sigma}}{a_\gamma - \sigma + 1} \left(\frac{\sigma}{\sigma - 1} \tau_{hj} \frac{1}{P_j \gamma^*_{hj}} \right)^{1-\sigma} E_j = \frac{a_\gamma \sigma}{a_\gamma - \sigma + 1} F_{hj}, \\ E\left[\pi_{hj}(\gamma) \middle| \gamma > \gamma^*_{hj} \right] &= \frac{r_{hj}\left(\tilde{\gamma}_{hj}\right)}{\sigma} - F_{hj} = \frac{\sigma - 1}{a_\gamma - \sigma + 1} F_{hj}. \end{aligned}$$

Country-h exports to country j can be expressed as

$$X_{hj} = N_{hj} r_{hj}\left(\tilde{\gamma}_{hj}\right) = N_{hj} \frac{a_\gamma \sigma}{a_\gamma - \sigma + 1} F_{hj}.$$

The industry's aggregate sales are then

$$R_h = \sum_j X_{hj} = \sum_j N_{hj} \frac{a_\gamma \sigma}{a_\gamma - \sigma + 1} F_{hj}.$$

The mass of country-h firms that select into market j is given by

$$N_{hj} = \left(\frac{k_h}{\gamma^*_{hj}} \right)^{a_\gamma} M_h.$$

Expected profits, aggregated across all destination markets, are

$$\Pi_h = \sum_j prob\left(\gamma > \gamma^*_{hj}\right) E\left[\pi_{hj}(\gamma) \middle| \gamma > \gamma^*_{hj} \right] = \sum_j \left(\frac{k_h}{\gamma^*_{hj}} \right)^{a_\gamma} \frac{\sigma - 1}{a_\gamma - \sigma + 1} F_{hj}.$$

Industry profits are therefore

$$M_h \Pi_h = M_h \sum_j \left(\frac{k_h}{\gamma^*_{hj}} \right)^{a_\gamma} \frac{\sigma - 1}{a_\gamma - \sigma + 1} F_{hj} = \frac{\sigma - 1}{a_\gamma \sigma} \sum_j X_{hj}.$$

Industry employment can be easily shown to be

$$L_h = M_h E\left[l_{hj}(\gamma)\right] = M_h \sum_j \left(\frac{k_h}{\gamma_{hj}^*}\right)^{a_\gamma} E\left[l_{hj}(\gamma) \middle| \gamma > \gamma_{hj}^*\right] = a_\gamma M_h \Pi_h.$$

and the price level P_j is given by

$$P_j = \left[\frac{a_\gamma}{a_\gamma - \sigma + 1} \sum_h N_{hj} \left(\frac{\sigma}{\sigma - 1} \frac{\tau_{hj} T_{hj}}{\gamma_{hj}^*}\right)^{1-\sigma}\right]^{\frac{1}{1-\sigma}}.$$

The expressions for industry level of growth rates are unchanged except for the price index equation:

$$\hat{P}_j = \left[\sum_h \frac{T_{hj} X_{hj}}{\sum_h T_{hj} X_{hj}} \hat{N}_{hj} \left(\hat{T}_{hj}\right)^{1-\sigma} \left(\hat{\gamma}_{hj}^*\right)^{\sigma-1}\right]^{\frac{1}{1-\sigma}}.$$

It is easy to show that

$$\hat{P}_j = \left[\sum_h \frac{T_{hj} X_{hj}}{\sum_h T_{hj} X_{hj}} \left(\hat{T}_{hj}\right)^{1-\frac{\sigma}{\sigma-1} a_\gamma}\right]^{-1/a_\gamma}. \tag{26}$$

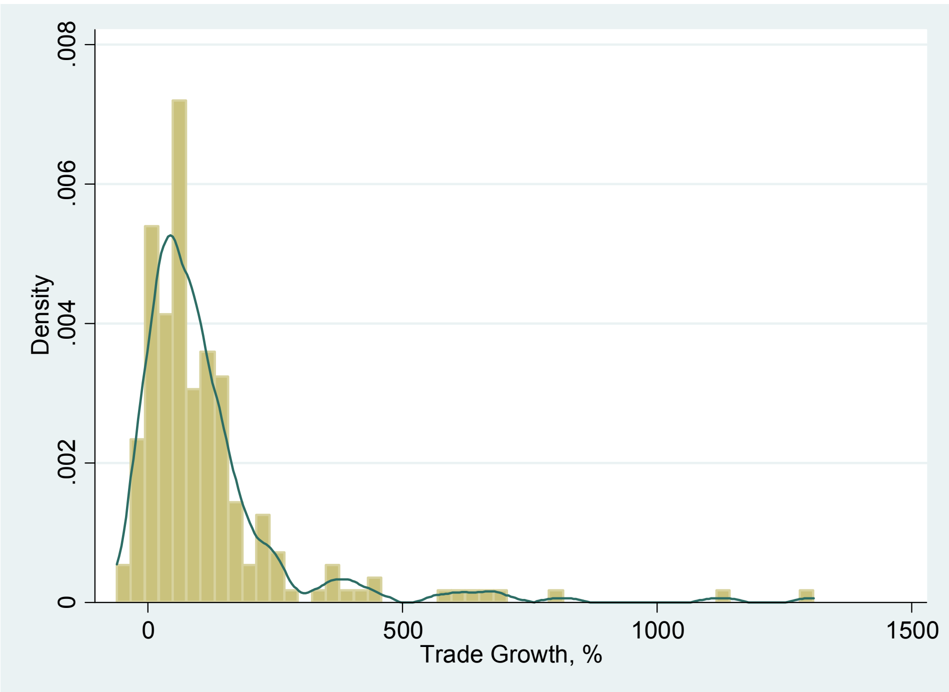
We can use the system (26) to solve for the growth rates of the price levels $\hat{P}_j$ as a function of the changes in tariffs $\hat{T}_{hj}$. From equations (25), we can solve for $\hat{\gamma}_{hj}^*$ as a function of $\hat{P}_j$ and $\hat{T}_{hj}$,

$$\hat{\gamma}_{hj}^* = \frac{\left(\hat{T}_{hj}\right)^{\frac{\sigma}{\sigma-1}}}{\hat{P}_j}.$$

and thereafter generate predictions for the industry aggregates of interest.

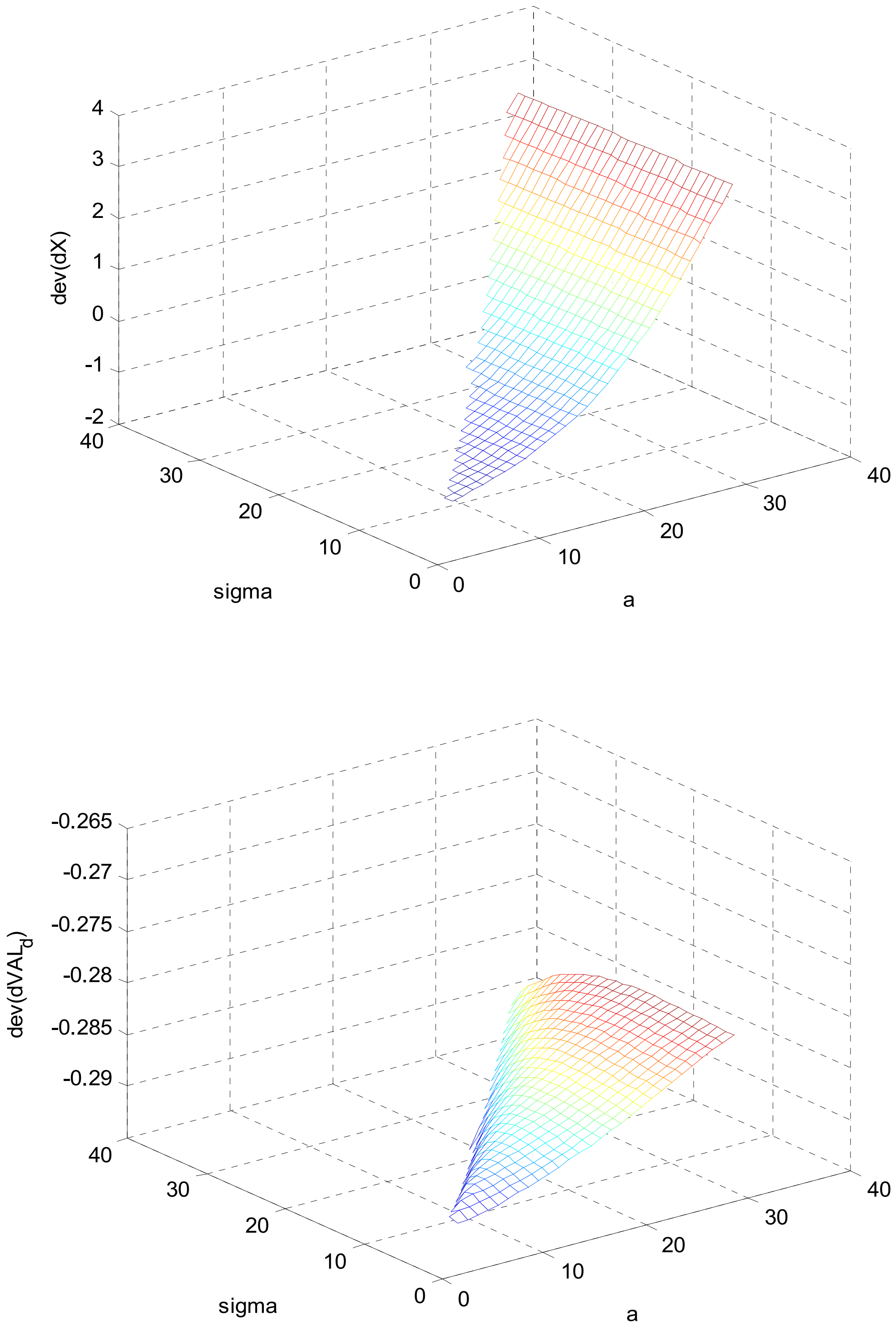
Figures and Table

Figure 1: Increases in Trade Flows and Labor Productivity in Canada, 1988-1996



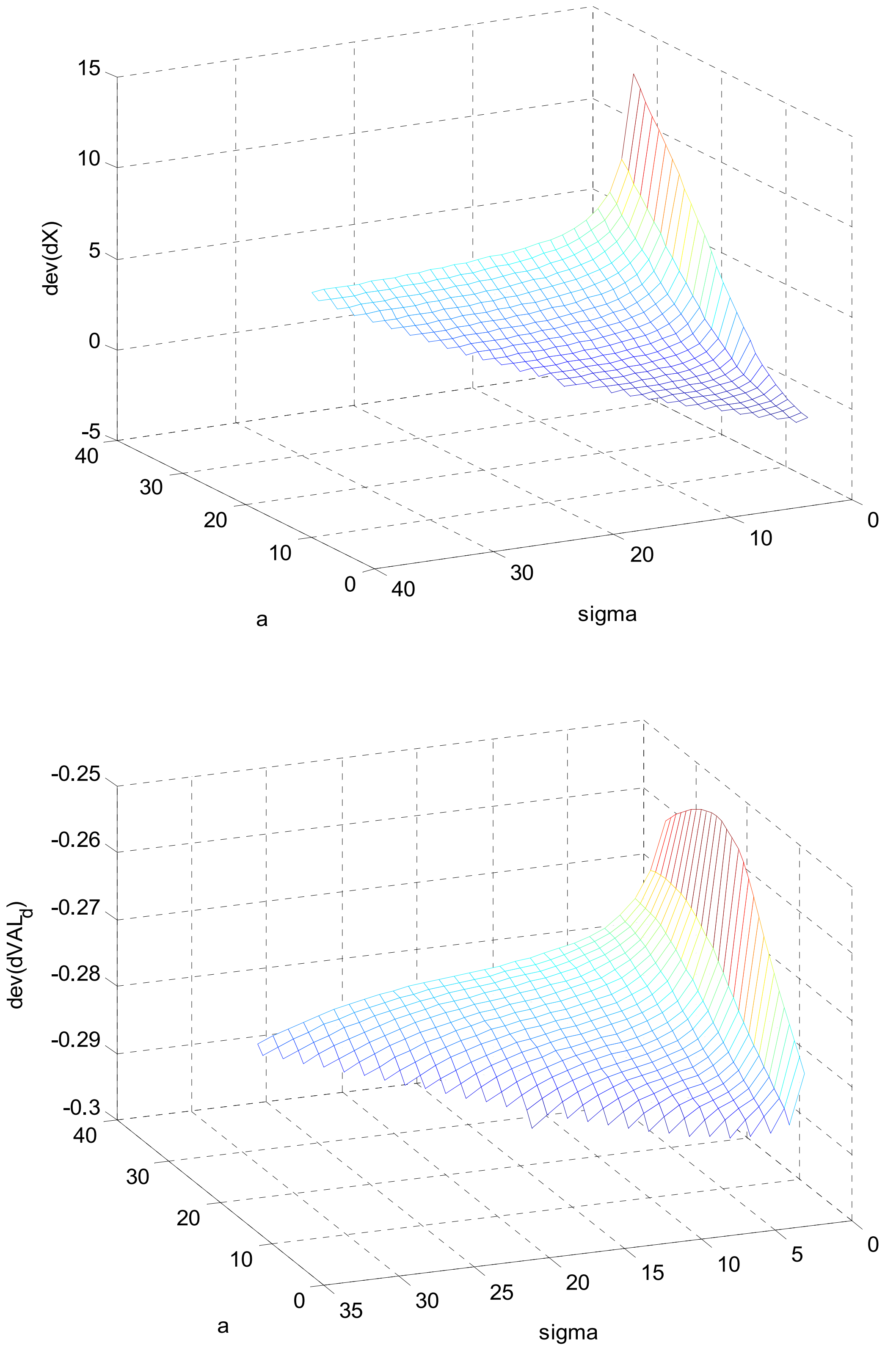
Notes: Figures show trade and labor productivity growth at the sectoral level (203 sectors) in Canadian manufacturing, 1988 to 1996. Trade is measured as Canadian exports plus imports, labor productivity is calculated as value added in production activities divided by total hours worked by production workers (see Appendix X for details). All data are expressed in 1992 Canadian dollars using 4-digit industry price and value added deflators, and the 1992 US-Canadian exchange rate.

Figure 2: Moment Deviations as a Function of a_γ and σ (trade and productivity growth, first moment; baseline model)



Notes: See Section 4 for details.

Figure 3: Moment Deviations as a Function of a_γ and $\boldsymbol{\sigma}$ (trade and productivity growth, first moment; alternative modeling of tariffs)



Notes: See Section 4 for details.

Table 1: Empirical Moments to be Matched

Moment	Mean(dX)	Mean(dVAL)	Cov(dX,dVAL)	Var(dX)	Var(dVAL)
Data	1.1820	0.3041	0.1007	3.0130	0.1153

Notes: Table shows empirical moments to be matched by our theoretical models. dX denotes trade growth and dVAL labor productivity growth (see Figure 1 and Section 4 for details).

Table 2: Results for Baseline Model (Matching Growth Rates 1988-1996)

Moments	**Mean(dX)**	**Mean(dVAL)**	**Cov(dX,dVAL)**	**Var(dX)**	**Var(dVAL)**
(1) Data	1.1820	0.3041	0.1007	3.0130	0.1153
(2) Model – Observed Parameter Values	0.3088	0.0139	0.0007	0.3374	0.0002
(3) Model – Optimized Parameter Values (First Step)	1.1408	0.0177	0.0039	3.0185	0.0002
(4) Model – Optimized Parameter Values (GMM)	1.0538	0.0174	0.0034	2.4004	0.0002
Parameters	**Optimized (value, SE)**	**Data (mean, sd)**			
σ	8.4942	3.4611			
	(121.9231)	(0.8765)			
a_γ	14.2482	5.0951			
	(1.1253)***	(2.6032)			
GMM objective (p-value)	91.7885				
	(0.00000)				

Notes: dX denotes trade growth and dVAL labor productivity growth (see Section 4 for details).

Table 3: Results for Baseline Model (Higher a_γ and **σ**)

Moments	**Mean(dX)**	**Mean(dVAL)**	**Cov(dX,dVAL)**	**Var(dX)**	**Var(dVAL)**
(1) Data	1.1820	0.3041	0.1007	3.0130	0.1153
(2) Model – Observed Parameter Values (σ x1.5)	0.7006	0.0153	0.0041	3.7628	0.0002
(3) Model – Observed Parameter Values (σ x2)	1.3795	0.0169	0.0164	29.4805	0.0002

Notes: dX denotes trade growth and dVAL labor productivity growth (see Section 4 for details).

Table 4: Results for Baseline Model (Drop Outliers)

Panel A: drop top and bottom 5%					
Moments	**Mean(dX)**	**Mean(dVAL)**	**Cov(dX,dVAL)**	**Var(dX)**	**Var(dVAL)**
(1) Data	0.9737	0.2858	0.0372	0.6675	0.0453
(2) Model – Observed Parameter Values	0.2893	0.0153	0.0005	0.1440	0.0002
(3) Model – Optimized Parameter Values (First Step)	0.7626	0.0181	0.0015	0.7445	0.0002
(4) Model – Optimized Parameter Values	0.8085	0.0183	0.0015	0.8770	0.0002
Parameters	**Optimized (value, SE)**	**Data (mean, sd)**			
σ	7.0894	3.5161			
	(72.9391)	(0.9040)			
a_γ	12.5859	5.1936			
	(0.8968)***	(2.5479)			
GMM objective (p-value)	107.378				
	(0.00000)				
Panel B: drop top 5% only					
(5) Data	0.8739	0.2495	0.0542	0.7049	0.0553
(6) Model – Observed Parameter Values	0.2679	0.0143	0.0006	0.1325	0.0002
(7) Model – Optimized Parameter Values (First Step)	0.7365	0.0162	0.0013	0.7526	0.0002
(8) Model – Optimized Parameter Values	0.7606	0.0172	0.0021	0.8324	0.0002
Parameters	**Optimized (value, SE)**	**Data (mean, sd)**			
σ	7.1215	3.5011			
	(80.0526)	(0.8933)			
a_γ	12.6347	5.1776			
	(0.9331)***	(2.5549)			
GMM objective (p-value)	112.996				
	(0.00000)				

Notes: dX denotes trade growth and dVAL labor productivity growth (see Section 4 for details).

Table 5: Results for Baseline Model (First Differences 1980-1988 to 1988-1996)

Moments	**Mean(dX)**	**Mean(dVAL)**	**Cov(dX,dVAL)**	**Var(dX)**	**Var(dVAL)**
(1) Data	0.4621	0.1095	0.0493	0.6642	0.1193
(2) Model – Observed Parameter Values	0.1367	0.0062	0.0011	0.0649	0.0002
(3) Model – Optimized Parameter Values (First Step)	0.5216	0.0112	0.0078	0.6409	0.0004
(4) Model – Optimized Parameter Values (GMM)	0.4772	0.0104	0.0064	0.5376	0.0003
Parameters	**Optimized (value, SE)**	**Data (mean, sd)**			
σ	11.1387	3.4611			
	(488.2403)	(0.8765)			
a_γ	19.9583	5.0951			
	(3.8789)***	(2.6032)			
GMM objective (p-value)	95.5912				
	(0.00000)				

Notes: dX denotes trade growth and dVAL labor productivity growth (see Section 4 for details).

Table 6: Results for Baseline Model (Diff-in-Diff Predicted Values)

Moments	**Mean(dX)**	**Mean(dVAL)**	**Cov(dX,dVAL)**	**Var(dX)**	**Var(dVAL)**
(1) Data	0.1457	0.0104	0.0087	0.0576	0.0044
(2) Model – Observed Parameter Values	0.1072	0.0032	0.0008	0.0292	0.0000
(3) Model – Optimized Parameter Values (First Step)	0.1487	0.0035	0.0013	0.0537	0.0000
(4) Model – Optimized Parameter Values (GMM)	0.1411	0.0017	0.0005	0.0483	0.0000
Parameters	**Optimized (value, SE)**	**Data (mean, sd)**			
σ	8.2290	3.4611			
	(1.9631)***	(0.8765)			
a_γ	7.2313	5.0951			
	(0.0983)***	(2.6032)			
GMM objective (p-value)	42.3101				
	(0.00000)				

Notes: dX denotes trade growth and dVAL labor productivity growth (see Section 4 for details).

Table 7: Results for Baseline Model (Prices at Factory Gate)

Moments	Mean(dX)	Mean(dVAL)	Cov(dX,dVAL)	Var(dX)	Var(dVAL)
(1) Data	1.1820	0.3041	0.1007	3.0130	0.1153
(2) Model – Observed Parameter Values	0.3857	0.0171	0.0005	0.4862	0.0002
(3) Model – Optimized Parameter Values (First Step)	1.1631	0.0198	0.0016	3.0156	0.0003
(4) Model – Optimized Parameter Values (GMM)	1.0653	0.0196	0.0014	2.3443	0.0003
Parameters	**Optimized (value, SE)**	**Data (mean, sd)**			
σ	8.0972	3.4611			
	(127.1901)	(0.8765)			
a_γ	13.2980	5.0951			
	(1.3123)***	(2.6032)			
GMM objective (p-value)	90.6741				
	(0.00000)				

Notes: dX denotes trade growth and dVAL labor productivity growth (see Section 4 for details).

Table 8: Results for Baseline Model (Alternative Modeling Approach to Tariffs)

Moments	Mean(dX)	Mean(dVAL)	Cov(dX,dVAL)	Var(dX)	Var(dVAL)
(1) Data	1.1820	0.3041	0.1007	3.0130	0.1153
(2) Model – Observed Parameter Values	0.5154	0.0191	0.0029	1.3670	0.0003
(3) Model – Optimized Parameter Values (First Step)	1.1584	0.0330	0.0058	3.0195	0.0009
(4) Model – Optimized Parameter Values (GMM)	1.0705	0.0323	0.0050	2.3986	0.0009
Parameters	**Optimized (value, SE)**	**Data (mean, sd)**			
σ	2.0101	3.4611			
	(1.5114)	(0.8765)			
a_γ	7.1208	5.0951			
	(5.3689)	(2.6032)			
GMM objective (p-value)	85.6412				
	(0.00000)				

Notes: dX denotes trade growth and dVAL labor productivity growth (see Section 4 for details).

Table 9: Results for Baseline Model with Free Entry

Moments	Mean(dX)	Mean(dVAL)	Cov(dX,dVAL)	Var(dX)	Var(dVAL)
(1) Data	1.1820	0.3041	0.1007	3.0130	0.1153
(2) Model – Observed Parameter Values	0.3455	0.0076	0.0001	0.3877	0.0001
(3) Model – Optimized Parameter Values (First Step)	1.2533	0.0091	0.0116	3.2869	0.0002
(4) Model – Optimized Parameter Values (GMM)	1.1451	0.0090	0.0089	2.4802	0.0001
Parameters	**Optimized (value, SE)**	**Data (mean, sd)**			
σ	8.3205	3.4611			
	(90.6883)	(0.8765)			
a_γ	13.1861	5.0951			
	(0.8983)	(2.6032)			
GMM objective (p-value)	83.2979 (0.0000)				

Notes: dX denotes trade growth and dVAL labor productivity growth (see Section 5 for details).

Table 10: Results for 'General Equilibrium' Extension

Moments	Mean(dX)	Mean(dVAL)	Cov(dX,dVAL)	Var(dX)	Var(dVAL)
(1) Data	1.1820	0.3041	0.1007	3.0130	0.1153
(2) Model – Observed Parameter Values	0.3533	0.0088	0.0005	0.3863	0.0001
(3) Model – Optimized Parameter Values (First Step)	1.1310	0.0098	0.0147	3.2430	0.0001
(4) Model – Optimized Parameter Values (GMM)	0.9590	0.0119	0.0122	1.9985	0.0002
Parameters	**Optimized (value, SE)**	**Data (mean, sd)**			
σ	7.1959	3.4611			
	(68.4995)	(0.8765)			
a_γ	11.5299	5.0951			
	(0.0796)***	(2.6032)			
GMM objective (p-value)	83.5599 (0.0000)				

Notes: dX denotes trade growth and dVAL labor productivity growth (see Section 5 for details).

Table 11: Results for 'Intermediate Inputs' Extension

Moments	**Mean(dX)**	**Mean(dVAL)**	**Cov(dX,dVAL)**	**Var(dX)**	**Var(dVAL)**
(1) Data	1.1820	0.3041	0.1007	3.0130	0.1153
(2) Model – Observed Parameter Values	0.3541	0.0295	0.0100	0.5171	0.0020
(3) Model – Optimized Parameter Values (First Step)	1.2208	0.0466	0.0245	2.9930	0.0013
(4) Model – Optimized Parameter Values (GMM)	1.4734	0.1526	0.2302	3.8323	0.0436
Parameters	**Optimized (value, SE)**	**Data (mean, sd)**			
σ	12.9001	3.4611			
	(0.0882)***	(0.8765)			
a_γ	11.9623	5.0951			
	(0.0016)***	(2.6032)			
α	0.9875	0.7065			
	(0.0016)***	(0.0918)			
GMM objective (p-value)	44.2633 (0.0000)				

Notes: dX denotes trade growth and dVAL labor productivity growth (see Section 5 for details).

Table 12: Results for Multiproduct-Firm Model

Moments	**Mean(dX)**	**Mean(dVAL)**	**Cov(dX,dVAL)**	**Var(dX)**	**Var(dVAL)**
(1) Data	1.1820	0.3041	0.1007	3.0130	0.1153
(2) Model – Observed Parameter Values	--	--	--	--	--
(3) Model – Optimized Parameter Values (First Step)	1.2392	0.2738	0.1552	3.0034	0.0976
(4) Model – Optimized Parameter Values (GMM)	1.2175	0.2855	0.1549	2.8239	0.1073
Parameters	**Optimized (value, SE)**	**Data (mean, sd)**			
X	1.1276	--			
	(0.0786)***				
a_γ	8.1552	--			
	(1.1506)***				
a_λ	4.9922	--			
	(0.5831)***				
GMM objective (p-value)	3.3434 (0.1879)				

Notes: dX denotes trade growth and dVAL labor productivity growth (see Section 5 for details).

Table 13: Out-of-Sample Predictions

Model	Parameters	Moments	d.o.f.	GMM objective in-sample (p-value)	GMM objective out-of-sample
Baseline	2	5	3	91.7885 (0.0000)	99.2693
Free entry	2	5	3	83.2979 (0.0000)	102.1245
General equilibrium	2	5	3	83.5599 (0.0000)	90.4165
Intermediates	3	5	2	44.2633 (0.0000)	106.2829
Multiproduct	3	5	2	3.3434 (0.1879)	42.7024

Notes: See Section 5 for details.