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Estimates of the Trade and Welfare Effects of NAFTA

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We build into a Ricardian model sectoral linkages, trade in intermediate goods, and sectoral heterogeneity in production to quantify the trade and welfare effects from tariff changes. We also propose a new method to estimate sectoral trade elasticities consistent with any trade model that delivers a multiplicative gravity equation. We apply our model and use our estimated elasticities to identify the impact of NAFTA's tariff reductions. We find that Mexico's welfare increases by 1.31%, U.S.'s welfare increases by 0.08%, and Canada's welfare declines by 0.06%. We find that intra-bloc trade increases by 118% for Mexico, 11% for Canada, and 41% for the U.S. We show that welfare effects from tariff reductions are reduced when the structure of production does not take into account intermediate goods or input–output linkages. Our results highlight the importance of sectoral heterogeneity, intermediate goods, and sectoral linkages for the quantification of the welfare gains from tariffs reductions.

Key words: Trade policy, Gains from trade, Intermediate inputs, Sectoral interrelations, Computational general equilibrium

JEL Codes: F10, F11, F13, F14, F17

1. INTRODUCTION

Sectors and countries are interrelated. When the U.S. reduces tariffs applied to Mexico in a given sector, it not only affects prices in that industry but also in sectors that purchase materials from that industry. Moreover, a tariff reduction affects prices in non-tradable sectors that are using inputs from tradable sectors. Of course, how important are these direct and indirect effects from tariff changes will depend on the extent to which sectors are inter-related. For instance, the larger is the share of tradable goods used in the production of non-tradable goods the larger are the gains for producers of non-tradable goods from a reduction in the price of tradables. Even more, if non-tradable goods are also used as inputs in the production of other goods, or as final goods in consumption, then the benefits spread to the rest of the economy. In fact, most of the final goods consumed are non-tradable goods.[1] However, recent developments in international

1. Non-tradable goods (services) accounted for more than 80% of the total final goods demanded in the year 1993 for the U.S.

trade pay little attention to understanding how the gains from tariff reductions spread across sectors.[2]

In this article, we build into a multi-country, multi-sector Ricardian model the interaction across tradable and non-tradable sectors observed in the input–output (I–O) tables. We use the model to identify the trade and welfare effects of tariff reductions from the North American Free Trade Agreement (NAFTA) between Mexico, Canada, and the U.S. NAFTA provides a unique example to quantify the trade and welfare effects of tariff changes for three main reasons. First, it is among the largest free trade area in the world, both in terms of population and GDP; secondly, it involves countries with very different structures of production, reflected by their GDP per capita and different sectoral specialization of economic activity; and thirdly, it is an archetypal agreement that resulted in the creation of a cross-border production chain, as revealed by the large share of intermediate goods and intra-industry trade across members.[3] These features are the key characteristics from NAFTA that help us understand more broadly the quantitative importance of sectoral heterogeneity, trade in intermediate goods, and sectoral linkages.

Adding more detail into a model comes at the cost of losing track of the mechanisms that deliver the main results. In fact, this complexity has lead to criticism of computational general equilibrium (CGE) models in the past.[4] To address this issue, we build on the seminal work of Eaton and Kortum, (2002) to develop a tractable and simple model for tariff policy evaluation that escapes the black box denigration of traditional CGE models. As a result, we can decompose and quantify the differential role that intermediate goods and sectoral linkages have as amplifiers of the gains from tariff reductions. We also show that regardless of the number of sectors and how complicated the interactions across sectors are, the model can be reduced to a system of one equation per country, and the solution depends on estimates of one set of parameters, the dispersion of productivity across sectors (trade elasticities). Our solution method simplifies considerably the data requirements and estimated parameters needed for the evaluation of tariff changes.

In our theory, production is at constant returns to scale and markets are perfectly competitive. Countries import intermediate goods subject to trade costs from the lowest cost supplier in the world.[5] Intermediate goods in a given sector are used for the production of a sectoral good which is then used as final good for consumption and as material in the production of tradable and non-tradable intermediate goods from all sectors. Productivity differences across individual producers in a sector are introduced in the same way as in Eaton and Kortum, (2002). The larger is the dispersion of productivities across producers, the larger are the gains from trade integration. In our model, productivity, as well as the dispersion of productivity, varies across sectors. This heterogeneity in the dispersion of productivities together with the share of intermediate goods in production and sectoral interrelations are key to capture how a tariff reduction has differential impact across sectors.

2. An exception is the work of Arkolakis *et al*. (2012) where they evaluate the welfare gains from trade openness implied by a variety of international trade models including multi-sector models.

3. In Section 2, we document that sectoral trade in intermediate goods is particularly important for NAFTA members.

4. These models have been criticized for their complexity, lack of transparency and analytical foundations, and the arbitrary choice of the value of key parameters (Baldwin and Venables, 1995 describe them as "black boxes").

5. The importance of trade in intermediate goods has been documented by several studies. For instance, Feenstra and Hanson (1996) find that the share of imported intermediates increased from 5.3% of total U.S. intermediate purchases to 11.6% between 1972 and 1990. Campa and Goldberg (1997) find similar evidence for Canada and the U.K. Hummels *et al*. (2001), and Yeats (2001) show that international trade in intermediate inputs has increased more than that in final goods.

We express the model in relative changes and identify the trade and welfare effects of NAFTA's tariff reductions.[6] Our simulations are performed with few data and parameter requirements. In particular, we only use data on bilateral trade flows, production, tariffs, and an estimate of sectoral trade elasticities. We develop a new method to estimate sectoral trade elasticities. The estimations are performed using trade and tariff data, without assuming bilaterally symmetric trade costs as is standard in the literature. Moreover, the method is consistent with any trade model that delivers a gravity-type trade equation. We estimate the parameters of the model at a sectoral level using data from 1993, the year before NAFTA went into effect. We calibrate a 31 countries 40 sector version of our model. Then, using the estimated parameters and incorporating the change in tariffs from 1993 to 2005, both between NAFTA members and with the rest of the world, we use the model to evaluate the welfare effects and quantify the changes in exports and imports in aggregate and at the sectoral level.

We find that NAFTA's tariffs reductions had a considerable impact on its member's economies, in particular for Mexico. NAFTA augmented aggregate intra-bloc trade by 118% for Mexico, 11% for Canada, and 41% for the U.S. We find that NAFTA increased the sectoral specialization of export activity in Mexico. After NAFTA the most export oriented sector in Mexico (Electrical Machinery) represented one-third of the total export shares, whereas before it was only one-fifth. For the case of Canada and U.S., the result is different; sectoral concentration of export activity was reduced.

We find that not all countries gained from NAFTA. Mexico and the U.S. gained 1.31% and 0.08%, respectively, whereas Canada suffered a welfare loss of 0.06%. Still, real wages increased for all NAFTA members and Mexico had the largest gains. We decompose the welfare effects into terms of trade and volume of trade effects and find that most of the gains from NAFTA are a result of an increase in the volume of trade. We find that the trade created, mostly between NAFTA members, was larger than the trade diverted from other economies. This was particularly so for Mexico and Canada. The welfare gains from trade creation with NAFTA members are 1.80% and 0.08% whereas the welfare loss from trade diversion with the rest of the world are 0.08%, and 0.04% for Mexico and Canada, respectively. Only a handful of sectors were responsible for the aggregate volume of trade effects. These were sectors highly protected before NAFTA, like Textiles in Mexico, with a large trade elasticity, like Petroleum, and with a large share of material use and sectoral interdependence, like Electrical Machinery and Autos.

The terms of trade effects were mixed. We find that Mexico's and Canada's terms of trade deteriorated by 0.41% and 0.11%, respectively, mostly due to reductions in export prices, whereas for the U.S. terms of trade increased by 0.04%; largely attributed to cheaper import prices from Mexico. We also decompose the terms of trade effects by sector and find that terms of trade effects were primarily concentrated in a few sectors. We show that certain sectors had a larger aggregate effect compared to others depending on the magnitude of sectoral reductions in import tariffs, the share of materials used in production, and sectoral linkages.

We also evaluate the welfare effects from observed world tariff changes. We find that all countries in the world gained. The welfare gains for NAFTA members were 1.36%, 0.10%, and

6. We perform a model-based identification of the trade effects due to NAFTA's tariff reductions by holding technology and other trade costs fixed. By doing this, we are not saying that technology or other trade costs might not have changed as a consequence of the change in tariffs. We are agnostic about how they might have changed and focus instead on the direct effect of tariff changes over the allocation of resources. An alternative exercise could have been to quantify the implied changes in technology and other trade costs in order for the model to deliver the observed change in trade flows after NAFTA. But the problem there is how to identify if these changes were due only to NAFTA. Unless a model of TFP or trade costs is written there is no hope for identification. In our case, we take as exogenous the observable change in tariff due to NAFTA to quantify the trade effects.

0.22% for Mexico, Canada, and the U.S. Netting out the effect of NAFTA, these figures show that Canada was the largest winner from world tariff reductions, followed by U.S. and then Mexico.

Finally, we quantify the trade and welfare effects from NAFTA's tariff reductions across different class of models. We find that welfare effects are on average 71% lower in a one-sector model, 62% lower in a model without materials, and 50% lower in a model without sectoral linkages. Trade effects are reduced on average 50%, 26%, and 18%, respectively. These results confirm that sectoral heterogeneity, intermediate inputs, and sectoral linkages are important mechanisms to quantify the trade and welfare effects from tariff changes.

Quantifying potential welfare gains and costs from trade policies has become increasingly important over the years.[7] Our article relates to a large literature that evaluates trade policy and is mostly related to studies that quantify the gains from trade from NAFTA.[8] In particular, Anderson and van Wincoop (2002) who use a one good gravity model to evaluate the gains from NAFTA. Relative to Anderson and van Wincoop (2002) our model has multiple sectors, intermediate goods trade, a production economy, non-tradable sectors, and builds on Ricardian motives of trade instead of love from variety.[9] Our results show that these features are quantitatively important.

Our article is closely related to a recent and growing literature that extends the Eaton and Kortum, (2002) model to multiple-sectors. For instance Arkolakis *et al*. (2012), Caliendo and Parro (2010), Chor (2010), Costinot *et al*. (2012), Donaldson (2012), Dekle *et al*. (2008), Eaton *et al*. (2011), Hsieh and Ossa (2011), and Shikher (2011).[10] Our article differs from these studies in several dimensions. First, we explicitly consider sectoral linkages between tradable sectors and between tradable and non-tradable sectors unlike previous Ricardian trade models. In our model, producers of non-tradable goods differ in productivity levels, demand tradable and non-tradable intermediate goods for production and supply goods not only for consumption but also for production in all sectors.[11] This feedback in production turns out to be important to quantify the trade and welfare effects of tariff reductions. Secondly, we show how accounting for intermediate goods in production and sectoral linkages does amplify the trade and welfare effects of trade costs and tariff reductions.[12] Thirdly, we extend the Ricardian model to perform a thoroughly quantitative evaluation of the trade and welfare effects from changes in

7. The number of regional trade agreements (RTAs) signed in the world has increased dramatically in the last 20 years. In 1990 there were close to 25 RTAs signed, by 2010 more than 180. By the year 2002 more than one-third of world trade was covered by RTAs.

8. Jacob Viner's (1950) work was among the first to study the welfare analysis of trade policy. Bhagwati *et al*. (1999) put together many of the major theoretical contributions since Viner. More recents are Anderson and van Wincoop (2004), Baier and Bergstrand (2009), Deardorff (1998), Redding and Anthony Venables (2004), Rose (2004), and Subramanian and Wei (2007). Bagwell and Staiger (2010) survey recent economic research on trade agreements, with special focus on the GATT/WTO. Several studies have focused on the case of NAFTA, for instance Krueger (1999) and the references therein, Lederman *et al*. (2005), Romalis (2007), and Trefler (2006). For results on CGE models in general see Brown *et al*. (1994), Brown and Stern (1989), Kehoe and Kehoe (1994), and for the case of NAFTA refer to Fox (1999), Kehoe (2003), Rolleigh (2008) and Shikher (2010).

9. This last distinction is important since it generates changes at the extensive margin of trade whereas this is not the case of an Armington-type model as commonly used in CGE analysis.

10. The Eaton and Kortum, (2002) model has been extended in many other directions also. One of the earliest studies was Yi (2003) who uses the model to understand if vertical specialization can explain the large growth in trade. More recent studies are Burstein *et al*. (2012), Burstein and Vogel (2012), Caselli *et al*. (2012), Fieler (2011), Kerr (2009), Levchenko and Zhang (2011), Parro (2013), Ossa (2012), Ramondo and Rodriguez-Clare (2013), and Waugh (2010). For a comprehensive survey of recent extensions of the Ricardian model of trade refer to Eaton and Kortum (2012).

11. Non-tradable good sectors are often modelled as an outside sector that does not use intermediate goods for production. For example, see Alvarez and Lucas (2007).

12. In Section 5.3, we compare the effects of NAFTA across different models and show that sectoral heterogeneity, intermediate goods, and sectoral linkages are quantitatively important.

trade policies. Finally, the way in which we take the model to the data is very different compared to other studies. We solve the multi-country and multi-sector model in changes, relative to a base year, allowing us to perform counterfactuals without relying on estimates of unobserved structural parameters, like fundamental productivity. We show that this approach is simple and useful to evaluate counterfactual changes in trade costs more broadly.

Our article is also related to studies that propose new methods to estimate trade elasticities.[13] We propose a new method that identifies sectoral and aggregate trade elasticities by exploiting the cross-sectional variation in trade shares induced by the cross-sectional variation in tariffs. The method relies on the multiplicative properties of the gravity equation consistent with a large variety of trade models (Krugman, 1981; Eaton and Kortum, 2002; Anderson Wincoop, 2003; Melitz, 2003; and Chaney, 2008).

The article is structured as follows. In Section 2, we motivate the importance of modeling trade in intermediates, multiple sectors, and sectoral linkages for tariff policy evaluation. In Section 3, we develop a methodology to evaluate the trade and welfare effects of tariff changes, we present the equilibrium conditions of the model, and show how to solve and calibrate the model. In Section 4, we propose a new method and estimate sectoral trade elasticities. In Section 5, we apply the model to evaluate the trade and welfare effects of NAFTA. In Section 6, we conclude.

2. TARIFFS, INTERMEDIATE GOODS AND SECTORAL LINKAGES

In this section we motivate the importance of modelling trade in intermediates, multiple sectors, and sectoral linkages for tariff policy evaluation. The Appendix "Data Sources and Description", at the end of the document, describes in detail the data sources that we use in this article. Throughout the article, whenever we make reference to a sector in the data, we refer to a 2-digit ISIC Rev. 3 industry. Table A1 in the Appendix "Data Sources and Description" provides a description of the sectoral categories.

Tariff rates vary substantially across sectors. In 1993, the year before NAFTA went into effect, sectoral tariff rates applied by Mexico, Canada, and the U.S. to NAFTA members were, on average, 12.5%, 4.2%, and 2.7%, respectively, with a large heterogeneity across sectors (Figure A1, in the appendix, presents the effective tariffs rates across NAFTA members for the year 1993). By 2005 they dropped almost to zero between NAFTA members, but tariffs that Mexico, Canada, and the U. S. applied to the rest of the world were, on average, 7.1%, 2.2%, and 1.7%, respectively.[14] The fact to take away is that by 2005 average tariffs had decreased considerably, but they still remained very dispersed across sectors. Trade and welfare effects of average changes in tariffs can be analyzed using a one-sector trade model; however, the effects of changes in the dispersion of tariffs can only be analyzed with a model that includes multiple sectors, sectoral linkages and intermediate goods.

13. For instance, Feenstra (1994), Head and Ries (2001), Anderson and van Wincoop (2004) and references therein, Romalis (2007), Simonovska and Waugh (2013) and Bergstrand *et al*. (2013).

14. The reason why tariffs decreased is mostly that several free trade agreements entered into force during the period 1993-2005. For instance, Mexico signed free trade agreements with Costa Rica in 1995, Nicaragua in 1998, Chile in 1999, the European Union in 2000, El Salvador, Guatemala and Honduras in 2001, and Japan in 2005; Canada signed agreements with Chile in 1997 and Costa Rica in 2002; and the U.S. signed agreements with Jordan in 2001, Chile, Costa Rica, the Dominican Republic, El Salvador, Guatemala, Honduras, Nicaragua and Singapore in 2004, and Australia in 2005.

Actually, most goods traded are intermediate goods.[15] In 1993, 68% of Mexico's imports from countries not belonging to NAFTA were intermediate goods. The share for Canada is 61.5% and for the U.S. 64.6%. Intermediate goods trade is even more important for NAFTA members. In fact, 82.1% of Mexico's imports from NAFTA were intermediate goods, whereas for Canada and the U.S. the values were 72.3% and 72.8%, respectively. Therefore, by 1993 most goods traded across NAFTA members were intermediate goods and trade of these types of goods was more important across NAFTA members than with the rest of the world.

Also, tradable and non-tradable sectors are interconnected. Using I–O tables, we can measure the proportion of spending from sectors on final and intermediate goods from other sectors. One salient characteristic of any I–O matrix is that it presents a strong diagonal, namely that the share of own industry material inputs purchased are important. However, this expenditure share is far from 100%. For example, for the U.S., the mean diagonal share is 16% and has a standard deviation of 15%, whereas for Mexico, the mean diagonal share is 13% and has a standard deviation of 14%.[16] If we focus only on tradable sectors, the mean share of the diagonal elements is 20% and 19% whereas the mean share of the diagonal elements for the non-tradable sectors are 11% and 7%, respectively, for the U.S. and Mexico. This means that industries purchase mostly intermediate inputs from other industries.[17] Moreover, I–O tables reflect that tradable and non-tradable sectors are interrelated. The average share of tradable sectors in the production of non-tradable sectors is 23% for the U.S. and 32% for Mexico, whereas the average share of non-tradable sectors in the production of tradable sectors is 34% for the U.S. and 26% for Mexico. This casual inspection of the I–O tables shows that sectors are strongly interrelated and that non-tradable sectors are a relevant input in the production of tradables and vice versa.

We finish this subsection concluding that an assessment of the economics effects of NAFTA needs to take into account that most goods traded are intermediate goods, that countries have different structure of production and that there is substantial sectoral heterogeneity in tariffs. We now proceed to describe a model that takes all of these mechanisms into account.

3. A QUANTITATIVE MODEL FOR TRADE POLICY EVALUATION

We develop a quantitative general equilibrium model with trade in intermediate goods, sectoral heterogeneity, and I–O linkages, that takes into consideration all the empirical facts described in the previous section. The model builds on the Ricardian trade model of Eaton and Kortum, (2002). There are N countries and J sectors. We denote countries by i and n and sectors by j and k. Sectors are of two types, either tradable or non-tradable and there is only one factor of production, labour. All markets are perfectly competitive and labour is mobile across sectors and not mobile across countries.

3.1. *The model*

3.1.1. Households. In each country, there are a measure of L_n representative households that maximize utility by consuming final goods C_n^j. The preferences of the households are given

15. The descriptive statistics presented in this paragraph use data from COMTRADE via WITS. The product categories are the HS Standard Product Groups, UNCTAD. We refer to intermediate goods to categories UNCTAD-SoP2 and UNCTAD-SoP4. The intermediate goods traded in the model that we present below map to these two categories.

16. These figures are computed using the I-O tables described in the Appendix "Data Sources and Description."

17. Jones (2007) presents a detailed description of the characteristics of I-O tables. He shows that, regardless of the level of sectoral disaggregation, the largest share is always the share of own industry material inputs purchased. However, the higher the level of disaggregation, the smaller the share is. For instance, the share of own industry material inputs purchased are, on average, 3.3% of total material purchases for the case of the U.S. using a 6-digit I-O table.

by

$$u(C_n)=\prod_{j=1}^{J} C_n^{j\,\alpha_n^j}, \text{ where } \sum_{j=1}^{J}\alpha_n^j=1. \tag{1}$$

We denote by I_n households' income. Income is derived from two sources; households supply labour L_n at a wage w_n and receive transfers on a lump-sum basis (tariff revenues and transfers from the rest of the world, as we will see in a moment).

3.1.2. Intermediate goods. A continuum of intermediate goods $\omega^j \in [0,1]$ is produced in each sector j. Two types of inputs, labour, and composite intermediate goods (also referred to as materials) from all sectors, are used for the production of each ω^j. Producers of intermediate goods across countries differ in the efficiency of production. We denote by $z_n^j(\omega^j)$ the efficiency of producing intermediate good ω^j in country n. The production technology of a good ω^j is

$$q_n^j(\omega^j)=z_n^j\left(\omega^j\right)\left[l_n^j(\omega^j)\right]^{\gamma_n^j}\prod_{k=1}^{J}\left[m_n^{k,j}(\omega^j)\right]^{\gamma_n^{k,j}},$$

where $l_n^j(\omega^j)$ is labour and $m_n^{k,j}(\omega^j)$ are the composite intermediate goods from sector k used for the production of intermediate good ω^j. The parameter $\gamma_n^{k,j} \geqslant 0$ is the share of materials from sector k used in the production of intermediate good ω^j, with $\sum_{k=1}^{J}\gamma_n^{k,j}=1-\gamma_n^j$, and the parameter $\gamma_n^j \geqslant 0$ is the share of value added. Both value added shares and intermediate goods shares vary across countries and sectors.[18]

Since production of intermediate goods is at constant returns to scale and markets are perfectly competitive, firms price at unit cost, $c_n^j/z_n^j(\omega^j)$, where c_n^j denotes the cost of an input bundle. In particular

$$c_n^j=\Upsilon_n^j w_n^{\gamma_n^j}\prod_{k=1}^{J} P_n^{k\,\gamma_n^{k,j}}, \tag{2}$$

where P_n^k is the price of a composite intermediate good from sector k, and Υ_n^j is a constant.[19] Equation (2) captures a key difference compared to the one-sector model or the multi-sector model without interrelated sectors, as the cost of the input bundle depends on wages and on the price of all the composite intermediate goods in the economy, tradable, and non-tradable. A change in policy that affects the price in any single sector will affect indirectly all the sectors in the economy via the input bundle. We show later that this interrelation plays an important role in evaluating the trade and welfare effects from trade openness.

3.1.3. Composite intermediate goods. Producers of composite intermediate goods in sector j and country n, supply Q_n^j at minimum cost by purchasing intermediate goods ω^j from the

18. The main reason why we assume a unit elasticity of substitution across materials is because, at the level of aggregation at which we conduct our empirical analysis, value added, and I–O shares are fairly constant over time. Using I–O tables for the years 1995 and 2005, at the two-digit ISIC rev 2, from 26 countries sourced from WIOD (http://www.wiod.org/), we evaluated the stability of input shares by calculating the correlation coefficient across all input shares over time. We find that for all countries, the correlation was higher than 0.91. Still, Appendix "CES Model" presents a general version of our model where we allow for any degree of substitutability across inputs.

19. Specifically, $\Upsilon_n^j \equiv \prod_{k=1}^{J}(\gamma_n^{k,j})^{-\gamma_n^{k,j}}(\gamma_n^j)^{-\gamma_n^j}$.

lowest cost suppliers across countries.[20] The production technology of Q_n^j is an Ethier (1982) or Dixit and Stiglitz (1977) aggregator given by

$$Q_n^j = \left[\int r_n^j(\omega^j)^{1-1/\sigma^j} d\omega^j \right]^{\sigma^j/(\sigma^j-1)},$$

where $\sigma^j > 0$ is the elasticity of substitution across intermediate goods within sector j, and $r_n^j(\omega^j)$ is the demand of intermediate goods ω^j from the lowest cost supplier. The solution to the problem of the composite intermediate good producer gives the following demand for good ω^j

$$r_n^j(\omega^j) = \left(\frac{p_n^j(\omega^j)}{P_n^j} \right)^{-\sigma^j} Q_n^j,$$

where P_n^j is unit price of the composite intermediate good

$$P_n^j = \left[\int p_n^j(\omega^j)^{1-\sigma^j} d\omega^j \right]^{\frac{1}{1-\sigma^j}},$$

and $p_n^j(\omega^j)$ denotes the lowest price of intermediate good ω^j across all locations n.

Composite intermediate goods from sector j are used as materials for the production of intermediate good ω^k in the amount $m_n^{j,k}(\omega^k)$ in all sectors k, and as final goods in consumption C_n^j.[21]

3.1.4. International trade costs and prices. We assume that trade in goods is costly. In particular, there are two types of trade costs: iceberg trade costs and an ad-valorem flat-rate tariffs. Iceberg costs are defined in physical units as in Samuelson (1954), where one unit of a tradable intermediate good in sector j shipped from country i to country n requires producing $d_{ni}^j \geq 1$ units in i, with $d_{nn}^j = 1$. Goods imported by country n from country i have to pay an ad-valorem flat-rate tariff τ_{ni}^j applicable over unit prices. We combine both trade costs, represented by

$$\kappa_{ni}^j = \tilde{\tau}_{ni}^j d_{ni}^j, \tag{3}$$

where $\tilde{\tau}_{ni}^j = (1+\tau_{ni}^j)$. We also assume that the triangular inequality holds; $\kappa_{nh}^j \kappa_{hi}^j \geqslant \kappa_{ni}^j$ for all n, h, i.

20. Allowing for producers of composite intermediate goods to search for the lowest cost supplier is a key distinction from models with Armington-type assumptions. In those models, because of the love for variety, regardless of the price, goods are always bought from all sources, since they are differentiated by country of origin. In the Eaton and Kortum, (2002) model, the source from which goods are purchased is endogenously determined and can change as a consequence of tariff reductions. This is crucial to understand why this model conceptually takes into account changes at the extensive new goods margin and not only changes at the intensive old goods margin, as is the case in Armington-type models. However, both models deliver similar aggregate moments for trade flows. In fact, the gravity equation implied from the Eaton and Kortum, (2002) model, equation (6) below, is identical to the Armington model after mapping the dispersion of productivity, θ, and the technology parameter, λ, to the elasticity of substitution and the home bias parameter in the Armington-type models.

21. The market clearing condition for the composite intermediate good in sector j is

$$Q_n^j = C_n^j + \sum_{k=1}^J \int m_n^{j,k}(\omega^k) d\omega^k.$$

After taking into account trade costs, a unit of a tradable intermediate good ω^j produced in country i is available in country n at unit prices $c_i^j \kappa_{ni}^j / z_i^j \left(\omega^j\right)$. Therefore, the price of intermediate good ω^j in country n is given by

$$p_n^j\left(\omega^j\right) = \min_i \left\{ \frac{c_i^j \kappa_{ni}^j}{z_i^j\left(\omega^j\right)} \right\}.$$

We model non-tradable sectors in the same way as tradable sectors but impose that $\kappa_{in}^j = \infty$; thus, in some sectors goods are not traded because it is always cheaper to buy goods from local suppliers. In non-tradable sectors, $p_n^j\left(\omega^j\right) = c_n^j / z_n^j\left(\omega^j\right)$ and the demand of intermediate goods is given by $r_n^j(\omega^j) = q_n^j(\omega^j)$.

Ricardian motives to trade are introduced following Eaton and Kortum's (2002) probabilistic representation of technologies allowing productivities to differ by country and also by sectors. In particular, we assume that the efficiency of producing a good ω^j in country n is the realization of a Fréchet distribution with a location parameter that varies by country and sector, $\lambda_n^j \geqslant 0$ and shape parameter that varies by sector, θ^j.[22] In the context of this model, a higher λ_n^j makes the average productivity in a sector higher, a notion of absolute advantage, whereas a smaller value of θ^j implies a higher dispersion of productivity across goods ω^j, a notion of comparative advantage. We assume that the distributions of productivities are independent across goods, sectors and countries, and that $1+\theta^j > \sigma^j$. With these assumptions on the distribution of efficiencies we can solve for the distribution of prices.[23] The price of the composite intermediate good is then given by

$$P_n^j = A^j \left[\sum_{i=1}^{N} \lambda_i^j (c_i^j \kappa_{ni}^j)^{-\theta^j} \right]^{-1/\theta^j}, \tag{4}$$

for all sectors j and countries n; where A^j is a constant. Note that equation (4) is also the price index of the non-tradable goods sector. The difference is that in that case, since $\kappa_{in}^j = \infty$, the price index is given by $P_n^j = A^j \lambda_n^{j-1/\theta^j} c_n^j$.

Consumers purchase final goods at prices P_n^j. With Cobb–Douglas preferences (equation 1), the consumption price index is given by

$$P_n = \prod_{j=1}^{J} (P_n^j / \alpha_n^j)^{\alpha_n^j}. \tag{5}$$

3.1.5. Expenditure shares. Total expenditure on sector j goods in country n is given by $X_n^j = P_n^j Q_n^j$. We denote by X_{ni}^j to the expenditure in country n of sector j goods from country i. It follows that country n's share of expenditure on goods from i are given by $\pi_{ni}^j = X_{ni}^j / X_n^j$.

22. For a description of the properties of the Fréchet distribution, refer to Eaton and Kortum, (2002). Donaldson (2012) relates this assumption to other standard assumptions used in models of international trade with heterogeneous firms, like those in Melitz, (2003), Chaney (2008), and others. Costinot *et al*. (2012) consider the case of more general distributions.

23. Appendix "Distribution of Prices and Expenditure Shares" presents a detailed derivation of the distribution of prices and how to solve for the price index (equation 4) as well as the expenditure shares (equation 6). The derivation follows Eaton and Kortum, (2002) applied to a multi-sector economy.

Using the properties of the Fréchet distribution, we can derive expenditure shares as a function of technologies, prices, and trade costs

$$\pi^j_{ni} = \frac{\lambda^j_i \left[c^j_i \kappa^j_{ni}\right]^{-\theta^j}}{\sum_{h=1}^N \lambda^j_h \left[c^j_h \kappa^j_{nh}\right]^{-\theta^j}}. \tag{6}$$

As we can see, bilateral trade shares π^j_{ni} take the form of a multi-sector version of a gravity equation. Changes in tariffs have a direct effect in trade shares via κ^j_{ni}, and from equation (2) note that changes in tariffs also have an indirect effect through the input bundle c^j_i since it incorporates all the information contained in the I–O tables.

3.1.6. Total expenditure and trade balance. Total expenditure on goods j is the sum of the expenditure on composite intermediate goods by firms and the expenditure by households. Then, X^j_n is given by

$$X^j_n = \sum_{k=1}^J \gamma^{j,k}_n \sum_{i=1}^N X^k_i \frac{\pi^k_{in}}{1+\tau^k_{in}} + \alpha^j_n I_n, \tag{7}$$

where

$$I_n = w_n L_n + R_n + D_n, \tag{8}$$

represents final absorption in country n, as the sum of labour income, trade deficit, and tariff revenues. In particular, $R_n = \sum_{j=1}^J \sum_{i=1}^N \tau^j_{ni} M^j_{ni}$, where $M^j_{ni} = X^j_n \frac{\pi^j_{ni}}{1+\tau^j_{ni}}$ are country n's imports of sector j goods from country i. The summation of trade deficits across countries is zero, $\sum_{n=1}^N D_n = 0$, and national deficits are the summation of sectoral deficits, $D_n = \sum_{k=1}^J D^k_n$. Sectoral deficits are defined by $D^j_n = \sum_{i=1}^N M^j_{ni} - \sum_{i=1}^N E^j_{ni}$, where $E^j_{ni} = X^j_i \frac{\pi^j_{in}}{1+\tau^j_{in}}$ are country $n's$ exports of sector j goods to country i. Aggregate trade deficits in each country are exogenous in the model, however, sectoral trade deficits are endogenously determined.

Finally, using the definition of expenditure and trade deficit we have that

$$\sum_{j=1}^J \sum_{i=1}^N X^j_n \frac{\pi^j_{ni}}{1+\tau^j_{ni}} - D_n = \sum_{j=1}^J \sum_{i=1}^N X^j_i \frac{\pi^j_{in}}{1+\tau^j_{in}}. \tag{9}$$

This condition reflects the fact that total expenditure, excluding tariff payments, in country n minus trade deficits equals the sum of each country's total expenditure, excluding tariff payments, on tradable goods from country n. We are adding over all sectors whether a sector is tradable or non-tradable. The non-tradable sectors will appear in both sides of the equation and cancel out.[24]

We now define formally the equilibrium under policies $\{\tau^j_{ni}\}$ in this model.

24. It is also possible to show that equation (9) implies labour market clearing. To see this, add equation (7) across sectors and substitute into equation (9) to obtain

$$w_n L_n = \sum_{j=1}^J \gamma^j_n \sum_{i=1}^N X^j_i \frac{\pi^j_{in}}{1+\tau^j_{in}}.$$

Definition 1. *Given L_n, D_n, λ_n^j, and d_{ni}^j, an equilibrium under tariff structure τ is a wage vector $\mathbf{w} \in \mathbf{R}_{++}^N$ and prices $\{P_n^j\}_{j=1,n=1}^{J,N}$ that satisfy equilibrium conditions (2), (4), (6), (7), and (9) for all j, n.*

3.1.7. Equilibrium in relative changes. Instead of solving for an equilibrium under policy τ we solve for changes in prices and wages after changing from policy τ to policy τ', what we define as an equilibrium in relative changes.[25] There are several advantages of doing so. First, we can match exactly the model to the data in a base year; secondly, we can identify the effect on equilibrium outcomes from a pure change in tariffs, which is what we are after in this article; and finally we can solve for the general equilibrium of the model without needing to estimate parameters which are difficult to identify in the data, as productivities λ_n^j, and iceberg trade costs d_{ni}^j.

We now define the equilibrium of the model under policy τ' relative to a policy under tariff structure τ.

Definition 2. *Let $(\mathbf{w}, P)$ be an equilibrium under tariff structure τ and let $(\mathbf{w}', P')$ be an equilibrium under tariff structure τ'. Define $(\hat{\mathbf{w}}, \hat{P})$ as an equilibrium under τ' relative to τ, where a variable with a hat "$\hat{x}$" represents the relative change of the variable, namely $\hat{x} = x'/x$. Using equations (2), (4), (6), (7), and (9) the equilibrium conditions in relative changes satisfy:*

Cost of the input bundles:

$$\hat{c}_n^j = \hat{w}_n^{\gamma_n^j} \prod_{k=1}^J \hat{P}_n^{k\ \gamma_n^{k,j}}. \tag{10}$$

Price index:

$$\hat{P}_n^j = \left[\sum_{i=1}^N \pi_{ni}^j [\hat{\kappa}_{ni}^j \hat{c}_i^j]^{-\theta^j}\right]^{-1/\theta^j}. \tag{11}$$

Bilateral trade shares:

$$\hat{\pi}_{ni}^j = \left[\frac{\hat{c}_i^j \hat{\kappa}_{ni}^j}{\hat{P}_n^j}\right]^{-\theta^j}. \tag{12}$$

Total expenditure in each country n and sector j:

$$X_n^{j'} = \sum_{k=1}^J \gamma_n^{j,k} \sum_{i=1}^N \frac{\pi_{in}^{k'}}{1+\tau_{in}^{k'}} X_i^{k'} + \alpha_n^j I_n'. \tag{13}$$

Trade balance:

$$\sum_{j=1}^J \sum_{i=1}^N \frac{\pi_{ni}^{j'}}{1+\tau_{ni}^{j'}} X_n^{j'} - D_n = \sum_{j=1}^J \sum_{i=1}^N \frac{\pi_{in}^{j'}}{1+\tau_{in}^{j'}} X_i^{j'}, \tag{14}$$

where $\hat{\kappa}_{ni}^j = (1+\tau_{ni}^{j'})/(1+\tau_{ni}^j)$ and $I_n' = \hat{w}_n w_n L_n + \sum_{j=1}^J \sum_{i=1}^N \tau_{ni}^{j'} \frac{\pi_{ni}^{j'}}{1+\tau_{ni}^{j'}} X_n^{j'} + D_n$.

25. This idea of expressing the equilibrium in relative changes follows Dekle *et al*. (2008). They use it to understand the effects of a change in trade deficits whereas we use it to compute the effects of a change in the tariff structure.

From inspecting equilibrium conditions (10 through 13) we can observe that the focus on relative changes allows us to perform policy experiments without relying on estimates of total factor productivity or transport costs. We only need two sets of tariff structures (τ and τ'), data on bilateral trade shares (π_{ni}^{j}), the share of value added in production (γ_n^j), value added (w_nL_n), the share of intermediate consumption ($\gamma_n^{k,j}$), and sectoral dispersion of productivity (θ^j). The share of each sector in final demand (α_n^j) is obtained from these data as we will show later on. The only set of parameters to estimate is the sectoral dispersion of productivity θ^j. We provide a new method to estimate them in Section 4.

3.1.8. Relative change in real wages. We conclude this subsection by briefly discussing how important it is to account for multiple sectors and sectoral linkages to quantify the effects on real wages from counterfactual changes in trade costs.[26] Using equations (10) and (12), we solve for the counterfactual change in real wages $\hat{w}_n/\hat{P}_n^j$ in each sector j as a function of the share of expenditure on domestic goods and sectoral prices. We then aggregate across sectors using consumption expenditure shares and obtain the following expression for the logarithm change in real wages

$$\ln\frac{\hat{w}_n}{\hat{P}_n}=\underbrace{-\sum_{j=1}^{J}\frac{\alpha_n^j}{\theta^j}\ln\hat{\pi}_{nn}^j}_{\text{Final goods}}\underbrace{-\sum_{j=1}^{J}\frac{\alpha_n^j}{\theta^j}\frac{1-\gamma_n^j}{\gamma_n^j}\ln\hat{\pi}_{nn}^j}_{\text{Intermediate goods}}\underbrace{-\sum_{j=1}^{J}\frac{\alpha_n^j}{\gamma_n^j}\ln\prod_{k=1}^{J}(\hat{P}_n^k/\hat{P}_n^j)^{\gamma_n^{k,j}}}_{\text{Sectoral linkages}}, \tag{15}$$

where $\hat{P}_n$ is the change in consumption prices (equation 5).[27] This decomposition shows that all the general equilibrium effects on real wages can be summarized by the change in the share of domestic expenditure in each sector, $\hat{\pi}_{nn}^j$ and the changes in sectoral prices, $\hat{P}_n^j$. Each term measures an additional effect compared to a certain benchmark model. For instance, consider the case where $\gamma_n^j=1$ for all j and n, then intermediate goods are produced only with labour and they are used only to produce final goods. In this case, $\ln\hat{w}_n/\hat{P}_n^j=-(1/\theta^j)\ln\hat{\pi}_{nn}^j$ and since α_n^j is the share spent on final goods from sector j, $-(\alpha_n^j/\theta^j)\ln\hat{\pi}_{nn}^j$ measures the contribution of the change in the real wage in sector j to the aggregate change in real wages. Adding across all sectors, $-\sum_{j=1}^{J}(\alpha_n^j/\theta^j)\ln\hat{\pi}_{nn}^j$ measures the aggregate effect of trade in final goods. This effect depends on the share of each sector in final demand and the sectoral trade cost elasticity. Note that the more negatively correlated are α_n^j/θ^j with $\hat{\pi}_{nn}^j$ the larger are the welfare effects for small changes in π_{nn}^j.[28] From this expression it is evident that sectoral heterogeneity in trade elasticities matters for welfare.[29]

26. Changes in real wages are not changes in welfare in a model where tariff revenue is lump-sum transferred. The change in welfare is a weighted average measure of the change in real wages and real tariff revenue, namely $\hat{I}_n/\hat{P}_n=\eta\hat{w}_n/\hat{P}_n+(1-\eta)\hat{R}_n/\hat{P}_n$, where $\eta=w_nL_n/I_n$. We focus on real wages in this subsection only as a mode to relate our findings to studies that evaluate welfare effects of trade openness in models in which tariffs are absent (for instance Arkolakis *et al*. 2012).

27. To obtain the expression for the change in real wages use (12) and (10) to solve for $\hat{w}_n/\hat{P}_n^j$, and then take the product for all sectors j weighted by α_n^j. Finally, apply logarithms from both sides and rearrange terms to obtain the expression for the percentage change in the real wage in country n, as presented in the text.

28. Arkolakis *et al*. (2012) show that within a variety of trade models there are two sufficient statistics to evaluate welfare gains: the share of expenditure on domestic goods and trade elasticities. Donaldson (2012) makes the same observation for the case of a multi-sector Eaton and Kortum, (2002) model.

29. In a recent study, Ossa (2012) evaluates the importance of sectoral variation in trade elasticities for welfare quantification.

Consider the model where $\gamma_n^j \neq 1$ and $\gamma_n^{j,j} = 1 - \gamma_n^j$ for all j and n. In this case, there are no sectoral interrelations since intermediate goods are produced with labour and materials only from the same sector. Reductions in trade cost reduce the price of tradable intermediate goods and in turn reduce the price of the composite intermediate good. As a consequence, producers of intermediate goods gain from this reduction in the cost of their inputs. This additional effect on real wages compared to a model with no intermediates goods is captured by the term $-\sum_{j=1}^{J} \frac{\alpha_n^j}{\theta^j} \frac{1-\gamma_n^j}{\gamma_n^j} \ln \hat{\pi}_{nn}^j$.

Finally, consider the general model. The materials price index $\prod_{k=1}^{J} (\hat{P}_n^k)^{\gamma_n^{k,j}}$ captures the effect of a change in the price of composite intermediates from sector k on real wages in sector j. The larger is $\gamma_n^{k,j}$ for sectors in which prices decline more, the larger is the reduction in the cost of material inputs used in production. In other words, it captures the importance of the I–O structure of the economy. The contribution to aggregate change in real wages is given by $-\sum_{j=1}^{J} \frac{\alpha_n^j}{\gamma_n^j} \ln \prod_{k=1}^{J} (\hat{P}_n^k / \hat{P}_n^j)^{\gamma_n^{k,j}}$. Note that this term resembles a geometric weighted average of the change in the price of materials. Only in the case where substantial symmetry in parameters is assumed this term will be equal to zero.[30]

3.2. *Welfare effects from tariff changes*

In this subsection, we decompose the welfare effects from tariff changes into terms of trade and volume of trade effects. We use this decomposition in the quantitative section of the article to evaluate the welfare effects of NAFTA's tariff changes. More generally, this welfare decomposition allows us to understand the effects of tariffs changes across different countries and sectors.

We denote welfare of the representative consumer in country n by $W_n = I_n / P_n$, where I_n is given by equation (8) and P_n by equation (5). Totally differentiating W_n and after using the equilibrium conditions of the model the change in welfare is given by

$$d \ln W_n = \frac{1}{I_n} \sum_{j=1}^{J} \sum_{i=1}^{N} \underbrace{\left(E_{ni}^j d \ln c_n^j - M_{ni}^j d \ln c_i^j \right)}_{\text{Terms of trade}} + \frac{1}{I_n} \sum_{j=1}^{J} \sum_{i=1}^{N} \underbrace{\tau_{ni}^j M_{ni}^j \left(d \ln M_{ni}^j - d \ln c_i^j \right)}_{\text{Volume of trade}}, \tag{16}$$

where the first term measures the *multi-lateral and multi-sectoral terms of trade* effect and the second term the *multi-lateral and multi-sectoral volume of trade* effect from tariff changes.[31]

The change in welfare due to the terms of trade effects from tariff changes quantifies the gains from an increase in exporter prices relative to the change in importer prices, measured at world prices.[32] In our model, this measure of terms of trade is a multi-lateral weighted change in

30. In fact, to see this consider the case of two sectors. Sectoral linkages are given by $(\alpha_n^1 \gamma_n^{2,1} / \gamma_n^1 - \alpha_n^2 \gamma_n^{1,2} / \gamma_n^2) \ln(\hat{P}_n^1 / \hat{P}_n^2)$. Note that this term will only be zero if prices change in the same proportion, and-or if the share of final good in demand and the share of intermediate goods in production is the same across sectors together with a symmetric I–O table.

31. Appendix "Welfare" presents a detailed derivation of equation (16). Other studies have also presented multi-lateral measures of terms of trade. For instance, Bagwell and Staiger (1999) and Ossa (2014). We borrow the term "volume of trade effect" from Dixit and Norman (1980) which they define in the context of a two-good two-country model.

32. Conditional on exporting, the world price (net of tariffs) of the intermediate good that country n exports to i is $c_n^j d_{ni}^j / z_n^j (\omega^j)$. Changes in tariffs impact only the input bundle, c_n^j and affect all exporters of intermediate goods in sector j proportionally. Of course, changes in tariffs can change the set of goods sourced from each country, but since prices change proportionally to c_n^j, the world price of the goods that country i is still sourcing from n change in the same way as the ones that it stops sourcing from n. Therefore, changes in input costs measure the change in trade prices in this model.

export and import prices at the sectoral level, where the weights are given by bilateral exports and imports, respectively. The contribution of each sector to the aggregate change in terms of trade depends on sectoral trade deficits (the difference between E_{ni}^j and M_{ni}^j) and sectoral changes in importer and exporter prices. In general, it is not possible to sign the particular contribution of each sector to the aggregate effect.[33] Doing so requires performing a quantitative assessment, as we do below for the case of NAFTA.

The variation across sectors on the terms of trade effects is a key distinction from a model with multiple sectors and intermediate goods relative to a model with no intermediate goods. In fact, if there are no intermediate goods in production the sectoral variation in trade flows plays absolutely no role on influencing the aggregate terms of trade. To see this, consider the case where $\gamma_n^j = 1$ for all j and n, then intermediate goods are only produced with labour. Input costs do not vary by sector, since $c_n^j = w_n$ and then $d\ln c_n^j = d\ln w_n$, and the aggregate terms of trade effects are given by $\sum_{j=1}^J \sum_{i=1}^N M_{ni}^j (d\ln w_n - d\ln w_i) = \sum_{i=1}^N M_{ni} (d\ln w_n - d\ln w_i)$, where M_{ni} are total imports by country n from country i. Hence, conditional on a change in wages and aggregate trade flows, a multi-sector model delivers the same aggregate terms of trade effects as a one-sector model. Still, terms of trade are going to vary bilaterally.[34]

The second term in equation (16) measures the welfare gains from changes in the volume of trade as a consequence of the change in tariffs. More trade is created the larger is the increase in the volume of trade, measured as import values deflated by import prices, and contributes positively to welfare. Initial tariffs and import volumes weight how important this effect is across sectors and countries.

From equation (16) we can define bilateral and sectoral measures of terms of trade and volume of trade that can be used to decompose the welfare effects across countries and sectors. The change in *bilateral terms of trade* between countries n and i is given by

$$d\ln tot_{ni} = \sum\nolimits_{j=1}^{J} \left(E_{ni}^j d\ln c_n^j - M_{ni}^j d\ln c_i^j \right), \tag{17}$$

whereas the change in the *bilateral volume of trade* is given by

$$d\ln vot_{ni} = \sum\nolimits_{j=1}^{J} \tau_{ni}^j M_{ni}^j \left(d\ln M_{ni}^j - d\ln c_i^j \right). \tag{18}$$

Similarly, we measure the change in *sectoral terms of trade* by

$$d\ln tot_n^j = \sum\nolimits_{i=1}^{N} \left(E_{ni}^j d\ln c_n^j - M_{ni}^j d\ln c_i^j \right), \tag{19}$$

whereas the change in *sectoral volume of trade* is given by

$$d\ln vot_n^j = \sum\nolimits_{i=1}^{N} \tau_{ni}^j M_{ni}^j \left(d\ln M_{ni}^j - d\ln c_i^j \right). \tag{20}$$

33. A sufficient condition for a sector to contribute positively to aggregate welfare is that the sector net export to the rest of the world and that exporter prices increase relative to importer prices. To see this, note that $d\ln c_n^j$ can be aproximated by $\hat{c}_n^j - 1$, then $\sum_{j=1}^J \sum_{i=1}^N (E_{ni}^j \hat{c}_n^j - M_{ni}^j \hat{c}_i^j) = \sum_{j=1}^J \sum_{i=1}^N \hat{c}_n^j M_{ni}^j (E_{ni}^j / M_{ni}^j - \hat{c}_i^j / \hat{c}_n^j)$. Therefore, if sector j is a net exporter, then $E_{ni}^j > M_{ni}^j$, and if exporter prices improve relative to importer prices, $\hat{c}_n^j > \hat{c}_i^j$, then the contribution of that sector to the aggregate terms of trade is positive since $E_{ni}^j / M_{ni}^j - \hat{c}_i^j / \hat{c}_n^j > 0$.

34. Ossa (2014), using a multi-sector Armington model, shows that the terms of trade effect can be viewed as a relative wage effect since world prices are proportional to wages in a model with no intermediate goods. We show that when there are intermediate goods, world prices are not proportional only to wages.

Of course, given these definitions, the change in welfare in country n can also be computed as $d\ln W_n = \frac{1}{I_n}\sum_{i=1}^{N}(d\ln tot_{ni} + d\ln vot_{ni}) = \frac{1}{I_n}\sum_{j=1}^{J}\left(d\ln tot_n^j + d\ln vot_n^j\right)$.

3.3. *Taking the model to the data*

A key advantage from solving the model in relative changes is that it minimizes the data requirements to calibrate the model. Concretely, the data needed are bilateral trade flows (M_{ni}^j– imports of n from i), value added (V_n^j), gross production (Y_n^j), and I–O tables. With these data we can calculate the data counterparts of π_{ni}^j, γ_n^j, $\gamma_n^{j,k}$, and α_n^j.

To obtain the bilateral trade share π_{ni}^j, we first calculate domestic sales in each country, M_{nn}^j as the difference between gross production and total exports; $M_{nn}^j = Y_n^j - \sum_{i=1, i\neq n}^{N} M_{in}^j$. We then define expenditure by country n of sector j goods imported from country i as X_{ni}^j. We calculate X_{ni}^j by multiplying trade flows by tariffs, *i.e.*, $X_{ni}^j = M_{ni}^j(1+\tau_{ni}^j)$. We obtain π_{ni}^j for each sector j and pair of countries n, i as follows $\pi_{ni}^j = X_{ni}^j / \sum_{i=1}^{N} X_{ni}^j$. The share of sector k's spending on sector j's goods $\gamma_n^{j,k}$, is calculated from the I–O matrix as the share of intermediate consumption of sector j in sector k over the total intermediate consumption of sector k times one minus the share of value added in sector j, $1-\gamma_n^j$, where the share of value added in each sector and country is given by $\gamma_n^j = V_n^j / Y_n^j$. To calculate final consumption share, α_n^j we take the total expenditure of sector j goods, substract the intermediate goods expenditure and divide by total final absorption, namely $\alpha_n^j = (Y_n^j + D_n^j - \sum_{k=1}^{J}\gamma_n^{j,k} Y_n^k)/I_n$, where trade deficits in each sector j and country n are given by $D_n^j = \sum_{i=1}^{N} M_{ni}^j - \sum_{i=1}^{N} M_{in}^j$. Finally, the only parameters missing are the sectoral dispersion of productivity, θ^j. In the next section, we present a new method to estimate these parameters.

3.4. *Solving the model for tariff changes*

Consider a change in policy from τ to the new policy τ', captured by $\hat{\kappa}_{ni}^j$. To solve for the equilibrium, we first guess a vector of wages $\hat{\mathbf{w}} = (\widehat{w}_1, ..., \widehat{w}_N)$, *e.g.* $\hat{\mathbf{w}} = 1$. Given a vector of wages, the equilibrium conditions (10) and (11) are JxN equations in JxN unknown prices. Therefore, we can solve for prices in each sector and each country. Let $\hat{p}_n^j(\hat{\mathbf{w}})$ and $\hat{c}_n^j(\hat{\mathbf{w}})$ be the solution for the price and cost of the input bundle in each sector j and country n consistent with the vector of wages $\hat{\mathbf{w}}$. Then use π_{ni}^j and θ^j together with the calculated $\hat{p}_n^j(\hat{\mathbf{w}})$ and $\hat{c}_n^j(\hat{\mathbf{w}})$ and solve for $\pi_{ni}^{j\prime}(\hat{\mathbf{w}})$ using (12). Given $\pi_{ni}^{j\prime}(\hat{\mathbf{w}})$, τ', γ_n^j, $\gamma_n^{j,k}$ and α_n^j, solve for total expenditure in each sector j and country n, $X_n^{j\prime}(\hat{\mathbf{w}})$ consistent with the vector of wages $\hat{\mathbf{w}}$ using (14). Substituting $\pi_{in}^{j\prime}(\hat{\mathbf{w}})$, $X_n^{j\prime}(\hat{\mathbf{w}})$, τ', and D_n into equation (13) we verify if the trade balance holds. If not, we adjust our guess of $\hat{\mathbf{w}}$ until equilibrium condition (13) is obtained. The Appendix "Solving the Model" describes in greater detail every step.

4. A NEW METHOD TO ESTIMATE TRADE ELASTICITIES

The trade elasticities θ^j are the key parameters for quantitative trade policy evaluation. In our model, these are the only parameters we need to estimate to identify the effects of tariff reductions. In the context of the Eaton and Kortum model, as well as ours, the trade elasticities are related to the dispersion of productivity parameter and it determines how trade flows react to changes in tariffs. If productivity is less dispersed, as indicated by a larger value of θ^j, then a change in tariffs will not change the share of traded goods in a substantial way. The reason is that goods are less substitutable. On the other hand, if the productivities are less concentrated —if there is high dispersion— small changes in tariffs can translate to large adjustments in the share of goods traded. The reason is that producers of the composite aggregate are more likely to change their suppliers, since goods are more substitutable. The change in the measure of goods traded is the adjustment at the extensive margin in this model.[35] To see these effects more formally, from equation (6) note how changes in trade costs impact trade shares according to θ^j.

We propose a new method to estimate the dispersion parameter *i.e.* consistent with any trade model that delivers a gravity equation like equation (6).[36] Consider three countries indexed by n, i, and h. Take the cross-product of goods from sector j shipped in one direction between the three countries, from n to i, from i to h, and from h to n, and then the cross-product of the same goods shipped in the other direction, from n to h, from h to i, and from i to n. Using equation (6), we can calculate each expression and then take the ratio:

$$\frac{X_{ni}^{j}X_{ih}^{j}X_{hn}^{j}}{X_{nh}^{j}X_{hi}^{j}X_{in}^{j}}=\left(\frac{\kappa_{ni}^{j}}{\kappa_{in}^{j}}\frac{\kappa_{ih}^{j}}{\kappa_{hi}^{j}}\frac{\kappa_{hn}^{j}}{\kappa_{nh}^{j}}\right)^{-\theta^{j}}. \tag{21}$$

All the terms involving prices and parameters are canceled out and we end up with a relation between bilateral trade and trade costs.[37] The advantage of using equation (21) is that unobservable trade costs cancel out.[38] For example, consider the following model of asymmetric trade costs.[39] From the definition of κ_{ni}^{j} in equation (3), trade costs are composed of tariffs (non-symmetric) and iceberg (also non-symmetric) trade costs, namely $\ln\kappa_{ni}^{j}=\ln\tilde{\tau}_{ni}^{j}+\ln d_{ni}^{j}$. Iceberg trade costs,

35. In our model, the elasticity of trade with respect to trade costs is the dispersion of productivity, and is not the elasticity of substitution as in Armington models. If we restrict producers of the intermediate good aggregate to purchase goods from the same source, regardless of the change in trade costs, then the trade elasticity will be given by the elasticity of substitution as in Armington models. This is the sense in which the dispersion of productivity can be related to the elasticity of substitution in an Armington model. Both models, the Ricardian and the Armington, deliver a similar gravity-type equation. However, conceptually the models are very different. Adjustments from changes in tariffs occur for different reasons in the two models. Refer to notes 9 and 20. Also, in a Ricardian trade model like, Eaton and Kortum, (2002), there are production-side gains from trade, whereas in a standard Armington model, like Anderson's (1979), gains are from the consumption side only.

36. The method relies on the multiplicative properties of the gravity equation derived from a variety of trade models, like Krugman (1981), Eaton and Kortum, (2002), Melitz, (2003), Anderson and van Wincoop (2003) and all of the class of models in Arkolakis *et al*. (2012).

37. The number of cross-product terms in our method is given by $\sum_{n=1}^{N-2} n(n+1)/2$, where N is the number of countries in the sample. For instance, for a sample of 10 countries there will be a maximum of 120 observations.

38. The method we propose is similar to the odds ratio method developed by Head and Ries (2001) and also presented in Head and Mayer (2001). Our method is also similar to the one Head *et al*. (2009) denote as "tetrads." Other papers using the "tetrad" are Martin *et al*. (2008), Hallak (2006), Romalis (2007), and Anderson and Marcouiller (2002). These methods were constructed to estimate trade costs. We instead propose a method to estimate trade elasticities. Compared to the odds ratio, our method does not need to assume symmetric trade costs and we do not need to rely on information of domestic sales at the sectoral level. The key differences with these methods are: 1) To identify the trade cost elasticity, our method does not involve the estimation of unobservable trade barriers, as it is the case using the Head and Ries index, or the methodology in Romalis (2007). Our triple differentiation eliminates all the unobservable components of trade costs, thus we only need to use trade and tariff data to identify the elasticity; 2) we do not need information on domestic sales at the sectoral level (data on gross production and trade flows combined) and this reduces the concern of measurement errors on total expenditure; 3) our method combines fewer countries in the calculation (three instead of four), which increases the sample size considerably; and finally, 4) we do not need to use a reference country to identify the parameters.

39. A standard assumption in the trade literature is to assume symmetric geographic trade costs; for instance, see Krugman (1991). With our method, we do not need to assume symmetry to get identification.

$\ln d_{ni}^j$, can be modelled quite generally as linear functions of cross-country characteristics. For instance,

$$\ln \kappa_{ni}^j = \ln \tilde{\tau}_{ni}^j + \ln d_{ni}^j = \ln \tilde{\tau}_{ni}^j + \nu_{ni}^j + \mu_n^j + \delta_i^j + \varepsilon_{ni}^j, \tag{22}$$

where $\nu_{ni}^j = \nu_{in}^j$ captures symmetric bilateral trade costs like distance, language, common border, and belonging to an FTA or not. The parameter μ_n^j captures an importer sectoral fixed effect, *e.g.* non-tariff barriers, and it is assumed to be common to all trading partners of country n. The parameter δ_i^j is an exporter sectoral fixed effect that can also capture non-tariff barriers, and it is assumed to be common to all trading partners of country i. Finally, ε_{ni}^j is a random disturbance term that represents remoteness deviation from symmetry and is assumed to be orthogonal to tariffs. Substituting equation (22) into equation (21) we get:

$$\ln\left(\frac{X_{ni}^j X_{ih}^j X_{hn}^j}{X_{in}^j X_{hi}^j X_{nh}^j}\right) = -\theta^j \ln\left(\frac{\tilde{\tau}_{ni}^j}{\tilde{\tau}_{in}^j}\frac{\tilde{\tau}_{ih}^j}{\tilde{\tau}_{hi}^j}\frac{\tilde{\tau}_{hn}^j}{\tilde{\tau}_{nh}^j}\right) + \tilde{\varepsilon}^j, \tag{23}$$

where $\tilde{\varepsilon}^j = \varepsilon_{in}^j - \varepsilon_{ni}^j + \varepsilon_{hi}^j - \varepsilon_{ih}^j + \varepsilon_{nh}^j - \varepsilon_{hn}^j$. Note that all the symmetric and asymmetric components of the iceberg trade costs cancel out. The terms $\kappa_{ni}^j/\kappa_{in}^j, \kappa_{ih}^j/\kappa_{hi}^j$, and $\kappa_{hn}^j/\kappa_{nh}^j$ will cancel the symmetric bilateral trade costs (ν_{ni}^j, ν_{ih}^j, and ν_{hn}^j). The terms $\kappa_{ni}^j/\kappa_{nh}^j$, $\kappa_{ih}^j/\kappa_{in}^j$, and $\kappa_{hn}^j/\kappa_{hi}^j$ cancel the importer fixed effects (μ_n^j, μ_i^j, and μ_h^j); and the terms $\kappa_{ni}^j/\kappa_{hi}^j$, $\kappa_{ih}^j/\kappa_{nh}^j$, and $\kappa_{hn}^j/\kappa_{in}^j$ cancel the exporter fixed effects (δ_i^j, δ_h^j, and δ_n^j). The only identification restriction is that $\tilde{\varepsilon}^j$ is assumed to be orthogonal to tariffs.[40]

It is important to notice that our methodology is consistent with a wide class of gravity-trade models, and therefore, the estimated trade cost elasticity from using this method does not depend on the underlying microstructure assumed in the model. We estimate the dispersion-of-productivity parameter sector by sector using the proposed specification equation (23) for 1993, the year before NAFTA was active.[41] Table 1 presents the (negative of the) estimates (θ^j) and heteroskedastic-robust standard errors. As we can see, the coefficients have the correct sign and the magnitude of the estimates varies considerably across sectors. The estimates range from 0.37 to 51.08. This heterogeneity was confirmed by being able to reject the null hypothesis of common estimates (we performed an F-test and the result is presented at the bottom of Table 1). Still, at the bottom of the table, we also present the estimated aggregate elasticity.

The estimation gives an equal weight to all countries; thus, as a robustness check we dropped observations with small trade flows. Table 1 shows the estimates for 99% of the sample and 97.5% of the sample. The 99% and 97.5% samples were constructed in the following way: in each sector, we ranked the countries according to the share of trade they contribute in that particular sector. We dropped the countries with the lowest 1% share and re-estimated the trade elasticity. Then we dropped the lowest 2.5%. As we compare across estimates, we note that three sectors are not

40. Of course, as any estimation of trade elasticities from bilateral trade and tariff data, our method is subject to the endogenous trade policy concern (Trefler, 1993; Baier and Bergstrand, 2007). Still, our triple differencing might alleviate some of these concerns given that the estimates we obtain are comparable to the range of previous elasticity estimates done with different methods and different data.

41. We estimate equation (23) by OLS, dropping the observations with zeros. Zeros in the bilateral trade matrix are very frequent and several studies are focused on understanding how robust the estimates of trade elasticities are if zeros are taken into account. For instance, Santos-Silva and Tenreyro (2010).

TABLE 1
Dispersion-of-productivity estimates

Sector	Full sample			99% sample			97.5% sample		
	θ^j	s.e.	N	θ^j	s.e.	N	θ^j	s.e.	N
Agriculture	8.11	(1.86)	496	9.11	(2.01)	430	16.88	(2.36)	364
Mining	15.72	(2.76)	296	13.53	(3.67)	178	17.39	(4.06)	152
Manufacturing									
Food	2.55	(0.61)	495	2.62	(0.61)	429	2.46	(0.70)	352
Textile	5.56	(1.14)	437	8.10	(1.28)	314	1.74	(1.73)	186
Wood	10.83	(2.53)	315	11.50	(2.87)	191	11.22	(3.11)	148
Paper	9.07	(1.69)	507	16.52	(2.65)	352	2.57	(2.88)	220
Petroleum	51.08	(18.05)	91	64.85	(15.61)	86	61.25	(15.90)	80
Chemicals	4.75	(1.77)	430	3.13	(1.78)	341	2.94	(2.34)	220
Plastic	1.66	(1.41)	376	1.67	(2.23)	272	0.60	(2.11)	180
Minerals	2.76	(1.44)	342	2.41	(1.60)	263	2.99	(1.88)	186
Basic metals	7.99	(2.53)	388	3.28	(2.51)	288	−0.05	(2.82)	235
Metal products	4.30	(2.15)	404	6.99	(2.12)	314	0.52	(3.02)	186
Machinery n.e.c.	1.52	(1.81)	397	1.45	(2.80)	290	−2.82	(4.33)	186
Office	12.79	(2.14)	306	12.95	(4.53)	126	11.47	(5.14)	62
Electrical	10.60	(1.38)	343	12.91	(1.64)	269	3.37	(2.63)	177
Communication	7.07	(1.72)	312	3.95	(1.77)	143	4.82	(1.83)	93
Medical	8.98	(1.25)	383	8.71	(1.56)	237	1.97	(1.36)	94
Auto	1.01	(0.80)	237	1.84	(0.92)	126	−3.06	(0.86)	59
Other Transport	0.37	(1.08)	245	0.39	(1.08)	226	0.53	(1.15)	167
Other	5.00	(0.92)	412	3.98	(1.08)	227	3.06	(0.83)	135
Test equal parameters			$F(17, 7294) = 7.52$				$\text{Prob} > F = 0.00$		
Aggregate elasticity	4.55	(0.35)	7212	4.49	(0.39)	5102	3.29	(0.47)	3482

robust since they changed sign as we restricted the sample.[42] These sectors are Basic metals, Machinery n.e.c., and Auto.[43]

Our estimates are in the range of the trade elasticities estimated in the literature.[44] Our benchmark estimates are the estimates presented in Table 1 for the 99% sample, since they control for outliers. For the sectors Basic metals, Machinery n.e.c., and Auto, we replace them by the mean estimate for the manufacturing sector. We also re-estimated the dispersion parameters including importer and exporters fixed effects as an additional robustness check. The results appear in Table A2, Appendix "Additional Results."

42. For the case of Chemicals China was an outlier. The estimates including China were 1.39 for the full sample, −0.64 for the 99% sample and −0.93 for the 97.5% sample. The numbers without China are presented in the table. China represented 5% of the share of trade in that sector.

43. Machinery n.e.c. corresponds to manufacture of electrical machinery and apparatus not elsewhere classified.

44. The magnitudes of the sectoral trade elasticities are within the range of the coefficient estimated by Eaton and Kortum, (2002) for the manufacturing sector as a whole using data from 1990. Their estimate ranged between 3.60 and 12.86, and their preferred estimate is 8.28. Other studies, *e.g.*: Anderson *et al*. (2005) document that the average elasticity is 17. Broda and Weinstein (2006) find that the simple average of the elasticities is 17 at the seven-digit (TSUSA), 7 at the three-digit (TSUSA), 12 at the ten-digit (HTS), and 4 at the three-digit (HTS) goods disaggregation. Clausing (2001) and Head and Ries (2001) find values between 7 and 11.4, Romalis (2007) finds values between 4 and 13. Bishop (2006) estimates the trade elasticity for the steel industry and finds values between 3 and 5. Yi (2003) compares several models and finds that to match the bilateral trade flows in the data, the Armington-type models need a value of elasticity of 15. Imbs and Méjean (2011) make the point that the "true" elasticity of substitution is more than twice the elasticity implied by the aggregate data. Hertel *et al*. (2003) estimate sectoral trade elasticities between 3 and 30.

5. QUANTIFYING THE TRADE AND WELFARE EFFECTS OF NAFTA

In this section, we evaluate the trade and welfare effects from the change in the tariff structure caused by NAFTA. Our base year is 1993, the year before the agreement came into force. We use data from different sources in order to calibrate the model to the base year. The criterion was to maximize the number of countries covered in our sample conditional on obtaining reliable tariff, production, and trade flows data. We end up with a sample of $N=31$, 30 countries and a constructed rest of the world, and $J=40$ sectors (20 tradable and 20 non-tradable). We now provide a short list with the data sources. Appendix "Data Sources and Description" provides a detailed description of all the sectoral and aggregate data used in this article.

Bilateral trade flows are sourced from the United Nations Statistical Division (UNSD) Commodity Trade (COMTRADE) database. Gross output and value added come from three different sources. From OECD STAN database for industrial analysis, the Industrial Statistics Database INDSTAT2, and the OECD Input-Output database. I–O tables are sourced from the World Input–Output Database (WIOD) and the OECD Input–Output Database.[45] Finally, ad-valorem tariffs for the years 1993 and 2005 are obtained from the United Nations Statistical Division, Trade Analysis and Information System (UNCTAD-TRAINS). We calibrate the model following the calibration strategy described in Section 3.3, and use the trade elasticities, θ^j sourced from the estimates presented in Table 1, column 5, to quantify the effects of tariff changes.

We quantify the economic effects of NAFTA's tariff changes performing two different but equally informative counterfactual exercises. In the first counterfactual exercise we introduce into the model the change in the tariff structure from 1993 to the year 2005 between NAFTA members and fix the tariff structure for the rest of the world to the levels in 1993. This counterfactual measures the effect of NAFTA's tariff reductions conditional on no other tariff changing. In the second counterfactual we measure the effects of NAFTA by quantifying the gains from NAFTA's tariff reductions given observed world tariff changes. We do this in the following way. First, we introduce into the model the observed change in world tariff structure from 1993 to the year 2005. Of course, the world tariff structure in 2005 incorporates the change in tariffs applied by NAFTA and all other bilateral, and multilateral, tariff changes.[46] With this exercise, we measure the economic effects of observed world tariff changes. We then recalibrate the model to the year 1993 and introduce the observed change in world tariff structure from 1993 to the year 2005 holding NAFTA tariffs fixed to the year 1993. With this exercise, we measure the economic effects of observed world tariff changes excluding the change in tariffs as a consequence of NAFTA. We then compare the gains between these two exercises, namely the gains from world tariff reductions with and without NAFTA.

Before we present the results it is important to note that with our calibration strategy the model matches exactly the base year. This means that if countries have an aggregate trade deficit the model is also going to account for the trade deficit in the base year. However, counterfactual changes to trade policy are not going to adjust the aggregate trade deficit given that they are exogenous to the model. We need to deal with this and we do so in two different ways. First,

45. It is worth noticing that in general, I–O tables distribute imports to sectors using the assumption that the distribution is the same as for domestic production in the sector. Future work might want to incorporate domestic and foreign intermediate import shares into the analysis and evaluate how important is this distinction for the trade and welfare effects of tariff changes.

46. The change in the tariff structure between NAFTA members is a consequence of signing NAFTA. However, the change in tariffs that NAFTA members applied to the rest of the world and the one the rest of the world applied to NAFTA has many consequences. As we documented earlier, NAFTA members signed independently free trade agreements with other countries. Moreover, given that we are using a model with 31 countries, many countries reduced tariffs between each other over this period, we account for this as well.

TABLE 2
Welfare effects from NAFTA's tariff reductions

Country	Welfare: Total	Terms of trade	Volume of Trade	Real wages
Mexico	1.31%	−0.41%	1.72%	1.72%
Canada	−0.06%	−0.11%	0.04%	0.32%
U.S.	0.08%	0.04%	0.04%	0.11%

we eliminate all aggregate deficits by first calibrating the model with trade deficits and then solving the model imposing zero aggregate deficit, $D'_n = 0$. We then use the implied no-deficit world economy as our base year. Secondly, we calibrate the model with aggregate deficits to the year 1993 and then calculate all counterfactuals holding the countries aggregate trade deficits constant, as a share of world GDP. We compute all the counterfactual exercises using both solution strategies but present in the main text only the results with no aggregate deficit in the base year. The Appendix "Additional Results" shows a variety of additional results including the case where aggregate trade deficits remain fixed as a share of world GDP.

5.1. *Trade and welfare effects from NAFTA's tariff reductions*

We now quantify the trade and welfare effects of NAFTA. Table 2 presents the welfare effects from NAFTA's tariff reductions while fixing the tariff to and from the rest of the world to the year 1993. Welfare effects are calculated using equation (16), and changes in real wages using equation (15). As we can see, Mexico's welfare increases by 1.31%. The effects for Canada and the U.S. are smaller. Canada loses 0.06% whereas the U.S. gains 0.08%. Still, we find that real wages increase for all NAFTA members and Mexico gains the most, followed by Canada and the U.S.[47]

Decomposing the welfare effects into terms of trade and volume of trade underscores the sources of these gains. The third column in Table 2 shows that the major source of gains are increases in volume of trade. The welfare gains from trade creation for Mexico, Canada, and the U.S. are 1.72%, 0.04% and 0.04%, respectively. We can look deeper and measure the extent to which the welfare effects are a result of trade creation with NAFTA members vis-a-vis the rest of the world. This is done by applying the bilateral volume of trade measures equation (18) defined before.

Column 3 in Table 3 shows that the trade created with NAFTA members is the single most important contributor to the positive welfare effects. The figures are 1.80%, 0.08%, and 0.04% for Mexico, Canada, and the U.S., respectively. This result unmasks an important channel by which NAFTA generated positive welfare effects to all of its members, by creating more trade within the bloc. On the other hand, column 4 from Table 3 shows that the reduction in volume of trade with the rest of the world has a negative welfare effect. This negative welfare effect, which we discuss further below, arises from NAFTA diverting trade from countries outside of the agreement.

Another source of welfare effects are changes in terms of trade. From column 2 of Table 2, we can see that Mexico and Canada's terms of trade deteriorate whereas the U.S. terms of trade

47. The welfare effects results in the model with trade deficits are very similar, 1.17%, −0.04%, and 0.09% for Mexico, Canada, and the U.S., respectively. Appendix "Additional Results", Tables A4–A7, includes this and additional results with trade deficits and it shows that all the results in this section are robust to include trade deficits or not.

TABLE 3
Bilateral welfare effects from NAFTA's tariff reductions

	Terms of trade		Volume of Trade	
Country	NAFTA	Rest of the world	NAFTA	Rest of the world
Mexico	−0.39%	−0.02%	1.80%	−0.08%
Canada	−0.09%	−0.02%	0.08%	−0.04%
U.S.	0.03%	0.01%	0.04%	0.00%

improve. One way to understand this differential effect is by looking at how export prices change in each country. From equation (10), notice that the change in unit costs, or the change in export prices, are an increasing function of input prices; namely wages and the price of materials. The last column of Table 2 shows that real wages increase for all NAFTA members but relatively more for Mexico and Canada compared to the U.S. So, all else equal, the increase in wages increase export prices. However, from equation (11) note that, all else equal, the price of materials fall with reductions in import tariffs. Therefore, export prices change according to how large is the increase in wages relative to the fall in the price of materials. It turns out that the average export prices across sectors fall by 2% and 0.6% for Mexico and Canada and increase by 0.1% for the U.S. If we now factor in that most trade between NAFTA members is with other NAFTA members, then this explains why terms of trade deteriorate for Mexico and Canada and increase for the U.S.

Table 3, columns 2 and 3, present the bilateral terms of trade changes with respect to NAFTA members and the rest of the world using equation (17). As we can see, Mexico and Canada's terms of trade deteriorate against both group of countries, but mostly with NAFTA countries. For the U.S. the story is different. Terms of trade improve with respect to all countries. However, the terms of trade improve relatively more against NAFTA members since the U.S. mostly sources intermediate goods from Mexico and Canada, countries that experience a reduction in export prices.

Table 4 presents the sectoral contribution to the aggregate terms of trade and volume of trade effects for each NAFTA member. These figures are calculated for each sector j as $d\ln tot_n^j/\sum_{j=1}^J d\ln tot_n^j$ and $d\ln vot_n^j/\sum_{j=1}^J d\ln vot_n^j$ using the sectoral measures defined in equations (19) and (20). As we can see, there is considerable variation in the sectoral contribution to the aggregate effects. Still, the aggregate change in terms of trade in each country is explained by a handful of sectors. The three sectors that contribute the most to Mexico's terms of trade deterioration account for 76% of the reduction. These sectors are Electrical Machinery, Communication Equipment, and Auto (Motor Vehicles). These same three sectors are also the sectors that contribute the most to U.S.'s terms of trade change accounting for 51% of the increase. In the case of Canada, the three sectors that contribute the most to the change in terms of trade account for 52.5% of the reduction. These sectors are, Auto, Other Transport, and Basic Metals. The main explanations why certain sectors have a large aggregate effect compared to others are the magnitude of the reduction in import tariffs, how large is the share of materials used in production, and how important are sectoral linkages.

To see this, consider the case of Mexico and U.S. From the previous discussion we know that Mexico's terms of trade deteriorate mainly as a consequence of the reduction in export prices and that most trade is with NAFTA, in particular with the U.S. Similarly, since the U.S. mostly imports goods from Mexico, and Mexican export prices fall, this is the first order effect why the U.S. aggregate terms of trade improve. So to understand why certain sectors contribute more to the aggregate terms of trade changes in Mexico and the U.S. we need to understand

TABLE 4
Sectoral contribution to welfare effects from NAFTA's tariff reductions

Sector	Mexico		Canada		United States	
	Terms of trade	Volume of trade	Terms of trade	Volume of trade	Terms of trade	Volume of trade
Agriculture	−0.13%	2.87%	3.41%	−0.01%	3.41%	0.65%
Mining	−3.01%	0.25%	4.04%	−0.20%	1.54%	0.04%
Manufacturing						
Food	0.45%	1.17%	3.56%	2.37%	3.16%	1.04%
Textile	3.30%	12.00%	1.15%	16.20%	4.32%	22.20%
Wood	0.30%	2.26%	4.17%	0.24%	1.31%	0.41%
Paper	0.39%	3.82%	5.86%	0.49%	2.83%	0.33%
Petroleum	−0.09%	14.60%	0.60%	30.40%	1.85%	11.40%
Chemicals	0.57%	2.15%	5.74%	0.08%	5.60%	1.11%
Plastic	0.62%	4.21%	2.53%	7.56%	1.61%	0.32%
Minerals	0.05%	0.73%	0.93%	0.47%	0.70%	0.57%
Basic metals	1.07%	3.02%	10.10%	1.48%	3.40%	1.05%
Metal products	0.90%	5.56%	2.22%	7.99%	1.61%	1.06%
Machinery n.e.c.	3.68%	4.32%	5.16%	−0.02%	5.63%	0.65%
Office	8.37%	4.72%	2.32%	−0.83%	3.50%	1.43%
Electrical	41.20%	25.80%	1.37%	7.18%	24.20%	42.20%
Communication	21.00%	3.64%	2.67%	0.15%	11.60%	4.58%
Medical	4.72%	1.34%	0.94%	−0.23%	3.48%	4.46%
Auto	13.80%	4.78%	29.50%	27.80%	15.80%	4.47%
Other Transport	0.21%	0.82%	12.90%	−0.97%	1.51%	0.32%
Other	2.63%	1.92%	0.81%	−0.11%	2.90%	1.69%

why export prices in these sectors fall so much as a consequence of NAFTA.[48] There are three reasons for this. First, the average tariffs applied by Mexico to imports from Canada and the U.S. on Electrical Machinery, Communication Equipment, and Autos in the year 1993 were 13.4%, 14.9%, and 15.5%, respectively. These sectors were not the sectors with the largest import tariffs but still larger than the average (12.4%), and the median (13.2%), import tariff applied across all sectors. Secondly, the share of materials used in production is 82% for the case of Electrical Machinery and Communication Equipment, and 73% for Autos. These figures are considerably larger than the average (49%), and the median (48.3%), share of material use in production for the rest of the sectors in the Mexican economy. Finally, these sectors are very interrelated. The shares of Electrical Machinery and Communication Equipment used for the production of Electrical Machinery are 37% and 3%, whereas for the production of Communication Equipment the shares are 53% and 7%. Therefore, the reduction in import tariffs in these sectors explain part of the effect on prices. The rest is explained by the fact that a reduction in the unit cost of production in any of these sectors has a multiplicative effect because of the strong I–O feedback that these sectors present. Also, a large share of material use in production makes, other things equal, reductions in import tariffs across sectors to have a larger impact in export prices in these sectors compared to the rest.

From Table 4 we can also learn how the sectoral contribution to the aggregate change in volume of trade varies across NAFTA members. The first thing to note is that for the case of Mexico and the U.S., every sector has a positive contribution to the welfare increase from volume of trade. Three sectors account for more than 50% of the sectoral contribution of Mexico's and U.S.'s volume of

48. In fact, trade weighted export prices of Electrical Machinery, Communication Equipment, and Autos fall by 6.6%, 3.5%, and 5.6% in Mexico; the largest reductions across all sectors.

TABLE 5
Trade effects from NAFTA's tariff reductions

	Mexico	Canada	U.S.
Mexico's imports	-	116.60%	118.31%
Canada's imports	58.57%	-	9.49%
U.S.'s imports	109.54%	6.57%	-

trade. These are Textiles, Petroleum, and Electrical Machinery. For the case of Canada, the sectors that contribute the most are Textiles, Petroleum, and Auto. In general, volume of trade effects depend on the magnitude of the tariff reduction, the trade elasticity, and the share of materials used in production and these factors weight differently for each of these sectors. Textiles was the most protected sector by Mexico in the year 1993. Applied import tariffs were on average 18%. So the large reduction in tariffs facilitates trade between members of NAFTA and results in a significant contribution to the increase in volume of trade. Petroleum is a homogenous good sector. As a consequence, small changes in import tariffs can have large trade effects since it is relatively easy to substitute suppliers, as documented by its high import tariff trade elasticity (see Table 1). The average import tariffs in Petroleum in the year 1993 across NAFTA members was 7%. Finally, NAFTA's tariffs reductions has important effects over the price of intermediate goods traded in some sectors compared to others. This is particularly important for the sectors Electrical Machinery and Autos for reasons we discussed in the previous paragraph. The reduction in trade prices in these sectors explains the increase in the volume of trade effect.

Table 5 presents aggregate trade effects from NAFTA. As we can see, NAFTA generated large aggregate trade effects for all members. Mexico's imports from NAFTA increased by more than 110% and equally so across both partners. For the case of Canada, we find that the percentage increase in imports from Mexico is more than five times larger than the percentage increase in imports from the U.S. This results reflect that Mexico's role as a supplier of intermediate goods to NAFTA members increased as a consequence of NAFTA. In fact, this is even more evident when we look at the case of the U.S. imports. Imports from Mexico increase more than 100% whereas from Canada only 6.57%. These figures reflect how interdependent these economies become after the tariff reductions imposed by the agreement. In short, NAFTA strengthened the trade dependence that these countries had before the agreement, and as a consequence Canada and the U.S. source more goods from Mexico, whereas Mexico sources more goods from Canada and the U.S.

NAFTA also had an effect on sectoral specialization. Table 6 presents export shares by industry before and after reducing NAFTA's tariffs. First, note that sectoral concentration varies considerably across sectors and countries. Consider the case of Mexico before NAFTA, the year 1993. Three sectors account for 52.75% of total exports. These sectors are Electrical Machinery, Autos, and Mining. For the case of Canada, the three sectors with the largest shares are Autos, Basic Metals, and Mining, and account for 43.7% of total exports. Whereas for the U.S. the three largest sectors are Machinery, Chemicals, and Autos, and account for 28.57% of total exports. These figures reflect that Mexico was the country with the highest degree of sectoral specialization whereas the U.S. the most diversified. In fact, the last row of the table presents the normalized Herfindahl index (henceforth, HHI) and we make use of it as a measure of sectoral specialization. As we can see, the HHI for Mexico was the largest and twice as large as the U.S. HHI, the smallest among all NAFTA members. After NAFTA's tariffs reductions we find that Mexico became more specialized whereas Canada and the U.S. more diversified. In fact, Mexico's share of exports from Electrical Machinery increase to 34.07% and the three largest sectors account for 54.95%

TABLE 6
Export shares by sector before and after NAFTA's tariff reductions

	Mexico		Canada		U.S.	
Sector	Before	After	Before	After	Before	After
Agriculture	4.72%	3.03%	4.99%	5.04%	6.91%	6.35%
Mining	15.53%	7.85%	8.99%	8.96%	1.72%	1.52%
Manufacturing						
Food	2.33%	1.48%	4.82%	4.68%	5.09%	4.73%
Textile	4.42%	6.92%	1.05%	1.49%	2.68%	3.49%
Wood	0.59%	0.52%	8.12%	8.05%	2.02%	1.98%
Paper	0.62%	0.51%	8.34%	8.44%	4.99%	4.89%
Petroleum	1.62%	5.28%	0.59%	0.78%	4.30%	5.71%
Chemicals	4.40%	2.53%	5.58%	5.40%	10.00%	9.25%
Plastic	0.80%	0.48%	2.06%	2.06%	2.28%	2.43%
Minerals	1.32%	0.84%	0.81%	0.78%	0.94%	0.92%
Basic metals	3.24%	2.00%	10.29%	10.19%	3.05%	3.11%
Metal products	1.22%	1.03%	1.47%	1.53%	2.23%	2.59%
Machinery n.e.c.	4.30%	2.53%	4.69%	4.49%	10.37%	9.70%
Office	3.34%	5.07%	2.44%	2.54%	7.70%	7.29%
Electrical	20.79%	34.07%	2.50%	2.35%	6.07%	7.97%
Communication	8.57%	7.08%	3.11%	3.02%	7.19%	6.81%
Medical	2.48%	3.28%	0.98%	1.03%	5.16%	4.79%
Auto	16.43%	13.05%	24.42%	24.07%	8.20%	8.09%
Other Transport	0.28%	0.26%	3.21%	3.58%	7.32%	6.65%
Other	3.02%	2.20%	1.55%	1.52%	1.77%	1.74%
Normalized Herfindahl	0.092	0.138	0.083	0.081	0.042	0.040

of total exports after NAFTA. This sectoral concentration is reflected in Mexico's HHI which increases to 0.138. On the other hand, the HHI indices of Canada and the U.S. decrease.[49]

The rest of the world was hardly affected by NAFTA's tariff reductions. Table A3 in Appendix "Additional Results", which we do not include in the main text for brevity, presents the change in welfare, terms of trade and volume of trade effects for the rest of the 28 countries in our sample. The effects are small. The two countries most impacted are China and Korea and in both cases welfare falls by 0.03%. This is mostly due to a reduction in the volume of trade for the case of China, and an equal reduction in the terms of trade and volume of trade for the case of Korea. Looking at other countries we find that volumes of trade decreased for most cases. These results are suggestive of countries having a negative impact from NAFTA mainly due to trade diversion towards NAFTA members. Still, the impact is small.

We now turn to the analysis of the effects of NAFTA given world tariff changes.

5.2. *The effects of NAFTA given world tariff changes*

From 1993 to 2005 more than 100 regional trade agreements entered into force.[50] Of these agreements, several involved NAFTA members. Since NAFTA was active during this process

49. Many factors, besides NAFTA, could have influenced the pattern of sectoral specialization in the data. Still, the pattern of sectoral specialization implied by the model from NAFTA's tariff reductions for NAFTA members is in line with the observed pattern in the year 2005. In fact, the correlations are 0.59, 0.86, and 0.83 for Mexico, Canada, and the U.S., respectively.

50. This figure was computed using the list of agreements in force from 1993 to 2005 from the WTO-RTA Database, (http://rtais.wto.org/).

TABLE 7
Welfare effects from world tariff reductions

Country	Welfare	Terms of trade	Volume of trade	Country	Welfare	Terms of trade	Volume of trade
Argentina	0.58%	0.10%	0.48%	Ireland	0.19%	−0.04%	0.23%
Australia	0.30%	−0.01%	0.31%	Italy	0.10%	−0.05%	0.15%
Austria	2.02%	0.38%	1.64%	Japan	0.21%	0.13%	0.08%
Brazil	0.32%	−0.10%	0.43%	Korea	0.20%	−0.21%	0.40%
Canada	0.10%	−0.08%	0.17%	Mexico	1.36%	−0.40%	1.76%
Chile	0.26%	−0.52%	0.78%	Netherlands	0.10%	−0.07%	0.16%
China	13.90%	−1.68%	15.57%	New Zealand	0.71%	−0.14%	0.84%
Denmark	0.08%	−0.13%	0.21%	Norway	0.54%	0.34%	0.20%
Finland	0.78%	0.12%	0.66%	Portugal	12.70%	11.48%	1.21%
France	0.25%	0.10%	0.15%	South Africa	1.87%	0.04%	1.83%
Germany	0.12%	−0.03%	0.15%	Spain	0.67%	0.49%	0.18%
Greece	1.15%	1.01%	0.13%	Sweden	0.84%	0.38%	0.46%
Hungary	1.63%	−0.16%	1.78%	Turkey	0.53%	0.20%	0.33%
India	3.64%	−0.72%	4.36%	U.S.	0.22%	0.11%	0.11%
Indonesia	1.91%	−0.54%	2.46%	U.K.	0.04%	−0.11%	0.15%
				ROW	2.83%	−0.22%	3.05%

of trade liberalization, we can evaluate to what extent the economic effects of NAFTA's tariff reductions were influenced by world tariff changes. To that end, we first use observable changes in tariffs and quantify the global effects from world tariff reductions, including the change in NAFTA's tariffs.

Table 7 presents the welfare effects for the 31 countries in our sample. As we can see, every single country gained from world tariff reductions. The largest winner was China, with a welfare gain of 13.9%.[51] The most important source of these gains for China are the increased volume of trade. This is also the case for most countries in the sample. Focusing on NAFTA members, all countries gained more compared to the case where only NAFTA tariff change. In the case of Canada, the gains are 0.10% and most of the gains arise from an increase in trade volumes. For the case of Mexico, the gains are similar, 1.36% compared to 1.31%, but the source is slightly different. Terms of trade deteriorate less, -0.40% compared to -0.41%, and volume of trade increase more, 1.76% instead of 1.72%. For the case of the U.S., the gains are considerably larger, 0.22% compared to 0.08%.

We also decompose the welfare effects into bilateral measures of terms of trade and volume of trade with respect to NAFTA members and the rest of the world. Table 8 shows the results for Mexico, Canada, and the U.S. We find that volume of trade effects with respect to the rest of the world increase. This is a key difference relative to the case where only NAFTA tariffs changed; compare the last columns from Tables 3 and 8. In fact, this reflects that trade was created with the rest of the world after NAFTA was in force, due in part to the reduction of world tariffs.

Focusing on other outcomes, Table 8 also shows that the terms of trade improvements for the U.S. are now mostly with countries outside NAFTA. In the case of Canada, the terms of trade effects are still negative with respect to NAFTA members, but now switched to positive with respect to other countries. These figures explain why Canada and the U.S. gained more from

51. The welfare gains in Table 7 are calculated using equation (16). We can use the model to understand more the source of the welfare gains for each country. For the case of China, we find that the gains due to the reduction in import tariffs that the rest of the world applied to China, are 13.4%. The gains from the reduction of China's import tariffs are 0.08%. Whereas if China's import and export tariffs did not changed it would have lost -0.16%.

TABLE 8
Bilateral welfare effects from world's tariff reductions

	Terms of trade		Volume of Trade	
Country	NAFTA	Rest of the world	NAFTA	Rest of the world
Mexico	−0.39%	−0.01%	1.64%	0.13%
Canada	−0.10%	0.02%	0.05%	0.12%
U.S.	0.03%	0.08%	0.04%	0.08%

TABLE 9
Welfare effects from NAFTA given world tariff changes

	Welfare			
Country	Total	Terms of trade	Volume of trade	Real wages
Mexico	1.17%	−0.38%	1.55%	1.63%
Canada	−0.06%	−0.09%	0.03%	0.31%
U.S.	0.08%	0.04%	0.04%	0.11%

global tariff reductions relative to only NAFTA tariff reductions. The results on terms of trade effects for Mexico are similar than before.

We also measured the sectoral contribution to the aggregate terms of trade and volume of trade effects for NAFTA members.[52] The salient difference, compared to the case where only NAFTA tariffs changed, is that for Canada the volume of trade effects are positive in almost all sectors, and that Textiles is the sector that contribute the most to welfare for Canada and the U.S. The main reason for this result is their bilateral volume of trade effect with respect to China. Regarding the sectoral specialization of export shares, qualitatively we find similar results as before. Namely, that Mexico became more specialized, whereas Canada and the U.S. more diversified. However, quantitatively we find that Mexico's HHI increased less, to 0.133, whereas the HHI of Canada and U.S. decreased more, to 0.079 and 0.04, respectively. These results reflect once again how sectoral variations in tariffs can have important effects for sectoral specialization.

We now recalibrate the model to the year 1993 and introduce the observed change in world tariff structure from 1993 to the year 2005 holding NAFTA tariffs fixed. In this way, we measure the economic effects of all observed world tariff changes excluding the reduction in NAFTA's tariffs. After this, we compare the gains from world tariff reductions with and without NAFTA. In other words, the effects of NAFTA given world tariff changes. Table 9 presents the welfare effects. As we can see, welfare and real wage changes for Canada and the U.S. are almost identical to the ones we find in the previous subsection, Table 2. For the case of Mexico, the welfare effects and real wage effects are somehow smaller. The main reason for this lower gains is that volume of trade effects are lower, 1.55% instead of 1.80%.

As we did before, we can make use of the bilateral measure of terms of trade to identify the reason why Mexico's volume of trade effects fall. We find that this is a consequence of the reduction in volume of trade effects with respect to the rest of the world, not with respect to NAFTA members. Table 10 presents these results. As we can see, Mexico's volume of trade

52. Table A8 in Appendix "Additional Results" presents these results. Table A9 reports the trade effects for NAFTA members from world tariff reductions. It shows that intra-bloc import growth are lower compared to the case when only NAFTA tariffs changed. We omit both tables from the main text for brevity.

TABLE 10
Bilateral welfare effects from NAFTA given world tariff changes

Country	Terms of trade		Volume of Trade	
	NAFTA	Rest of the world	NAFTA	Rest of the world
Mexico	−0.37%	−0.01%	1.78%	−0.23%
Canada	−0.08%	−0.01%	0.08%	−0.05%
U.S.	0.03%	0.01%	0.04%	0.00%

effects fall by 0.23% with the rest of the world. Therefore, we find a larger negative effect due to trade diversion compared to the case when only NAFTA's tariff changed, last column of Table 3. The logic of this result is as follows. When we evaluate the effects of NAFTA holding world tariffs fixed, trade is diverted from the lowest cost supplier outside NAFTA to a new lower cost supplier inside the bloc, because of the lower tariffs. Now, as we also allow tariffs with respect to the rest of the world to change, there is a larger pool of lowest cost suppliers in the world that Mexico is not getting access to, because of low NAFTA tariffs. In this sense, what the model is measuring is the implied trade diversion from NAFTA. Said differently, the change in world tariffs has raised the opportunity cost, measured by the volume of trade effect, of belonging to NAFTA.[53]

5.3. *The effects of NAFTA across different models*

We now quantify the role that different mechanisms in our model have at explaining the results. We compare the results from our model (Benchmark) to a one-sector model (One sector), a multi-sector model with no materials used in production (No materials), and with no I–O connections (No I–O).[54] We calibrate each of these models to the year 1993 and compute the welfare and trade responses from NAFTA's tariff reductions. Table 11 presents the simulated trade and welfare effects implied by the different models. The first column shows the welfare effect from the one-sector model. The second column presents the welfare result for the no materials model, and the third column presents the welfare result for the no I–O model.

We find that for all models the welfare effects are smaller compared to the benchmark model. Still, in all cases Mexico gains the most followed by the U.S. then Canada. The results one-sector model reflect the importance of accounting for sectoral heterogeneity. In fact, recent studies have emphasized that the sectoral variation in trade elasticities is particularly important for the

53. Tables A10–A13 in Appendix "Additional Results" presents additional welfare and trade effects at the aggregate and sectoral level. Overall, we find that the results are similar to the case when only NAFTA's tariff change, Section 5.1. We also performed an additional counterfactual exercise to quantify how the welfare gains from NAFTA compare to a unilateral tariff elimination by each member. We do this exercise calibrating the model to the year 1993 and then, for each NAFTA member independently, we reduce their import tariffs to zero with respect to every country in the world. As a result, we find a welfare increase of 0.54% for Mexico and a welfare loss of 0.03% and 0.02% for Canada and the U.S., respectively. Real wage increase by 1.53%, 0.60%, and 0.19%, for Mexico, Canada, and the U.S. These welfare effects are due to the standard optimal tariff reasons.

54. The one-sector model has one tradable sector and one non-tradable sector. Production uses materials from both sectors, (I-O). We agregate all sectoral data to calibrate the parameters and use the median tariff across sectors. We use our specification (23) to estimate an aggregate elasticity, the value is $\theta = 4.5$. In the multi-sector model "No materials" there are no materials used in production, $\gamma_n^j = 1$, and as a result value added is equal to gross output. In the multi-sector model "No I-O", materials are used in production, $\gamma_n^j < 1$, but we zero out the off-diagonal elements of the I–O matrix. Firms can only use materials sourced from the same sector they operate, $\gamma_n^{j,j} = 1 - \gamma_n^j$. We use I–O tables for each country to calibrate $\gamma_n^{j,j}$. For all cases, we first calibrate the model and then eliminate the observed aggregate trade deficits.

TABLE 11

Trade and welfare effects from NAFTA across different models

	Welfare			Imports growth from NAFTA members			
		Multi-sector			Multi-sector		
Country	One sector	No materials	No I–O	One sector	No materials	No I–O	Benchmark
Mexico	0.41%	0.50%	0.66%	60.99%	88.08%	98.96%	118.28%
Canada	−0.08%	−0.03%	−0.04%	5.98%	9.95%	10.14%	11.11%
U.S.	0.05%	0.03%	0.04%	17.34%	26.91%	30.70%	40.52%

quantification of the welfare gains.[55] The calculations also show that intermediate goods amplify the welfare effects from tariff reductions. Mexico's figure increase from 0.50% to 0.66%, Canada's deteriorate more from −0.03% to −0.04% and the U.S. increase from 0.03% to 0.04% as we move from a model with no materials to a model with materials. We also find that the model with I–O linkages amplifies the effects as well. If we compare the third column on Table 11 to the results from the benchmark model, Table 2, we can clearly see that the welfare effects are substantially larger for the countries that win and lower for the countries that loose.

Trade effects are also smaller across these models compared to the benchmark case. The last four columns of Table 11 presents, for the case of Mexico, Canada, and the U.S., the change in imports from NAFTA members implied by the different models. As we can see, the trade effects are reduced substantially compared to the benchmark case. In the one-sector model, the trade responses are almost reduced by half. The intuition for this result relates to the result on welfare. By averaging out the effects, a one-sector model fails to capture the large increase in trade flows from certain sectors. In fact, we know from Tables 4 and 6 that NAFTA generated very heterogenous responses across sectors. If we compare the results from column five to column six we can see that adding intermediate goods increases the trade effects. The intuition for this result is as follows. In the model with no materials, goods are only traded to produce final goods for consumption and not for the production of intermediate goods. However, in the no I–O model, materials are also used for the production of intermediate goods. Therefore, a tariff reduction delivers a larger trade effect due to the increase in demand of tradable goods for the production of intermediates. Finally, we can also compare the implied changes in trade flows from a model with intermediate goods in production but no sectoral linkages, the no I–O model, to the benchmark case. The trade effects from tariff reductions are lower in the no I–O model than in the model with sectoral interrelations (Benchmark). The reason is that since producers are only using inputs from one sector they are not exploiting the benefits of having access to cheaper materials from other sectors. This in turn delivers a smaller trade effect from tariff changes. In short, the results from this subsection unmask the importance of accounting for sectoral heterogeneity, intermediate goods in production and I–O linkages to evaluate the trade and welfare gains from tariff changes, in general, and in particular for the case of NAFTA.

6. CONCLUSION

This study develops a general equilibrium model to quantify the trade and welfare effects of tariff changes. The model is able to perform complex trade policy evaluations for an arbitrary number of

55. In a recent study, Ossa (2012) shows that the heterogeneity in trade elasticities per se has an important effect on the quantification of the welfare gains from trade. He shows this for the case of iceberg trade costs and by calculating welfare losses from reverting to autarky.

sectors and countries in a parsimonious way with few data and parameter requirements. Using the model, we decompose the different channels by which a reduction in tariffs can spread the gains across sectors in the economy. We show that accounting for sectoral interrelations is quantitatively and economically meaningful. With the model, one can quantify and decompose the effects that a reduction or increase in a tariff in a particular sector can have on the price of intermediate inputs in that sector and in the rest of the economy, the general equilibrium price effects of tariff reductions at home and abroad, the impact on factor allocations across sectors, the change in factor payments and the extent to which the structure of production of a particular economy can spread the gains from having access to cheaper intermediate goods and more efficient technology.

Evaluating the effects of NAFTA has receive considerable attention in the economic literature. Therefore, it is important to clarify how our results about NAFTA should be interpreted. We use the model to perform a model-based identification of the effects of NAFTA's tariff reductions. Unquestionably, NAFTA had more provisions than only reducing tariff between members and by no means our results should be interpreted as the trade and welfare effects of the entire agreement. For instance, non-tariff barriers or unobservable trade costs might also have changed as a consequence of NAFTA. Moreover, NAFTA might have even influenced the rate of technological change of each member. Certainly, we could have used the model to quantify what is the implied change in fundamental TFP and trade costs such that the model matches the trade patterns observed in the data. However, understanding how fundamental TFP changed as a consequence of NAFTA is outside of the scope of this article. In our model, fundamental TFP is exogenous and by holding it fixed during the period of analysis we are able to identify the pure direct effect of tariff reductions. Our study uses the case of NAFTA to show how the effects of tariff reductions are amplified as we take into account the interrelation across sectors observed in the data. We find that the trade and welfare effects from tariff reductions are lower if intermediate goods in production and I–O linkages are ignored in the analysis. With this results we hope to convey the message that modelling sectoral interrelations is not only feasible but also important for quantitative analysis.

APPENDIX

A. DISTRIBUTION OF PRICES AND EXPENDITURE SHARES

The efficiency of country n in producing an intermediate good ω^j in sector j is the realization of a random variable z_i^j drawn for each ω^j in each sector j from the distribution $F_n^j(z) = e^{-\lambda_n^j z^{-\theta^j}}$. Therefore, the cost of purchasing an intermediate good ω^j from country i, where we abuse of notation and denote by $p_{ni}^j(z_i^j)$, is the realization of the random variable $p_{ni}^j(z_i^j) = c_i^j \kappa_{ni}^j / z_i^j$. First note that $p_{ni}^j(z_i^j)$ has a Fréchet distribution, in particular

$$\Pr\left[p_{ni}^j \leq p\right] = 1 - e^{-T_{ni}^j p^{\theta^j}}, \tag{A1}$$

where $T_{ni}^j = \lambda_i^j (c_i^j \kappa_{ni}^j)^{-\theta^j}$. Given this, the lowest price of an intermediate good ω^j in country n, namely $p_n^j(\omega^j)$, has also a Fréchet distribution,

$$\Pr\left[p_n^j \leq p\right] = 1 - \prod_{i=1}^N \Pr\left[p_{ni}^j \geq p\right], \tag{A2}$$

and using equation (A1) we obtain

$$\Pr\left[p_n^j \leq p\right] = 1 - e^{-\Phi_n^j p^{\theta^j}}, \tag{A3}$$

where $\Phi_n^j = \sum_{i=1}^N T_{ni}^j = \sum_{i=1}^N \lambda_i^j (c_i^j \kappa_{ni}^j)^{-\theta^j}$. The object Φ_n^j plays a critical role in our model. It's a sufficient statistic of the states of technologies around the world, input costs, geographic barriers, and tariff policies. In Eaton and Kortum, (2002), this object is country specific, whereas in our model it is also sector specific. Note that Φ_n^j is correlated across sectors since sectors are interrelated and the input costs are functions of prices from all sectors. The shares $\gamma_n^{k,j}$ will determine the extent of the correlation. Note that in a non-tradable goods sector, since $\kappa_{in}^j = \infty$, $\Phi_n^j = \lambda_n^j (c_n^j)^{-\theta^j}$.

It is convenient to work with $p_n^j(\omega^j)^{\theta^j}$. Note that since $p_n^j(\omega^j)$ is Fréchet with shape parameter θ^j, then $p_n^j(\omega^j)^{\theta^j}$ has an exponential distribution. To see this, define the function $g(x) = x^{\theta^j}$ and suppose that x has a Fréchet distribution with location parameter Φ_n^j and shape parameter θ^j. Let $f_x(x)$ denote the density function of x, namely $f_x(x) = \theta^j \Phi_n^j x^{\theta^j - 1} e^{-\Phi_n^j x^{\theta^j}}$. It follows that the density function of $y = g(x)$ is given by $f_y(y) = f_x\left(g^{-1}(y)\right) \left|\frac{\partial g^{-1}(y)}{\partial y}\right|$. Then since $g^{-1}(y) = y^{\frac{1}{\theta^j}}$, and $\frac{\partial g^{-1}(y)}{\partial y} = \frac{1}{\theta^j} y^{\frac{1}{\theta^j} - 1}$, the density function of y is $f_y(y) = \Phi_n^j e^{-\Phi_n^j y}$, which is an exponential distribution with parameter Φ_n^j. Given this result, the price index is

$$(P_n^j)^{1-\eta^j} = \int \Phi_n^j y^{(1-\eta^j)/\theta^j} e^{-y\Phi_n^j} dy,$$

which follows since we have just derived that $y = p_n^j(\omega^j)^{\theta^j}$ has probability density function, $\Phi_n^j e^{-\Phi_n^j y}$. Now consider the change of variables $u = \Phi_n^j y$. Then $(P_n^j)^{1-\sigma^j} = (\Phi_n^j)^{-(1-\sigma^j)/\theta^j} \int u^{(1-\sigma^j)/\theta^j} e^{-u} du$, and finally

$$P_n^j = A^j \Phi_n^{j\ -1/\theta^j},$$

which is the same as equation (4), where $A^j = \Gamma\left(\xi^j\right)^{1/(1-\sigma^j)}$, and $\Gamma\left(\xi^j\right)$ is a Gamma function evaluated at $\xi^j = 1 + \left(1 - \sigma^j\right)/\theta^j$. For the case of a non-tradeable sector, $\Phi_n^j = \lambda_n^j (c_n^j)^{-\theta^j}$, and therefore $P_n^j = A^j \lambda_n^j (c_n^j)^{-\theta^j}$.

To derive the expenditure shares $\pi_{ni}^j = X_{ni}^j / X_n^j$, note that

$$X_{ni}^j = \Pr\left[\frac{c_i^j \kappa_{ni}^j}{z_i^j(\omega^j)} \leq \min_{h \neq i} \frac{c_h^j \kappa_{nh}^j}{z_h^j(\omega^j)}\right] X_n^j.$$

Then using equations (A1) and (A3), note that

$$X_{ni}^j = \frac{T_{ni}^j}{\Phi_n^j}\left[\int_0^\infty \Phi_n^j e^{-\Phi_n^j p^{\theta^j}} \theta^j p^{\theta^j - 1} dp\right] X_n^j = \frac{\lambda_i^j (c_i^j \kappa_{ni}^j)^{-\theta^j}}{\sum_{i=1}^N \lambda_i^j (c_i^j \kappa_{ni}^j)^{-\theta^j}} X_n^j,$$

and in this way obtain equation (6).

B. WELFARE

We present a detailed derivation of the expression for the change in welfare, equation (16).

Welfare is given by $W_n = \frac{w_n L_n}{P_n} + \frac{R_n}{P_n} + \frac{D_n}{P_n}$, where recall that $R_n = \sum_{j=1}^J \sum_{i=1}^N \frac{\tau_{ni}^j M_{ni}^j}{P_n}$. Totally differentiating welfare and assuming that exogenous trade deficits remain constant, $dD_n = 0$, and holding iceberg trade costs fixed, namely $d\ln \kappa_{ni}^j = d\ln \tilde{\tau}_{ni}^j$, we obtain

$$d\ln W_n = \frac{w_n L_n}{I_n} d\ln w_n + \frac{R_n}{I_n} d\ln R_n - d\ln P_n. \tag{B1}$$

Now, totally differentiating tariff revenue we obtain

$$dR_n = \sum\nolimits_{j=1}^J \sum\nolimits_{i=1}^N \tau_{ni}^j M_{ni}^j d\ln M_{ni}^j + \sum\nolimits_{j=1}^J X_n^j \sum\nolimits_{i=1}^N \pi_{ni}^j d\ln \tilde{\tau}_{ni}^j. \tag{B2}$$

Totally differentiating the consumption price index equation (5) we obtain,

$$d\ln P_n = \sum\nolimits_{j=1}^J \alpha_n^j d\ln p_n^j = \sum\nolimits_{j=1}^J \alpha_n^j \sum\nolimits_{i=1}^N \pi_{ni}^j \left(d\ln c_i^j + d\ln \tilde{\tau}_{ni}^j\right), \tag{B3}$$

where we use the definition of sectoral prices (equation 4), which then implies that $d\ln p_n^j = \sum_{i=1}^N \pi_{ni}^j [d\ln c_i^j + d\ln \tilde{\tau}_{ni}^j]$, by (6). Finally, from the definition of the input bundle (equation 2), we can obtain an expression for the change in wages. Totally differentiating this expression we get

$$d\ln w_n = \frac{1}{\gamma_n^j} d\ln c_n^j - \sum_{k=1} \frac{\gamma_n^{k,j}}{\gamma_n^j} d\ln p_n^k. \tag{B4}$$

Substituting equations (B2) and (B3), into equation (B1) we get

$$\begin{aligned} d\ln W_n \ =\ & \frac{w_n L_n}{I_n} d\ln w_n + \frac{1}{I_n} \sum\nolimits_{j=1}^J \sum\nolimits_{i=1}^N \tau_{ni}^j M_{ni}^j d\ln M_{ni}^j \\ & + \frac{1}{I_n} \sum\nolimits_{j=1}^J X_n^j \sum\nolimits_{i=1}^N \pi_{ni}^j d\ln \tilde{\tau}_{ni}^j \\ & - \sum\nolimits_{j=1}^J \alpha_n^j \sum\nolimits_{i=1}^N \pi_{ni}^j \left(d\ln c_i^j + d\ln \tilde{\tau}_{ni}^j\right), \end{aligned}$$

using the intermediate goods market clearing condition (7) to solve for α_n^j, we obtain

$$
\begin{aligned}
d\ln W_n = {} & \frac{w_n L_n}{I_n} d\ln w_n + \frac{1}{I_n}\sum\nolimits_{j=1}^{J}\sum\nolimits_{i=1}^{N}\tau_{ni}^j M_{ni}^j d\ln M_{ni}^j \\
& \sum\nolimits_{j=1}^{J}\sum_{k=1}\frac{\gamma_n^{j,k}}{\gamma_n^k}\frac{w_n L_n^k}{I_n}\sum\nolimits_{i=1}^{N}\pi_{ni}^j\left(d\ln\tilde{\tau}_{ni}^j + d\ln c_i^j\right) \\
& -\sum\nolimits_{j=1}^{J}\frac{X_n^j}{I_n}\sum\nolimits_{i=1}^{N}\pi_{ni}^j d\ln c_i^j,
\end{aligned}
$$

adding and substracting $\frac{1}{I_n}\sum_{j=1}^{J}\sum_{i=1}^{N} E_{ni}^j d\ln c_n^j$, we obtain

$$
\begin{aligned}
d\ln W_n = {} & \frac{w_n L_n}{I_n} d\ln w_n + \frac{1}{I_n}\sum\nolimits_{j=1}^{J}\sum\nolimits_{i=1}^{N}\tau_{ni}^j M_{ni}^j\left(d\ln M_{ni}^j - d\ln c_i^j\right) \\
& -\frac{1}{I_n}\sum\nolimits_{j=1}^{J}\sum\nolimits_{i=1}^{N}E_{ni}^j\left(d\ln c_n^j - \sum_{k=1}\gamma_n^{k,j} d\ln p_n^k\right) \\
& +\frac{1}{I_n}\sum\nolimits_{j=1}^{J}\sum\nolimits_{i=1}^{N}\left(E_{ni}^j d\ln c_n^j - M_{ni}^j d\ln c_i^j\right),
\end{aligned}
$$

and finally we use equation (B4) to obtain equation (16).

C. SOLVING THE MODEL

We present a step by step description on how to solve the model. Consider a change in policy from τ to the new policy τ', captured by $\hat{\kappa}_{ni}^j$ or a change in D_n to D_n'.

- Step 1: Guess a vector of wages $\hat{\mathbf{w}} = (\widehat{w}_1, ..., \widehat{w}_N)$
- Step 2: Use equilibrium conditions (10) and (11) to solve for prices in each sector and each country, $\hat{p}_n^j(\hat{\mathbf{w}})$ and input costs, $\hat{c}_n^j(\hat{\mathbf{w}})$ consistent with the vector of wages $\hat{\mathbf{w}}$.
- Step 3: Use the information on π_{ni}^j and θ^j together with the solutions to $\hat{p}_n^j(\hat{\mathbf{w}})$ and $\hat{c}_n^j(\hat{\mathbf{w}})$ from step 2 and solve for $\pi_{ni}^{j\prime}(\hat{\mathbf{w}})$ using (12).
- Step 4: Given $\pi_{ni}^{j\prime}(\hat{\mathbf{w}})$ from step 3, the new tariff vector τ', and data for γ_n^j, $\gamma_n^{j,k}$ and α_n^j, solve for total expenditure in each sector j and country n, $X_n^{j\prime}(\hat{\mathbf{w}})$ consistent with the vector of wages $\hat{\mathbf{w}}$ in the following way. Note that from (13), the total expenditure in the counterfactual scenario is given by

$$X_n^{j\prime} = \sum\nolimits_{k=1}^{J}\gamma_n^{j,k}\sum\nolimits_{i=1}^{N}\frac{\pi_{in}^{k\prime}(\hat{\mathbf{w}})}{1+\tau_{in}^{k\prime}}X_i^{k\prime} + \alpha_n^j\left(\widehat{w}_n w_n L_n + \sum\nolimits_{j=1}^{J}\sum\nolimits_{i=1}^{N}\tau_{ni}^{j\prime}M_{ni}^{j\prime}(\hat{\mathbf{w}}) + D_n'\right). \tag{C1}$$

Equation (C1) is a system of $J \times N$ equations in $J \times N$ total expenditures. Notice that if $\tau' = \tau$, and $D_n' = D_n$ then $\hat{\mathbf{w}} = 1$ and $X_n^{j\prime}(1) = X_n$. It is convenient to re-write the system of equations in matrix form:

$$\mathbf{\Omega}(\hat{\mathbf{w}})X = \Delta(\hat{\mathbf{w}}),$$

where $\mathbf{X}$ is the vector of expenditures for each sector and country and $\Delta(\hat{\mathbf{w}})$ is a vector containing the shares of each sector and country in final demand, value added and aggregate trade deficit by country. Concretely,

$$\mathbf{X} = \begin{pmatrix} X_1^{1\prime} \\ \vdots \\ X_1^{J\prime} \\ \vdots \\ X_n^{1\prime} \\ \vdots \\ X_N^{J\prime} \end{pmatrix}_{JN\times 1} \quad ; \quad \Delta(\hat{\mathbf{w}}) = \begin{pmatrix} \alpha_1^1\left(\hat{w}_1 w_1 L_1 + D_1'\right) \\ \vdots \\ \alpha_1^J\left(\hat{w}_1 w_1 L_1 + D_1'\right) \\ \vdots \\ \alpha_N^1\left(\hat{w}_N w_N L_N + D_N'\right) \\ \vdots \\ \alpha_N^J\left(\hat{w}_N w_N L_N + D_N'\right) \end{pmatrix}_{JN\times 1}.$$

The matrix $\mathbf{\Omega}(\hat{\mathbf{w}})$ is a square matrix of dimensions $JN \times JN$. $\mathbf{\Omega}(\hat{\mathbf{w}})$ captures the general equilibrium effects of how changes in tariffs from one sector and one country impact expenditure in all other sectors of the economy and the world. $\mathbf{\Omega}(\hat{\mathbf{w}})$ is constructed by adding three square matrices, I, $\digamma(\hat{\mathbf{w}})$, and $\tilde{H}(\hat{\mathbf{w}})$. The matrix I is the identity matrix with dimensions $JN \times JN$. The square matrix $\digamma(\hat{\mathbf{w}})$ is constructed using the following vectors,

$$A_n = \begin{pmatrix} \alpha_n^1 \\ \vdots \\ \alpha_n^J \end{pmatrix}_{J\times 1}, \tilde{F}_n'(\hat{\mathbf{w}}) = \left(\left(1 - F_n^{1\prime}(\hat{\mathbf{w}})\right) \cdots \left(1 - F_n^{J\prime}(\hat{\mathbf{w}})\right) \right)_{1\times J},$$

where $F_n^{j\prime}(\hat{\mathbf{w}}) = \sum_{i=1}^{N} \frac{\pi_{ni}^{j\prime}(\hat{\mathbf{w}})}{1+\tau_{ni}^{j\prime}}$. Then the matrix $\digamma(\hat{\mathbf{w}})$ is defined as

$$\digamma(\hat{\mathbf{w}}) = \begin{pmatrix} A_1 \otimes \tilde{F}_1'(\hat{\mathbf{w}}) & 0_{J\times J} & \cdots & 0_{J\times J} & 0_{J\times J} \\ 0_{J\times J} & A_2 \otimes \tilde{F}_2'(\hat{\mathbf{w}}) & \cdots & \vdots & \vdots \\ 0_{J\times J} & 0_{J\times J} & \ddots & 0_{J\times J} & 0_{J\times J} \\ \vdots & \vdots & \cdots & A_{N-1} \otimes \tilde{F}_{N-1}'(\hat{\mathbf{w}}) & 0_{J\times J} \\ 0_{J\times J} & 0_{J\times J} & \cdots & 0_{J\times J} & A_N \otimes \tilde{F}_N'(\hat{\mathbf{w}}) \end{pmatrix}_{JN\times JN}.$$

The square matrix $\tilde{H}(\hat{\mathbf{w}})$ is given by:

$$\tilde{H}(\hat{\mathbf{w}}) = \begin{pmatrix} \gamma_1^{1,1}\tilde{\pi}_{1,1}^{1\prime}(\hat{\mathbf{w}}) & \cdots & \gamma_1^{1,J}\tilde{\pi}_{1,1}^{J\prime}(\hat{\mathbf{w}}) & \cdots & \gamma_1^{1,1}\tilde{\pi}_{N,1}^{1\prime}(\hat{\mathbf{w}}) & \cdots & \gamma_1^{1,J}\tilde{\pi}_{N,1}^{J\prime}(\hat{\mathbf{w}}) \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ \gamma_1^{J,1}\tilde{\pi}_{1,1}^{1\prime}(\hat{\mathbf{w}}) & \cdots & \gamma_1^{J,J}\tilde{\pi}_{1,1}^{J\prime}(\hat{\mathbf{w}}) & \cdots & \gamma_1^{J,1}\tilde{\pi}_{N,1}^{1\prime}(\hat{\mathbf{w}}) & \cdots & \gamma_1^{J,J}\tilde{\pi}_{N,1}^{J\prime}(\hat{\mathbf{w}}) \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ \gamma_N^{1,1}\tilde{\pi}_{1,N}^{1\prime}(\hat{\mathbf{w}}) & \cdots & \gamma_N^{1,J}\tilde{\pi}_{1,N}^{J\prime}(\hat{\mathbf{w}}) & \cdots & \gamma_N^{1,1}\tilde{\pi}_{N,N}^{1\prime}(\hat{\mathbf{w}}) & \cdots & \gamma_N^{1,J}\tilde{\pi}_{N,N}^{J\prime}(\hat{\mathbf{w}}) \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ \gamma_N^{J,1}\tilde{\pi}_{1,N}^{1\prime}(\hat{\mathbf{w}}) & \cdots & \gamma_N^{J,J}\tilde{\pi}_{1,N}^{J\prime}(\hat{\mathbf{w}}) & \cdots & \gamma_N^{J,1}\tilde{\pi}_{N,N}^{1\prime}(\hat{\mathbf{w}}) & \cdots & \gamma_N^{J,J}\tilde{\pi}_{N,N}^{J\prime}(\hat{\mathbf{w}}) \end{pmatrix}_{JN\times JN},$$

where $\tilde{\pi}_{in}^{k\prime}(\hat{\mathbf{w}}) = \frac{\pi_{in}^{k\prime}(\hat{\mathbf{w}})}{1+\tau_{in}^{k\prime}}$. Finally, $\mathbf{\Omega}(\hat{\mathbf{w}}) = I - \digamma(\hat{\mathbf{w}}) - \tilde{H}(\hat{\mathbf{w}})$. The interactions presented in $\mathbf{\Omega}(\hat{\mathbf{w}})$ are the key differences compared to a one-sector model and a multi-sector model without I–O linkages. For example, in the special case in which $\gamma_n^{j,j} = 1 - \gamma_n^j$, tariffs do not appear in $\mathbf{\Omega}(\hat{\mathbf{w}})$ and expenditures in each country can be solved independently of the expenditures from other countries. For the case in which there is only one sector, $\mathbf{\Omega}(\hat{\mathbf{w}})$ collapses to a scalar as in Alvarez and Lucas (2007) and Eaton and Kortum, (2002). In a two-sector model without tariffs and exogenous sectoral deficit, as in Dekle, Eaton and Kortum (2008), $\mathbf{\Omega}(\hat{\mathbf{w}})$ depends only on technology and preference parameters, (γ, α). We solve for the vector $\mathbf{X}(\hat{\mathbf{w}})$ by inverting the matrix $\mathbf{\Omega}(\hat{\mathbf{w}})$.

$$\mathbf{X}(\hat{\mathbf{w}}) = \Omega^{-1}(\hat{\mathbf{w}})\,\Delta(\hat{\mathbf{w}}).$$

Denote by $X_n^{j\prime}(\hat{\mathbf{w}})$ the entry j of the vector $\mathbf{X}(\hat{\mathbf{w}})$ (the expenditure in sector j and country n). This expression is crucial to solve for the general equilibrium, since it allows us to express all the equilibrium conditions as a function of one vector of unknowns, the vector of factor prices, $\hat{\mathbf{w}}$.

- Step 5: Substitute $\pi_{in}^{j\prime}(\hat{\mathbf{w}})$, $\mathbf{X}(\hat{\mathbf{w}})$, τ', and D_n' into (14) and obtain:

$$\sum_{j=1}^{J}\sum_{i=1}^{N} \frac{\pi_{ni}^{j\prime}(\hat{\mathbf{w}})}{1+\tau_{ni}^{j\prime}} X_n^{j\prime}(\hat{\mathbf{w}}) - D_n' = \sum_{j=1}^{J}\sum_{i=1}^{N} \frac{\pi_{in}^{j\prime}(\hat{\mathbf{w}})}{1+\tau_{in}^{j\prime}} X_i^{j\prime}(\hat{\mathbf{w}}). \tag{C2}$$

  Notice that we have just reduced the system of equilibrium conditions (10 through 13) to a system of N equations (one trade balance per country) and N unknowns (one wage per country).
- Step 6: Verify if equation (C2) holds. If not, we adjust our guess of $\hat{\mathbf{w}}$ and proceed to step 1 again until equilibrium condition (C2) is obtained.

D. CES MODEL

In this appendix, we develop a model that allows for different degrees of substitutability across inputs. Consider a double nested constant elasticity of substitution (CES) production function, with an outer nest between labour and materials and an inner CES aggregator of materials from all sectors. Concretely, the production function of intermediate goods ω^j is given by

$$q_n^j(\omega^j) = z_n^j\left(\omega^j\right)\left[\left[\chi_n^j\right]^{\frac{1}{\eta}}\left[l_n^j(\omega^j)\right]^{\frac{\eta-1}{\eta}} + \left[1-\chi_n^j\right]^{\frac{1}{\eta}}\left[M_n^j(\omega^j)\right]^{\frac{\eta-1}{\eta}}\right]^{\frac{\eta}{\eta-1}},$$

where materials and labour are combined with a CES function with elasticity of substitution equal to η and weights given to χ_n^j varying by sector and country. $M_n^j\left(\omega^j\right)$ is the total materials demanded in sector j by producer ω^j in country n. We also allowed for a varying degree of substitution where materials from sector k used to produce intermediate goods in sector j are combined with a CES function with elasticity equal to ρ and weights equal to $\delta_n^{k,j}$ that vary across sectors and countries where $\sum_{k=1}^{J}\delta_n^{k,j}=1$,

$$M_n^j\left(\omega^j\right) = \left[\sum\nolimits_{k=1}^{J}\left[\delta_n^{k,j}\right]^{\frac{1}{\rho}}\left[m_n^{k,j}(\omega^j)\right]^{\frac{\rho-1}{\rho}}\right]^{\frac{\rho}{\rho-1}}.$$

In terms of the characterization of the equilibrium, two equations have to be modified with a CES model. First, the cost of the bundle of inputs now adopts a nested CES functional form given by

$$c_n^j = \left[\left[\chi_n^j\right][w_n]^{1-\eta} + \left[1-\chi_n^j\right]\left[P_n^{M,j}\right]^{1-\eta}\right]^{\frac{1}{1-\eta}}, \tag{D1}$$

where $P_n^{M,j}$ is the price index of materials used in production, given by

$$P_n^{M,j} = \left[\sum\nolimits_{k=1}^{J}\delta_n^{k,j}\left[P_n^k\right]^{1-\rho}\right]^{\frac{1}{1-\rho}}. \tag{D2}$$

Secondly, the input shares are not constant with a CES model, and therefore, the equation for total expenditure is given by

$$X_n^j = \sum\nolimits_{k=1}^{J}\xi_n^{j,k}\sum\nolimits_{i=1}^{N}X_i^k\frac{\pi_{in}^k}{1+\tau_{in}^k} + \alpha_n^j I_n, \tag{D3}$$

where $\xi_n^{j,k}$ is the share of inputs from sector j in sector k gross output.

Mapping this shares to our previous notation, this implies that

$$\gamma_n^{k,j} \equiv \xi_n^{k,j} = \left(1-\chi_n^j\right)\left[\frac{P_n^{M,j}}{c_n^j}\right]^{1-\eta}\delta_n^{k,j}\left[\frac{P_n^k}{P_n^{M,j}}\right]^{1-\rho}, \text{ and } \gamma_n^j \equiv \chi_n^j\left[\frac{w_n}{c_n^j}\right]^{1-\eta}.$$

Equilibrium in relative changes

In relative changes, the cost of bundle of inputs (equation D1) becomes:

$$\hat{c}_n^j = \left[\zeta_n^{l,j}\left[\hat{w}_n\right]^{1-\eta} + \sum\nolimits_{k=1}^{J}\xi_n^{k,j}\left[\hat{P}_n^{M,j}\right]^{1-\eta}\right]^{\frac{1}{1-\eta}}, \tag{D4}$$

and the price index (equation D2) becomes

$$\hat{P}_n^{M,j} = \left[\sum\nolimits_{k=1}^{J}\xi_n^{k,j}\right]^{-\frac{1}{1-\rho}}\left[\sum\nolimits_{k=1}^{J}\xi_n^{k,j}\left[\hat{P}_n^k\right]^{1-\rho}\right]^{\frac{1}{1-\rho}} \tag{D5}$$

where $\zeta_n^{l,j}$ is the share of labour in sector j gross output.

Total expenditure (equation D3) in the counterfactual equilibrium is given by

$$X_n^{j\prime} = \sum\nolimits_{k=1}^{J}\xi_n^{j,k\prime}\sum\nolimits_{i=1}^{N}X_i^{k\prime}\frac{\pi_{in}^{k\prime}}{1+\tau_{in}^{k\prime}} + \alpha_n^j I_n^{\prime}, \tag{D6}$$

with

$$\xi_n^{j,k\prime} = \left[\frac{\zeta_n^{l,k}}{\sum_{j=1}^{J}\xi_n^{j,k}}\left[\frac{\hat{P}_n^{M,k}}{\hat{w}_n}\right]^{\eta-1} + 1\right]^{-1}\left[\sum\nolimits_{h=1}^{J}\frac{\xi_n^{h,k}}{\xi_n^{j,k}}\left[\frac{\hat{P}_n^k}{\hat{P}_n^h}\right]^{\rho-1}\right]^{-1}$$

Equations (D4)–(D6), together with equations (12) and (13) describe the equilibrium in relative changes in a CES model.

E. DATA SOURCES AND DESCRIPTION

This appendix describes the data sources and data construction we use in the article. The list of countries included in our database is: Argentina, Australia, Austria, Brazil, Canada, Chile, China, Denmark, Finland, France, Germany, Greece, Hungary, India, Indonesia, Ireland, Italy, Japan, Korea, Mexico, Netherlands, New Zealand, Norway, Portugal, South Africa, Spain, Sweden, Turkey, U.K., U.S., and a constructed rest of the world. The list of sectors is reported in Table A1. All the data and programs used are included in the online Supplementary data.

Bilateral trade flows. We use bilateral trade flows for the 20 tradable sectors described in Table A1 and our sample of 31 countries for the year 1993. Bilateral trade data come from the United Nations Statistical Division (UNSD) Commodity Trade (COMTRADE) database. Values are reported in thousands of U.S. dollars at current prices and include cost, insurance and freight (CIF). Commodities are defined using the Harmonized Commodity Description and Coding System (HS)1988/1992 at the 6-digit level of aggregation and were concorded to 2-digit ISIC Rev. 3 using the United Nations concordance table. To construct imports from the rest of the world, we use data on imports of each country n in our sample from the world and subtract total imports of that country n from the rest of the countries included in our sample. Analogously, to construct exports to the rest of the world, we use data on exports of each country n in our sample to the world and subtract total imports of the rest of the countries included in our sample from that country n.

TABLE A1
Tradable and non-tradable sectors

Product Classification System: International Standard Industrial Classification (ISIC) Revision 3.

Number	Industry	Description	ISIC Rev.3
1	Agriculture	Agriculture forestry and fishing	1 – 5
2	Mining	Mining and quarrying	10 – 14
3	Food	Food products, beverages and tobacco	15–16
4	Textile	Textiles, textile products, leather and footwear	17–19
5	Wood	Wood and products of wood and cork	20
6	Paper	Pulp, paper, paper products, printing and publishing	21–22
7	Petroleum	Coke refined petroleum and nuclear fuel	23
8	Chemicals	Chemicals	24
9	Plastic	Rubber and plastics products	25
10	Minerals	Other nonmetallic mineral products	26
11	Basic metals	Basic metals	27
12	Metal products	Fabricated metal products, except machinery and equipment	28
13	Machinery n.e.c	Machinery and equipment n.e.c	29
14	Office	Office, accounting and computing machinery	30
15	Electrical	Electrical machinery and apparatus, n.e.c.	31
16	Communication	Radio, television and communication equipment	32
17	Medical	Medical, precision and optical instruments, watches and clocks	33
18	Auto	Motor vehicles trailers and semi-trailers	34
19	Other Transport	Other transport equipment	351 – 359
20	Other	Manufacturing n.e.c and recycling	36 –37
21	Electricity	Electricity Gas and Water Supply	40 – 41
22	Construction	Construction	45
23	Retail	Wholesale and retail trade repairs	50 – 52
24	Hotels	Hotels and restaurants	55
25	Land Transport	Land transport transport via pipelines	60
26	Water Transport	Water transport	61
27	Air Transport	Air transport	62
28	Aux Transport	Support. & aux. transport act. travel agencies activ.	63
29	Post	Post and telecommunications	64
30	Finance	Financial intermediation	65 – 67
31	Real State	Real estate activities	70
32	Renting Mach	Renting of machinery and equipment	71
33	Computer	Computer and related activities	72
34	R&D	Research and development	73
35	Other Business	Other business activities	74
36	Public	Public admin. and defense compulsory social security	75
37	Education	Education	80
38	Health	Health and social work	85
39	Other services	Other community social and personal services	90 – 93
40	Private	Private households with employed persons	95

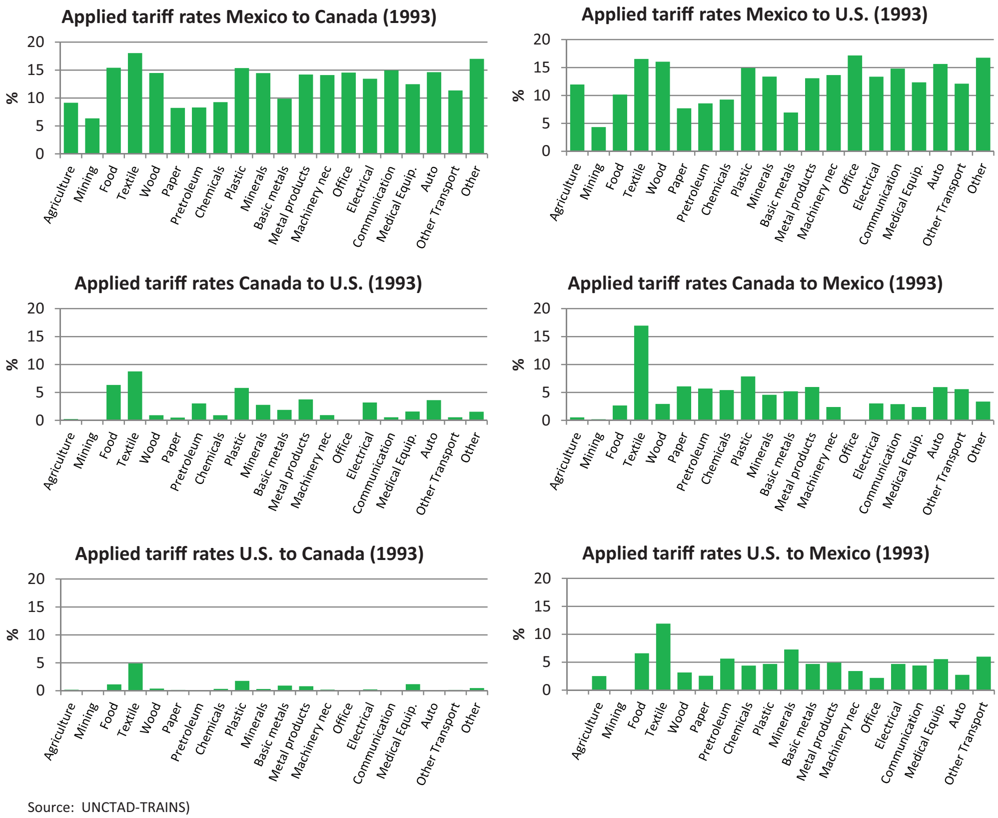

FIGURE A1
Effective applied tariff rates before NAFTA

Tariffs. Bilateral tariffs data at the sectoral level for the years 1993 and 2005 are obtained from the United Nations Statistical Division-Trade Analysis and Information System (UNCTAD-TRAINS). The tariff measures are tariff lines and are reported in two ways; simple and weighted average effective applied rates at 2-digit ISIC Rev. 3 industries. Effective applied rates refers to the actual tariff applied, taking into account whether there is any trade agreement between the countries. We also downloaded the most-favoured-nation (MFN) tariffs for each country. Under the rules of the World Trade Organization (WTO), members cannot discriminate between their trading partners; therefore, they need to grant all countries the same favourable treatment as all other WTO members. The tariff that considers this rule is the MFN tariff. If countries sign bilateral and multilateral trade agreements, then they are exempt from this rule. We compared both measures to see if they were consistent, that is, if the effective applied rates are lower or equal than the MFN tariffs. We decided to use weighted average rates in the counterfactual exercises, although we checked that the results are robust by also using the simple averages. When tariff data for the year 1993 was not available, we input this value with the closest value available, searching for the four previous years. When tariff data were not available in 2005, we input the value of 2006 or 2004. When the effective applied tariff was not available in all these years, which occurs in about 2% of all the observations, we input the most-favoured-nation (MFN) tariff rate for each country. Figure A1 presents the effective tariffs rates across NAFTA members for the year 1993.

Value added and gross production. We obtained data on gross output and value added at the sectoral level for the year 1993 from three different sources. First, we collected data from OECD STAN database for industrial analysis that contains gross output and value added data for OECD countries at the sectoral level based on ISIC Rev. 3 at current prices and in national currency. We use data from OECD STAN exchange rates to covert values into U.S. dollars. Secondly, value added and gross output data for the remaining countries are sourced from the Industrial Statistics Database INDSTAT2. This database contains data at current prices in U.S. dollars for 23 ISIC Rev. 3 manufacturing sectors at 2-digit level of aggregation. These two databases allow us to complete gross output and value added for about two-third of the total number of countries and sectors in our sample, and nearly all the observations in the manufacturing sectors.

For the remaining countries and sectors where data from these two databases were not available, we construct sectoral value added and gross output using information from the OECD Input–Output database. The OECD database provides I–O tables for 48 countries for the years 1995, 2000, and 2005, and contain information for 37 ISIC Rev. 3 industries. We obtained gross output and value added for the missing sectors and countries for the year 1995 from these I–O tables. To convert value added and gross output to the year 1993, we assume that the sectoral shares of value added in GDP and the share of value added in sectoral gross output remained constant between 1993 and 1995. We then combine this information with sectoral value added data for the year 1993 from the United Nations National Accounts Database. This database contains value added data over the period 1970–2011 for 200 countries. Value added data is disaggregated into the following sectors: Agricultural, Hunting, Forestry, Fishing (ISIC A-B); Mining, Utilities (ISIC C-E); Manufacturing (ISIC D); Construction (ISIC F); Wholesale, retail trade, restaurants and hotels (ISIC G-H); Transport, storage, and communication (ISIC I); and Other Activities (ISIC J-P). We use the shares of value added in GDP from the I–O tables to split these subcategories into our ISIC Rev. 3 sectors and we use the shares of value added in gross output to convert value added into gross output in our sectors.

To construct sectoral value added and gross output for the rest of the world, we first obtain world's value added for these seven ISIC industries from the United Nations database by adding value added data for 200 countries. We then apply the median shares of sectoral value added in GDP from our sample to split value added into our ISIC Rev. 3 categories, and we then apply the median shares of value added in gross output to convert value added into gross output for the world. After doing so, we calculate the rest of the world by simply subtracting total value added and gross output in our sample of countries from the world's aggregates. With value added and gross output data, we calculate the share of value added in gross output for all sectors and countries in our sample. A number of observations (2.01%) present values of gross output equal to zero. Nearly all these cases correspond to non-tradable sectors. A zero in gross output could mean either a missing value or that no goods are produced in that sector and country. In those cases prices are undetermined and this generates further complications to computation of the model. To avoid this we input a value of 1 in these cases. This has a negligible effect since 1 corresponds to 2e-9% of the average gross output across sectors and countries. We also deal with this problem in different ways, such as inputting a value of zero to the bilateral trade shares, and find that the computed equilibrium is unchanged.

I–O tables and intermediate consumption. We constructed the share of intermediate inputs from each sector in sectoral gross output by combining information from the WIOD and the OECD Input-Output Database. The WIOD database contains I–O tables for 40 countries over the period 1995–2011. Each I–O table provides complete information on intermediate consumption for 35 ISIC Rev. 2 industries. We calculate the I–O coefficients from the WIOD database. The I–O tables present intermediate consumption for the aggregate ISIC Rev.3 sectors 27–28, 30–33, 34–35, 71–74. We use the information from the OECD I–O tables to split these aggregate sectors into our sectoral classification. Input-Output tables for Argentina, Chile, New Zealand, Norway, and South Africa were not available in the WIOD database. For Norway we use the I–O table from OECD STAN. For the rest of these 5 countries, I–O tables were incomplete, thus we decided to input the median coefficients across our sample of countries. The I–O table for the rest of the world was also constructed using the median coefficients.

Estimation of dispersion of productivity. To estimate the dispersion of productivity, we collect data on trade flows and tariff rates for 16 economies: Argentina, Australia, Brazil, Canada, Chile, China, the European Union, India, Indonesia, Japan, Korea, New Zealand, Norway, Switzerland, Thailand, and U.S.. Brazil was dropped from the sample because it was experiencing a currency crisis (large devaluation, high inflation). Bilateral trade data for 1993 are not difficult to find; however, we are restricted by the information on tariffs. Countries were included in the sample provided they had reliable tariff data and they had cross bilateral trade with many countries. To increase the sample size we had to input the values for some countries. If a country in the list did not have tariff data available in 1993, we input this value with the closest value available, searching up to four previous years, up to 1989. Our estimation is performed excluding Mexico from the sample. Canada and the U.S. are included in the estimation; however, we remove all the interaction (triple combinations in equation (23)) terms involving Canada and the U.S. We leave the interaction of these countries with other countries to have a larger number of observations since these countries have a large number of trading partners. The sample of countries represented more than 80% of the world's trade in 1993 and at least 72% in each sector. Data on trade flows are from the United Nations COMTRADE database for 1993. Values are recorded in U.S. dollars for commodities defined using the HS-1992 at two digits of aggregation, corresponding to 30 sectors. Using concordance tables we obtained trade flows for 20 ISIC-rev. 3 sectors. The reporter country is the importer, and imports are at CIF. values. Data on tariffs are from UNCTAD-TRAINS for 1989–1995. Tariffs represent the effective tariff rate applied by each country. Tariffs are available for industries at four digits ISIC-rev.3. and were aggregated up to two digits using a weighted average, where the weights are given by the import values. Whenever data on bilateral tariffs are not available in 1993, we input this value with the closest value available, searching up to four previous years. The total number of observations for the 20 sectors is 9138, with an average of 457 observations per sector.

F. ADDITIONAL RESULTS

TABLE A2
Dispersion-of-productivity estimates (with importer and exporter fixed effects)

	Full sample			99% sample			97.5% sample		
Sector	θ^j	s.e.	N	θ^j	s.e.	N	θ^j	s.e.	N
Agriculture	8.59	(2.00)	496	9.54	(2.11)	430	16.97	(2.48)	364
Mining	14.83	(2.87)	296	11.96	(3.84)	178	14.84	(4.38)	152
Manufacturing									
Food	2.84	(0.57)	495	3.02	(0.57)	429	2.89	(0.65)	352
Textile	5.99	(1.24)	437	8.55	(1.38)	314	0.61	(1.89)	186
Wood	10.19	(2.24)	315	10.72	(2.63)	191	9.30	(2.82)	148
Paper	8.32	(1.66)	507	15.20	(2.69)	352	0.51	(2.86)	220
Petroleum	69.31	(19.32)	91	68.47	(19.08)	86	65.92	(19.51)	80
Chemicals	3.64	(1.75)	430	3.23	(1.76)	341	−0.02	(2.07)	220
Plastic	0.88	(1.57)	376	3.10	(2.24)	272	1.95	(2.22)	180
Minerals	3.38	(1.54)	342	3.03	(1.73)	263	3.85	(2.07)	186
Basic metals	6.58	(2.28)	388	0.88	(2.58)	288	−1.31	(2.77)	235
Metal products	5.03	(1.93)	404	7.30	(2.01)	314	0.82	(2.83)	186
Machinery n.e.c.	2.87	(1.85)	397	3.88	(3.14)	290	0.70	(4.24)	186
Office	13.88	(2.21)	306	9.85	(5.60)	126	21.57	(5.78)	62
Electrical	11.02	(1.46)	343	13.95	(1.66)	269	4.66	(2.82)	177
Communication	4.86	(1.69)	312	3.27	(2.07)	143	3.33	(2.19)	93
Medical	7.63	(1.22)	383	7.49	(1.48)	237	2.45	(1.25)	94
Auto	0.49	(0.91)	237	1.59	(1.04)	126	−2.13	(1.34)	59
Other Transport	0.90	(1.16)	245	0.91	(1.15)	226	1.05	(1.22)	167
Other	4.95	(0.92)	412	3.52	(1.04)	227	2.61	(0.81)	135

TABLE A3
Welfare effects from NAFTA's tariff reductions

Country	Welfare	Terms of trade	Volume of trade	Country	Welfare	Terms of trade	Volume of trade
Argentina	0.001%	0.000%	0.001%	Ireland	−0.018%	−0.012%	−0.006%
Australia	0.000%	0.000%	−0.000%	Italy	−0.004%	−0.003%	−0.001%
Austria	−0.004%	−0.002%	−0.002%	Japan	−0.007%	−0.005%	−0.002%
Brazil	−0.002%	−0.002%	0.000%	Korea	−0.029%	−0.018%	−0.011%
Chile	0.010%	0.009%	0.001%	Netherlands	−0.005%	−0.003%	−0.002%
China	−0.028%	−0.006%	−0.022%	New Zealand	0.002%	0.002%	−0.000%
Denmark	−0.002%	−0.001%	−0.001%	Norway	0.003%	0.004%	−0.001%
Finland	−0.001%	0.000%	−0.001%	Portugal	−0.003%	−0.002%	−0.001%
France	−0.004%	−0.003%	−0.001%	South Africa	0.003%	0.002%	0.002%
Germany	−0.005%	−0.003%	−0.001%	Spain	−0.008%	−0.004%	−0.001%
Greece	0.000%	0.001%	−0.000%	Sweden	−0.009%	−0.006%	−0.002%
Hungary	−0.003%	−0.002%	−0.002%	Turkey	−0.001%	−0.001%	−0.001%
India	−0.005%	−0.002%	−0.003%	U.K.	−0.005%	−0.003%	−0.002%
Indonesia	−0.001%	0.000%	−0.001%	ROW	−0.003%	−0.001%	−0.002%

TABLE A4

Welfare effects from NAFTA's tariff reductions, with trade deficit

	Welfare			
Country	Total	Terms of trade	Volume of trade	Real wages
Mexico	1.17%	−0.42%	1.59%	1.64%
Canada	−0.04%	−0.08%	0.04%	0.33%
U.S.	0.09%	0.05%	0.04%	0.12%

TABLE A5

Bilateral welfare effects from NAFTA's tariff reductions, with trade deficit

	Terms of trade		Volume of trade	
Country	NAFTA	Rest of the world	NAFTA	Rest of the world
Mexico	−0.39%	−0.02%	1.69%	−0.10%
Canada	−0.08%	−0.01%	0.08%	−0.04%
U.S.	0.03%	0.02%	0.04%	−0.00%

TABLE A6

Sectoral contribution to welfare effects from NAFTA's tariff reductions, with trade deficit

	Mexico		Canada		U.S.	
Sector	Terms of trade	Volume of trade	Terms of trade	Volume of trade	Terms of trade	Volume of trade
Agriculture	0.77%	3.00%	2.06%	0.05%	3.47%	0.79%
Mining	−0.03%	0.21%	0.58%	−0.02%	2.08%	0.07%
Manufacturing						
Food	0.92%	1.17%	2.74%	3.00%	3.30%	1.21%
Textile	3.54%	12.30%	1.11%	20.00%	4.84%	23.20%
Wood	0.38%	2.26%	1.65%	0.34%	0.99%	0.47%
Paper	0.54%	3.78%	4.16%	0.93%	2.32%	0.44%
Petroleum	0.17%	15.20%	0.43%	18.90%	0.51%	10.30%
Chemicals	1.39%	2.09%	5.90%	0.73%	6.05%	1.35%
Plastic	0.82%	4.22%	2.83%	8.77%	1.71%	0.36%
Minerals	0.29%	0.75%	0.99%	0.94%	0.81%	0.67%
Basic metals	1.51%	2.97%	9.50%	1.61%	3.13%	1.16%
Metal products	1.07%	5.59%	2.76%	9.19%	1.76%	1.25%
Machinery n.e.c.	4.17%	4.28%	6.14%	0.20%	6.61%	0.78%
Office	6.54%	4.53%	2.46%	−0.79%	4.31%	1.31%
Electrical	36.30%	25.00%	1.75%	7.30%	21.40%	39.50%
Communication	20.00%	3.64%	2.82%	0.34%	12.10%	4.85%
Medical	4.44%	1.33%	1.25%	−0.12%	3.84%	4.65%
Auto	14.10%	4.90%	33.10%	29.40%	15.40%	5.16%
Other Transport	0.22%	0.80%	17.30%	−1.12%	2.15%	0.43%
Other	2.87%	1.99%	0.44%	0.39%	3.17%	2.00%

TABLE A7
Sectoral composition of exports, with trade deficit

	Mexico		Canada		U.S.	
Sector	Before	After	Before	After	Before	After
Agriculture	4.81%	3.15%	4.69%	4.75%	6.41%	5.84%
Mining	14.00%	7.37%	9.37%	9.25%	1.60%	1.39%
Manufacturing						
Food	2.57%	1.60%	4.65%	4.54%	5.43%	4.98%
Textile	4.48%	7.04%	1.07%	1.51%	2.79%	3.68%
Wood	0.60%	0.54%	7.54%	7.46%	1.77%	1.74%
Paper	0.58%	0.52%	8.96%	8.99%	4.41%	4.38%
Petroleum	0.42%	4.51%	0.95%	1.29%	1.08%	3.38%
Chemicals	4.65%	2.62%	5.44%	5.28%	11.00%	10.00%
Plastic	0.87%	0.51%	2.00%	2.00%	2.58%	2.71%
Minerals	1.44%	0.90%	0.80%	0.77%	1.05%	1.01%
Basic metals	3.38%	2.05%	9.87%	9.81%	3.38%	3.39%
Metal products	1.29%	1.08%	1.48%	1.55%	2.38%	2.74%
Machinery n.e.c.	4.77%	2.73%	4.53%	4.37%	11.70%	10.80%
Office	3.02%	4.51%	2.22%	2.29%	7.39%	6.90%
Electrical	20.6%	33.80%	2.52%	2.36%	5.99%	7.99%
Communication	9.40%	7.55%	3.03%	2.94%	7.75%	7.23%
Medical	2.61%	3.41%	0.97%	1.02%	5.20%	4.76%
Auto	16.90%	13.50%	25.20%	24.70%	8.59%	8.44%
Other Transport	0.29%	0.27%	3.20%	3.55%	7.62%	6.81%
Other	3.28%	2.36%	1.56%	1.54%	1.90%	1.85%
Normalized Herfindahl	0.091	0.136	0.086	0.084	0.046	0.042

TABLE A8
Sectoral contribution to welfare effects from world's tariff reductions

	Mexico		Canada		U.S.	
Sector	Terms of trade	Volume of trade	Terms of trade	Volume of trade	Terms of trade	Volume of trade
Agriculture	−0.24%	3.31%	7.39%	0.10%	0.45%	0.25%
Mining	−1.25%	0.32%	21.20%	−0.16%	6.79%	0.04%
Manufacturing						
Food	−0.02%	1.08%	6.49%	1.32%	1.35%	1.00%
Textile	0.47%	11.80%	−41.60%	42.30%	35.00%	44.40%
Wood	0.07%	2.21%	18.40%	0.89%	0.32%	0.85%
Paper	−0.06%	3.89%	16.30%	3.00%	−0.42%	0.73%
Petroleum	−0.11%	14.40%	0.82%	9.75%	−1.07%	3.62%
Chemicals	−0.76%	2.80%	5.05%	4.31%	0.50%	2.61%
Plastic	−0.85%	3.95%	0.55%	3.21%	2.46%	0.40%
Minerals	0.10%	0.86%	0.71%	0.66%	0.22%	1.03%
Basic metals	0.17%	3.07%	27.70%	2.76%	3.05%	1.46%
Metal products	0.42%	5.50%	−1.11%	4.85%	1.64%	1.65%
Machinery n.e.c.	2.74%	4.45%	−2.79%	1.85%	1.02%	1.00%
Office	8.59%	5.59%	−8.30%	0.56%	5.28%	2.67%
Electrical	44.40%	23.10%	−2.64%	7.34%	13.80%	20.80%
Communication	21.40%	3.60%	−11.70%	1.01%	11.30%	3.49%
Medical	4.88%	1.32%	−2.87%	1.40%	0.82%	4.82%
Auto	17.60%	5.30%	55.50%	9.76%	6.42%	1.08%
Other Transport	−0.27%	1.30%	21.60%	0.77%	−2.23%	2.19%
Other	2.66%	2.10%	−10.60%	4.36%	13.20%	5.93%

TABLE A9
Import growth from world's tariff reductions

Country	Mexico	Canada	U.S.
Mexico		109.85%	107.29%
Canada	49.54%		4.52%
U.S.	96.15%	4.76%	

TABLE A10
Welfare effects from NAFTA given world tariff reductions

Country	Welfare	Terms of trade	Volume of trade	Country	Welfare	Terms of trade	Volume of trade
Argentina	−0.002%	−0.002%	0.000%	Ireland	−0.113%	−0.100%	−0.013%
Australia	−0.003%	−0.002%	−0.001%	Italy	−0.004%	−0.002%	−0.002%
Austria	−0.007%	−0.002%	−0.005%	Japan	−0.007%	−0.006%	−0.002%
Brazil	−0.012%	−0.007%	−0.005%	Korea	−0.031%	−0.017%	−0.015%
Chile	0.002%	0.002%	0.000%	Netherlands	−0.007%	−0.003%	−0.003%
China	−0.063%	−0.008%	−0.056%	New Zealand	−0.003%	−0.001%	−0.002%
Denmark	−0.002%	−0.000%	−0.001%	Norway	0.001%	0.002%	−0.001%
Finland	−0.003%	−0.001%	−0.002%	Portugal	−0.030%	−0.021%	−0.010%
France	−0.006%	−0.004%	−0.002%	South Africa	0.000%	−0.000%	0.001%
Germany	−0.006%	−0.004%	−0.002%	Spain	−0.008%	−0.006%	−0.003%
Greece	−0.002%	−0.000%	−0.001%	Sweden	−0.010%	−0.007%	−0.004%
Hungary	−0.001%	−0.000%	−0.001%	Turkey	−0.003%	−0.001%	−0.002%
India	−0.015%	−0.001%	−0.015%	U.K.	−0.004%	−0.001%	−0.003%
Indonesia	−0.004%	−0.001%	−0.003%	ROW	−0.009%	−0.002%	−0.007%

TABLE A11
Sectoral contribution to welfare effects from NAFTA given world tariff changes

	Mexico		Canada		U.S.	
Sector	Terms of trade	Volume of trade	Terms of trade	Volume of trade	Terms of trade	Volume of trade
Agriculture	0.03%	3.10%	3.14%	0.02%	3.69%	0.81%
Mining	−2.73%	0.25%	3.03%	−0.21%	0.80%	0.06%
Manufacturing						
Food	0.56%	1.29%	3.41%	3.71%	3.72%	1.31%
Textile	3.66%	12.30%	0.52%	−4.65%	4.46%	16.50%
Wood	0.34%	2.30%	3.41%	0.36%	1.13%	0.57%
Paper	0.46%	3.96%	5.48%	0.85%	3.50%	0.53%
Petroleum	−0.04%	13.40%	0.62%	40.00%	1.98%	12.10%
Chemicals	0.77%	2.27%	5.93%	0.37%	6.77%	1.49%
Plastic	0.71%	4.50%	2.64%	11.00%	1.44%	0.40%
Minerals	0.09%	0.80%	0.97%	0.69%	0.65%	0.74%
Basic metals	1.22%	3.24%	10.00%	2.23%	3.09%	1.34%
Metal products	0.98%	5.82%	2.42%	10.20%	1.53%	1.38%
Machinery n.e.c.	3.80%	4.58%	5.55%	0.13%	5.91%	0.82%
Office	7.56%	3.09%	2.27%	−1.06%	3.49%	1.34%
Electrical	40.50%	26.60%	1.40%	1.45%	22.40%	42.70%
Communication	20.20%	3.67%	2.35%	0.20%	11.30%	5.12%
Medical	4.55%	1.29%	1.08%	−0.81%	3.20%	4.80%
Auto	14.40%	4.91%	30.90%	37.80%	17.00%	5.48%
Other Transport	0.21%	0.62%	14.30%	−1.86%	1.75%	0.47%
Other	2.75%	2.06%	0.63%	−0.44%	2.19%	2.08%

TABLE A12
Sectoral composition of exports from NAFTA given world tariff changes

	Mexico		Canada		U.S.	
Sector	Before	After	Before	After	Before	After
Agriculture	4.72%	3.11%	4.99%	5.03%	6.91%	6.29%
Mining	15.53%	8.06%	8.99%	8.91%	1.72%	1.50%
Manufacturing						
Food	2.33%	1.51%	4.82%	4.70%	5.09%	4.69%
Textile	4.42%	7.15%	1.05%	1.47%	2.68%	3.45%
Wood	0.59%	0.53%	8.12%	8.04%	2.02%	1.96%
Paper	0.62%	0.53%	8.34%	8.40%	4.99%	4.84%
Petroleum	1.62%	5.69%	0.59%	0.75%	4.30%	5.55%
Chemicals	4.40%	2.58%	5.58%	5.42%	10.00%	9.17%
Plastic	0.80%	0.49%	2.06%	2.07%	2.28%	2.41%
Minerals	1.32%	0.85%	0.81%	0.78%	0.94%	0.91%
Basic metals	3.24%	2.04%	10.29%	10.23%	3.05%	3.08%
Metal products	1.22%	1.05%	1.47%	1.54%	2.23%	2.57%
Machinery n.e.c.	4.30%	2.57%	4.69%	4.51%	10.37%	9.62%
Office	3.34%	4.54%	2.44%	2.52%	7.70%	7.43%
Electrical	20.79%	33.34%	2.50%	2.38%	6.07%	8.58%
Communication	8.57%	7.04%	3.11%	3.02%	7.19%	6.78%
Medical	2.48%	3.22%	0.98%	1.03%	5.16%	4.79%
Auto	16.43%	13.22%	24.42%	24.08%	8.20%	8.05%
Other Transport	0.28%	0.26%	3.21%	3.59%	7.32%	6.61%
Other	3.02%	2.23%	1.55%	1.53%	1.77%	1.72%
Normalized Herfindahl	0.092	0.134	0.083	0.081	0.042	0.040

TABLE A13
Import growth from NAFTA given world tariff reductions

Country	Mexico	Canada	U.S.
Mexico		118.85%	127.80%
Canada	57.57%		10.53%
U.S.	105.92%	6.09%	

Supplementary Data

Supplementary materials are available at *Review of Economic Studies* online.

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