Predicting the Effects of NAFTA: Now We Can Do It Better!

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Abstract The North American Free Trade Agreement (NAFTA) is one of the most influential events in the North American economic history, but the economic forecasts regarding its effects on trade turned out to be vastly incorrect. This paper suggests and evaluates a new model for forecasting the effects of trade liberalizations that uses the framework to explain intra-industry trade instead of the usual approach. The performance of the model is evaluated by using it to forecast the effects of NAFTA from the point of view of 1989. The predictions of the model are compared with the post-NAFTA data and the forecasts of the existing models. The results show that the new model is able to predict the effects of NAFTA noticeably better than the existing trade models. The paper analyzes the reasons for this difference.

Keywords: trade liberalization, NAFTA, trade forecasting, computable models, heterogeneous producers

JEL codes: F1, F13, F15, F17

1. Introduction

The goal of NAFTA, which went into effect on January 1, 1994 was a gradual reduction and then elimination of all tariff and many non-tariff barriers to trade between the U.S., Canada, and Mexico. Being one of the most significant events in recent U.S. economic history, its merits were hotly debated, with many concerned parties participating in the discussion. Predictions ranged from significant benefit to the U.S. economy to significant harm to it. At the end, many predictions turned out to be incorrect. Unfortunately, many of the forecasts made by economic models also turned out to be incorrect.

Quantitative economic analysis was extensively used before the ratification of NAFTA to make predictions about its effects. The forecasts were made using computable general equilibrium (CGE) models that relied on the Armington (1969) assumption to explain two-way trade between countries and home bias in consumption. The models were generally similar, with the type of competition in the goods market being the biggest difference. Their predictions pointed to little effect on trade, output, and employment in the U.S., and moderate effects on Mexico.[1]

In actuality, NAFTA had a significant effect on trade between its members and a small-to-moderate effect on their incomes and employment (Burfisher, Robinson, and Thierfelder, 2001; Anderson and van Wincoop, 2002; Romalis, 2007). Between 1993 and 2008, the total NAFTA trade relative to the total NAFTA GDP grew 48%, the fraction of U.S. income that was spent on

Mexican goods grew 121%, and the fraction of Mexican goods in total Canadian imports went up 74%.

We can now say that the CGE models significantly underpredicted the effect of NAFTA on trade. In addition, the industry-level changes in bilateral trade they forecasted turned out to have little correlation with the actual post-NAFTA changes. These results cast doubt on the ability of the existing models of trade to accurately forecast the effects of trade policies.

It is important that the models that are used to predict the effects of government policies are transparent and subjected to thorough testing and evaluation. However, it is difficult to fully evaluate the models of trade used to predict the effects of NAFTA because their equations and data are not publicly available and, therefore, replication is not possible.

This paper proposes a new model for forecasting the effects of trade liberalizations, which are of great importance to policy-makers. Instead of using the Armington assumption, this model employs the framework of Eaton and Kortum (2002) to motivate intra-industry trade. The model is called the HPPC model, which stands for heterogeneous producers, perfect competition. The equations and data for the HPPC model are posted online and this paper tests its ability to accurately forecast the effects of trade liberalizations.

The performance of the model is evaluated by using it to forecast the effects of NAFTA from the point of view of 1989. The predictions are compared with the post-NAFTA data and forecasts of other CGE models. The comparisons show that the changes in NAFTA trade predicted by the HPPC model are close to the actual post-NAFTA changes and much closer to them than the predictions of other CGE models. The HPPC model is also able to better explain the variation of the predicted changes across countries and industries.

The paper studies the reasons for better performance of the HPPC model vs. the previous CGE models. It focuses on the Brown, Deardorff, and Stern (1992a) model as a representative CGE model. The paper finds that the BDS model, like other CGE models, used low Armington elasticities of substitution, which resulted in small forecasted changed in trade overall. The BDS model also suffered from using inaccurate estimates of the policy barriers to be removed by NAFTA.

The paper is organized as follows. Section 2 describes the general equilibrium model of trade with heterogeneous producers. Section 3 evaluates the performance of this model by comparing its predictions to the data and predictions of other models. Section 4 analyzes the results and Section 5 concludes.

2. Model with heterogeneous producers

This section presents an alternative to the currently available computable models of trade. The new model is formally described in Section 2.1 and the parametrization procedure is explained in Section 2.2. The NAFTA simulation results are presented in Section 3.

The model is based on the neoclassical assumptions of multiple industries, constant returns to scale, perfectly competitive markets, and several factors that are mobile across industries. Each industry is characterized by a particular level of technology, set of factor intensities, and a demand function. Countries differ in their factor endowments.[2] In all of these aspects, the model is similar to the currently available computable models of trade.

However, while other models use the Armington assumption to explain two-way trade between countries, this model relies on the Eaton-Kortum (EK) framework at the industry level. Within each industry, there is a continuum of goods produced with different productivities. Production of each good has constant returns to scale, and goods are priced at marginal cost. Since the heterogeneous producers and perfect competition are the defining characteristics of this model, it will be referred to in this paper as the HPPC model.[3]

The use of the Eaton and Kortum (2002) framework instead of the Armington (1969) approach has several key implications. The goods are differentiated by their features, not by their country of origin. The home bias in consumption and cross-country price differentials are explained by trade costs rather than the demand-side parameters. Note that the use of the Eaton-Kortum methodology instead of the Armington assumption by itself does not improve the forecasting abilities of a model since the key equations are the same in both models (as explained in Eaton and Kortum (2002)).

2.1 Description of the model

There are *N* countries, indexed by *i* or *n*, *J* industries, indexed by *j* or *m*, and two factors of production: capital and labor. The industry cost functions has a Cobb-Douglas form:

$$c_{ij} = r_i^{\alpha_j} w_i^{\beta_j} \rho_{ij}^{1-\alpha_j-\beta_j}, \tag{1}$$

where r_i is the rate of return on capital, w_i is the wage, ρ_{ij} is the price of intermediate inputs used in industry *j* of country *i*, and $\alpha_j > 0$, $\beta_j > 0$, and $1-\alpha_j+\beta_j > 0$ are the capital, labor, and intermediate goods shares, respectively. The price of inputs ρ_{ij} is the Cobb-Douglas function of industry prices:

$$\rho_{ij} = \prod_{m=1}^{J} p_{im}^{\eta_{jm}}, \tag{2}$$

where $\eta_{jm} > 0$ is the share of industry *m* goods in the input of industry *j*, such that $\sum_{m=1}^{J} \eta_{jm} = 1$, $\forall j$.

Intra-industry production, trade, and prices are modeled using the framework of Eaton and Kortum (2002). In each industry, there is a continuum of goods, with each good indexed on the interval [0,1] by l and produced with its own productivity. Productivities $z_{nj}(l)$ are the result of the R&D process and probabilistic, drawn independently from the Fréchet distribution with cdf

$F_{ij}(z) = e^{-T_{ij}z^{-\theta}}$, where $T_{ij} > 0$ and $\theta > 1$ are the parameters.[4] Consumers have CES preferences over the continuum of goods within an industry with the elasticity of substitution $\sigma > 0$.
The price of good l of industry j produced in country i and delivered to country n is $p_{nij}(l) = c_{ij}d_{nij} / z_{ij}(l)$, where d_{nij} is the Samuelson's iceberg transportation cost of delivering industry j goods from country i to country n.[5] In country n, consumers buy from the lowest-cost supplier, so the price of good l in country n is $p_{nj}(l) = \min\{p_{nij}(l), i = 1,\ldots,N\}$.

For the purposes of this paper, it is necessary to separate the total trade costs d_{nij} into policy-related trade costs τ_{nij} and non-policy-related trade costs t_{nij}. The policy-related trade barriers (tariffs and tariff equivalents of NTBs) can be imposed on the f.o.b. or c.i.f. values of goods. If they are imposed on the f.o.b. values, then $d_{nij} = 1 + t_{nij} + \tau_{nij}$. If they are imposed on the c.i.f. values, then $d_{nij} = (1 + t_{nij})(1 + \tau_{nij})$. The NAFTA simulations in this paper assume that the policy-related barriers are imposed on the f.o.b. values, which corresponds to the practice in the United States, Canada, and Mexico (for NAFTA countries).

The distribution (cdf) of prices p_{nij} is $G_{nij}(p) = 1 - F_{ij}(c_{ij}d_{nij} / p) = 1 - e^{-T_{ij}(c_{ij}d_{nij})^{-\theta} p^{\theta}}$. The distribution of p_{nj} is $G_{nj}(p) = 1 - \prod_{i=1}^{N}[1 - G_{nij}(p)] = 1 - e^{-\Phi_{nj}p^{\theta}}$, where $\Phi_{nj} = \sum_{i=1}^{N} T_{ij}(c_{ij}d_{nij})^{-\theta}$ summarizes technology, input costs, and transport costs around the world. The exact price index for the within-industry CES objective function is then $p_{nj} = \left[\int_0^1 p_{nj}(l)^{1-\sigma} dl\right]^{1/(1-\sigma)} =$ $= \left[\int_0^{\infty} p_{nj}^{1-\sigma} dG_{nj}(p)\right]^{1/(1-\sigma)} = E\left[P_{nj}^{1-\sigma}\right]^{1/(1-\sigma)} = \gamma\Phi_{nj}^{-1/\theta}$, where $\gamma \equiv \Gamma((\theta + 1 - \sigma)/\theta)^{1/(1-\sigma)}$.[6] This price index can also be written as

$$p_{nj} = \gamma\left[\sum_{i=1}^{N} T_{ij}(d_{nij}c_{ij})^{-\theta}\right]^{-1/\theta}, \tag{3}$$

where γ is a constant. Plugging this price index into (1), the cost equation becomes

$$c_{ij} = r_i^{\alpha_j} w_i^{\beta_j} \prod_{m=1}^{J}\left[\gamma^{-\theta}\sum_{n=1}^{N} T_{nm}(d_{inm}c_{nm})^{-\theta}\right]^{-\frac{\eta_{jm}(1-\alpha_j-\beta_j)}{\theta}}. \tag{4}$$

To derive the industry-level bilateral trade flows, we note that the probability that a producer from country i has the lowest price in country n for good l is $\pi_{nij} \equiv \Pr\left[p_{nij}(l) \le \min\{p_{nsj}(l); s \ne i\}\right] = \int_0^{\infty} \prod_{s \ne i}[1 - G_{nsj}(p)] dG_{nij}(p) = T_{ij}(\gamma c_{ij}d_{nij} / p_{nj})^{-\theta}$. Since there is a continuum of goods on the interval $[0,1]$, this probability is also the fraction of industry j goods that country n buys from i. It is also the fraction of n's expenditure spent on industry j goods from i or X_{nij} / X_{nj} (this is true because conditional on the fact that country i actually supplies a particular good, the distribution of the price of this good is the same regardless of the source i). So, the industry-level bilateral trade is given by

$$\pi_{nij} = \frac{X_{nij}}{X_{nj}} = T_{ij}\left(\frac{\gamma c_{ij} d_{nij}}{p_{nj}}\right)^{-\theta}, \tag{5}$$

where X_{nij} is the spending of country n on industry j goods produced in country i and X_{nj} is the total spending in country n on industry j goods.

Parameter T represents industry-level productivity and, therefore, determines comparative advantage across industries. For example, country n has a comparative advantage in industry j if $T_{nj}/T_{nm} > T_{ij}/T_{im}$.[7] Parameter θ determines the comparative advantage across goods within an industry. Lower value of θ means more dispersion of productivities among producers, leading to stronger forces of within-industry comparative advantage.

Industry output Q_{ij} is determined as follows. The goods market clearing equation is

$$Q_{ij} = \sum_{n=1}^{N} X_{nij} = \sum_{n=1}^{N} \pi_{nij} X_{nj} = \sum_{n=1}^{N} \pi_{nij}\left(Z_{nj} + C_{nj}\right), \tag{6}$$

where Z_{nj} and C_{nj} are amounts spent by country n on industry j's intermediate and consumption goods, respectively. The spending on intermediate goods is $Z_{nj} = \sum_m \eta_{mj} w_n L_{nm}(1-\alpha_m-\beta_m)/\alpha_{gm}$, where L_{nm} is the stock of labor employed in industry m of country n.[8]

Consumer preferences are two-tier: Cobb-Douglas across industries and, as previously mentioned, CES across goods within each industry. Therefore, $C_{nj} = \psi_{nj} Y_n$, where Y_n is the total income (GDP) in country n and $\psi_{nj} \geq 0$ is a parameter of the model.[9] Plugging the expressions for intermediate and consumption spending into (6), the output equation becomes

$$Q_{ij} = \sum_{n=1}^{N} \pi_{nij}\left(\left(\sum_{m=1}^{J} \frac{\eta_{mj}(1-\alpha_m-\beta_m)}{\beta_m} w_n L_{nm}\right) + \psi_{nj} Y_n\right). \tag{7}$$

Since production is Cobb-Douglas, industry factor employments are given by $K_{ij} = \alpha_j Q_{ij}/r_i$ and $L_{ij} = \beta_j Q_{ij}/w_i$. Factors of production can be freely and instantaneously moved across industries within a country, subject to the constraints $\sum_{j=1}^{J} K_{ij} = K_i$ and $\sum_{j=1}^{J} L_{ij} = L_i$, where K_i and L_i are the country factor stocks, which are fixed.

Due to data limitations, only the manufacturing industries are modeled. The nonmanufacturing sector's price index is normalized to 1 and its purchases of the manufacturing intermediates are treated as final consumption. Country income Y_i is the sum of the manufacturing income Y_i^M and nonmanufacturing income Y_i^O:

$$Y_i = Y_i^M + Y_i^O = w_i L_i + r_i K_i + Y_i^O. \tag{8}$$

The manufacturing is assumed to be a constant proportion of the GDP, so that $Y_i^O = \xi_i Y_i$, where $\xi_i \geq 0$ is a parameter of the model. Factor stocks K_i and L_i are specific to manufacturing. Capital and labor are not mobile between the manufacturing and nonmanufacturing sectors.

The model is given by equations (3)-(5), (7)-(8), and the four factor employment and factor clearing equations. Model parameters are α_j, β_j, η_{jm}, θ, ψ_{nj}, t_{nij}, τ_{nij}, T_{nj}, K_i, L_i, and ξ_i. The model solves for all other variables including all prices, industry factor employments, output, and trade.[10]

2.2 Assigning parameter values

The model is parametrized using 1989 data for 8 two-digit manufacturing industries in 19 OECD countries.[11] The included countries and industries can be seen in Table 1. The values for parameters α_j, β_j, η_{jm}, and θ are taken from the data or literature. The value of the technology distribution parameter θ is taken from Eaton and Kortum (2002), where it is estimated to be 8.28 using trade and price data.[12] Sources for all data are described in the appendix. Estimation of the trade costs is discussed in Sections 2.2.1 and 2.2.2. The values for parameters ψ_{nj}, T_{nj}, K_i, L_i, and ξ_i are obtained by fitting a subset of the model to data, which is described in Section 2.2.3.

2.2.1 Total trade barriers

This section estimates total trade costs d_{nij}. The next section will describe the magnitudes of policy-related barriers τ_{nij} obtained from data. The non-policy-related barriers t_{nij} are calculated as the difference between d_{nij} and τ_{nij}.

Total bilateral trade barriers d_{nij} are estimated by applying the approach of Eaton and Kortum (2002) at the industry level. The ratio of n 's spending on i 's goods to its spending on its domestically-made goods is obtained from equation (5):

$$\frac{\pi_{nij}}{\pi_{nnj}} = \frac{X_{nij}}{X_{nnj}} = \frac{T_{ij}}{T_{nj}} d_{nij}^{-\theta} \left(\frac{c_{ij}}{c_{nj}} \right)^{-\theta}. \tag{9}$$

To relate the unobservable trade cost to the observable country-pair characteristics, the following trade cost function is used:

$$\log d_{nij} = d_{kj}^{phys} + b_j + l_j + f_j + m_{nj} + \delta_{nij}, \tag{10}$$

where d_{kj}^{phys} $(k = 1,\ldots,6)$ is the effect of physical distance lying in the kth interval[13], b is the effect of common border, l is the effect of common language, f is the effect of belonging to the same free trade area, m_n is the overall destination effect, and δ_{ni} is the sum of transport costs that are due to all other factors.

Then, the gravity-like estimating equation is obtained by taking logs of both sides of (9):

$$\log \frac{X_{nij}}{X_{nnj}} = -\theta d_{kj}^{phys} - \theta b_j - \theta l_j - \theta f_j + D_{ij}^{\exp} + D_{nj}^{imp} - \theta \delta_{nij}, \tag{11}$$

where $D_{ij}^{\exp} = T_{ij} c_{ij}^{-\theta}$ is the exporter dummy, $D_{nj}^{imp} = -\theta m_{nj} - \log T_{nj} c_{nj}^{-\theta}$ is the importer dummy.[14,15]

The average (across country pairs and industries) estimated transport cost is 2.27. This transport cost includes all costs necessary to move goods between countries, such as freight, insurance, tariffs, non-tariff barriers, and theft in transit. Trade costs vary across country pairs and industries. For example, the Machinery and Textile products are typically cheaper to move between countries than the Wood and Food products.

2.2.2 Policy-related trade barriers

In order to simulate the effects of NAFTA, it is necessary to know the extent of the policy-related trade barriers before its implementation. This includes both tariff and non-tariff barriers, the latter expressed in terms of ad-valorem tariff equivalents. Obtaining such data is not trivial.

The main source for the magnitudes of the pre-NAFTA policy-related trade barriers used in this paper is Nicita and Olarreaga (2007) that has information on both tariff and non-tariff barriers. This paper uses 1989 applied tariff data for Canada and the United States and 1991 data for Mexico, which is the closest available year.[16,17]

Compared to tariffs, the tariff equivalents of non-tariff barriers are much harder to collect and estimate. Consequently, there are fewer sources of this data. The earliest years for which the ad-valorem equivalents of NTBs for Canada, Mexico, and the U.S. are available in Nicita and Olarreaga (2007) are 1999-2001. In the absence of other data, this paper uses the information from 1999-2001 to proxy for 1989 magnitudes. Due to NAFTA's reduction of NTBs, the average levels of NTBs for the NAFTA countries have probably fallen between 1989 and 1999-2001. Therefore, using the 1999-2001 levels results in smaller forecasted growth in trade due to NAFTA.[18] However, the pattern of NTBs across industries is less likely to have changed.

The tariffs and tariff equivalents of non-tariff barriers used in the simulations are presented in Tables 2(a)-(c). The average tariffs imposed by Canada, Mexico, and the United States on manufacturing goods, shown in the last column, were about 8.5%, 13.7%, and 4.7% respectively, while the tariff equivalents of NTBs were 3.3%, 17.7%, and 4.1%. The total policy-related barriers, therefore, were 11.8% in Canada, 31.4% in Mexico, and 8.8% in the United States.

Tables 2(a)-(c) also report tariffs and tariff equivalents of NTBs by industry. There is noticeable heterogeneity of protection levels across industries. The Textile industry is one of the most protected industries in all three countries with total policy-related barriers ranging between 16% in the United States to 40% in Mexico. The Paper industry is the least protected industry in all three countries with barriers ranging between 1.29% in the United States to 17% in Mexico.

The ranking of industries according to total protection levels varied across countries. For example, the Wood industry is fairly heavily protected in Canada, but relatively less protected in Mexico and the United States. The same is true of the Metals industry. On the other hand, the Nonmetals industry has less protection relative to other industries in Canada than it does in Mexico or the United States.

The prevalent type of policy-related protection also varied across industries and countries. For example, in the United States, the Textile and Nonmetals industries are protected mostly by tariffs, while the Food industry is protected mostly by NTBs. In Canada, the Chemicals and Nonmetals industries are protected mostly by tariffs, while the Metals industry is protected mostly by NTBs.

2.2.3 Technology and other fitted parameters

The parameters ψ_{nj}, T_{nj}, K_i, L_i, and ξ_i are obtained by fitting a subset of the simulation model, together with a long-run equilibrium condition, to domestic data.[19] The subset of the model includes the cost equation (4), reproduced here:

$$c_{ij} = r_i^{\alpha_j} w_i^{\beta_j} \prod_{m=1}^{J} \left[\gamma^{-\theta} \sum_{n=1}^{N} T_{nm} \left(d_{inm} c_{nm} \right)^{-\theta} \right]^{-\frac{\eta_{jm}\left(1-\alpha_j-\beta_j\right)}{\theta}}, \tag{12}$$

and a simplified version of the output equation (industry output):

$$Q_{ij} = \sum_{n=1}^{N} \pi_{nij} X_{nj}, \tag{13}$$

where import shares π_{nij} are given by the following equation, derived from equations (5) and (3):

$$\pi_{nij} = \frac{T_{ij}\left(c_{ij} d_{nij}\right)^{-\theta}}{\sum_{i=1}^{N} T_{ij}\left(c_{ij} d_{nij}\right)^{-\theta}}. \tag{14}$$

The values of Q_{ij}, X_{nj}, and w_i are taken from data. Data on the rates of return r_i is not available, so their values in the base year are approximated at 20%.[20] The values of trade costs

d_{nij} were estimated in the previous section. Equations (12)-(14) are solved to find the 1989 values of T_{nm} and c_{ij}. The system (12)-(14) is exactly identified since there are as many equations ($2NJ$) are unknowns.

The industry employments of capital and labor are then calculated as $K_{ij} = \alpha_j Q_{ij} / r_i$ and $L_{ij} = \beta_j Q_{ij} / w_i$.[21] The country factor stocks K_i and L_i are calculated as the sum of industry factor employments. Nonmanufacturing share ξ_i is calculated as $1-(r_i K_i + w_i L_i)/Y_i$, where the total income Y_i is taken from data. The taste parameters are calculated as $\psi_{ij} = C_{ij} / Y_i$, where the consumption is calculated as $C_{ij} = X_{ij} - Z_{ij} = X_{ij} - \sum_{m=1}^{J} \eta_{mj} (1-\alpha_{km} - \alpha_{lm}) Q_{im}$.[22]

The estimated industry technology parameters relative to the United States are presented in Table 1. They show that countries have different relative technologies in different industries. These differences provide industry-level (inter-industry) Ricardian comparative advantages.

3. Evaluating the predictions of the model

The simulation of NAFTA performed in this paper entails the removal of all policy-related trade barriers τ_{nij} reported in Table 2(c) between the three NAFTA countries, while maintaining all other trade barriers t_{nij}. This section evaluates the accuracy of the model's predictions regarding the changes in total manufacturing trade and trade in individual industries. The simulations results are compared with the actual post-NAFTA data and results of several previous NAFTA simulations.[23]

3.1 Benchmarks

The data against which the results of the simulations are compared is from 1989-2008. The initial point (1989) is given by the year in which the model was parametrized.[24] The end year (2008) is the latest year for which trade data is available.

NAFTA was implemented in 1994 and provided for graduate bilateral trade barrier reductions between the participating countries. Both the tariff barriers and non-tariff barriers were to be reduced over a period of time. The average length of phase-outs for U.S. tariffs was 1.4 years and Mexican tariffs 5.6 years (Kowalczyk and Davis, 1996). Therefore, by the year 2008, which is the 15th year of NAFTA implementation, the vast majority of the trade barriers that were to be eliminated under NAFTA had been eliminated.[25]

The effects of NAFTA have been previously forecasted by several teams of researchers.[26] The forecasts employed computable general equilibrium models that utilized the Armington assumption. These models assumed either constant or increasing returns to scale.[27] Assuming IRS resulted in greater predicted effects of NAFTA. Some models had constant capital stock, while others allowed capital accumulation. Allowing international movement of capital typically caused large inflows of capital into Mexico.

The effects of NAFTA were simulated by removing the pre-NAFTA policy-related trade barriers. Some studies, such as Brown et al. (1992a) and Roland-Holst et al. (1994), simulated the removal of the non-tariff barriers (NTBs) in addition to the removal of tariffs, which resulted in greater predicted effects of NAFTA.[28]

Very few studies exist that systematically evaluate the predictions made by economic models regarding NAFTA. This is unfortunate, since NAFTA was an important test for general equilibrium models of trade, so it is interesting to see how they performed. Because the purpose of the CGE models typically is to make economic forecasts, the quality of those forecasts is an important criterion by which the models should be judged.

Instead, most post-NAFTA studies focus on analyzing the effects of NAFTA, typically using the gravity model rather than a CGE model.[29] These studies generally find that NAFTA had a relatively small effect on employment, prices, and welfare, as pre-NAFTA studies predicted. They also find that NAFTA had a large effect on trade, which is where the pre-NAFTA economic forecasts badly stumbled.

One paper that evaluates the performance of the pre-NAFTA forecasts is Kehoe (2005).[30] By systematically comparing model predictions to data, he finds that many of the predictions made before NAFTA turned out to be significantly off.[31] Specifically, the pre-NAFTA forecasts significantly underestimated the effects of NAFTA on trade, sometimes by several orders of magnitude. In addition, the models did poorly in explaining the variation of changes in trade flows across countries and industries.

Section 3.2 will compare the forecasts of the HPPC model to the forecasts of the Brown-Deardorff-Stern (BDS) and Roland-Holst-Reinert-Shiells (RRS) models.[32] Section 4 will discuss possible reasons for the differences in forecasts.

3.2 Results

Table 3 shows the overall effect of NAFTA: change in the share of NAFTA trade in the total trade of the NAFTA countries.[33] The HPPC model predicts that this share would grow 25.9% while it actually grew 23.8%. Relative to the total NAFTA income, the predicted growth in NAFTA trade is 62.2% while the actual growth is 66.5%. Therefore, the HPPC model slightly overestimates the change in NAFTA trade relative to the total trade of the NAFTA countries, and underestimates somewhat the change in NAFTA trade relative to NAFTA income. This means that the total trade of the NAFTA countries relative to their income grew more than what the model predicts. This could be due to a decrease in non-policy related trade costs across the world, for example.[34]

Table 4 gives a more detailed look at the changes in trade of the NAFTA countries. It shows the actual and predicted percent changes in the total exports and imports of Canada, Mexico, and the United States, relative to their respective GDPs. The numbers are also plotted in Figure 1.

The first column shows the actual 1989-2008 changes. Mexican exports and imports have grown the most, followed by Canada's and then the United States'. The changes predicted by the RRS and BDS models are many times smaller than the actual changes. The RRS model, whether with constant or increasing returns to scale, performs the worst in terms of correlation with data. The BDS model performs better, but its predicted changes in Canadian and Mexican exports and imports are smaller than the actual changes by an order of magnitude. The HPPC model performs the best: its predicted changes are the closest to the actual, as can easily be seen on Figure 1. Its predicted changes also exhibit the best correlation with the actual changes: 0.98.

Next, we investigate the accuracy of the models' forecasts at the industry level. Only the HPPC and BDS models are considered. The BDS model is chosen because it seems to be the best-performing out of previous NAFTA simulations and because of the availability of the detailed simulation results.[35]

Tables 5a-c show the actual vs. predicted percent changes in the import shares for each pair of the NAFTA countries by industry. The share of country i in industry j imports of country n is X_{nij} / IM_{nj} , where IM_{nj} are the total imports of industry j goods in country n. Figure 2 plots the data shown in Table 5. Figures 2a and 2b plot the changes for the US-Canada and US-Mexico trade, which together constitute about 99% of NAFTA trade.[36]

It can be seen from these figures that the predictions of the HPPC model are generally close to the actual values, while the BDS model tends to significantly underpredict trade changes. The HPPC model is also better able to explain the variation of changes in trade across industries: the correlation of its predictions with data is 0.95, while for the BDS model it is 0.31. As an example, consider U.S. imports from Canada and Mexico. The HPPC model correctly predicts that the largest increases will occur in the Textile industry, while the BDS model does not.

Figures 2c and 2d plot the actual vs. predicted changes in import shares for the Canada-Mexico trade. Trade between these two countries exhibits the largest discrepancies between the actual and predicted changes. Trade between Canada and Mexico trade is small: it constituted just under 1% of NAFTA trade in 1989 and about 1.5% in 2008. Canadian exports to Mexico were only $400M in 1989 and $3B in 2008. I believe that small trade flows (most likely done by just a handful of firms in a few transactions) are more susceptible to data irregularities than larger trade flows.[37]

Very extreme observations are reported in some industries: the Wood industry data shows a 1580% increase in Mexican exports to Canada and the Chemicals industry data shows a 413% increase in Mexican exports to Canada.[38] The predictions of both the HPPC and BDS models correlate poorly with the actual changes in trade: the correlation is 0.08 for the HPPC and -0.08 for the BDS model.

Table 6 shows the correlations between the actual and predicted changes in import shares for each pair of countries. It also shows the estimated intercepts and slopes for the regressions of actual on predicted changes. Ideally, we would like the intercept to be zero and slope one. The correlation is a measure of how much of the variation in the data is explained by the model.[39]

The table shows, for example, that on average the HPPC's estimates of changes in Mexican import shares in the U.S. have to be multiplied by 0.93 and the product reduced by 15.70

percentage points to match the actual changes in those import shares. By comparison, BDS model's predicted changes have to be multiplied by 2.23 and the product increased by 65.84 percentage points to match the actual changes. The correlation between the actual and predicted changes is 0.98 for the HPPC model and 0.44 for the BDS model.

4. Analysis of the results

The previous section has shown that there are significant disparities between the NAFTA forecasts of the HPPC and the other models. Specifically, it noted two problems with the forecasts of the other models: the overall magnitude of the predicted changes in trade is too low and the correlation (across industries and country pairs) between the predicted and actual changes is poor. This section will investigate the causes for the differences in the forecasts.[40]

Equation (14), which is obtained by combining equations (5) and (3), shows how trade flows are predicted in the HPPC model. Its analogue in the Armington model is

$$\pi_{nij} = \frac{\lambda_{nij}^{\sigma-1} p_{nij}^{-(\sigma-1)}}{\sum_{s=1}^{N}\left(\lambda_{nsj}^{\sigma-1} p_{nsj}^{-(\sigma-1)}\right)}, \tag{15}$$

where σ is the (Armington) elasticity of substitution between goods sourced from different countries and λ_{nij} is the weight placed in the utility function of country n on industry j goods sourced from country i (see, for example, Eaton and Kortum (2002) or Ruhl (2008)). In the presence of tariffs, price p_{nij} is equal to $c_{ij}(1+\tau_{nij})$, where c_{ij} is the cost of producing country i's variety of good j and τ_{nij} is the tariff.

We can see that parameter θ in the HPPC model and σ in the Armington model are key to determining how changes in trade costs affect trade flows. The HPPC model sets $\theta = 8.28$ while the BDS model sets the Armington elasticity σ at around 3.[41] As discussed in Ruhl (2008), lower values of σ are estimated by studies of high-frequency changes in prices, while higher values are produced by cross-country studies and studies of changes in trade policy.

Holding everything else equal, using $\sigma = 8.28$ instead of 3 results in about 2.76 times greater predicted changes in trade flows. So the use of the low Armington elasticities by the BDS model can explain its small forecasted changes in trade flows due to NAFTA. However, since the BDS model uses very similar elasticities in different industries (they vary between 2.7 and 3.0 across industries), the values of σ cannot explain the poor correlation of the forecasted and actual changes in trade across country pairs and industries. HPPC model assumes constant θ in all industries.

To check the effects of the difference in magnitude between σ and θ on the forecasts, I set $\theta = 3$ and re-simulate the effects of NAFTA.[42] The results of this and other simulations discussed in this section are shown in Table 7. The columns present various measures of the relationship between the actual and predicted changes in industry-level import shares (excluding Canada-Mexico trade). The measures include correlation, intercept and slope from the regression of the actual on predicted trade changes, and the average absolute change in import shares (which helps to measure the overall magnitude of the predicted trade changes).

The first line of the table shows the results for the original model configurations and parameter values. It shows that the forecasts of the HPPC model correlate highly with the data and are of similar magnitude to the data, as evidenced by the average absolute change and regression results.[43] The second line shows that setting $\theta = 3$ results in much smaller predicted changes in trade. The overall magnitudes of the forecasted changes in trade in this case are similar to those of the BDS model, but the correlation between the predicted and actual changes is much higher at 0.87 (vs. 0.32 for the BDS model).

So why do the changes in trade flows predicted by the BDS model correlate much more poorly with the data than the changes in trade flows predicted by the HPPC model?

One possible reason is that the BDS model (same as all the Armington-based models) treats the policy barriers as being imposed on the c.i.f. goods values instead of their f.o.b. values, which results in greater percent changes in trade costs and, therefore, greater forecasted changes in trade. With $\theta = 8.28$, the increase is about 50% on average for the HPPC model's NAFTA forecasts.[44]

However, the choice of the assumption does not have a big impact on the correlation between the actual and predicted changes. Though, $d\tau/(1+\tau)$ is less correlated with the actual changes in NAFTA trade than $d\tau/(1+t+\tau)$, 0.06 vs. 0.2, the correlation is low in either case, meaning that the variation in trade costs can explain only a fraction of the variation in the actual trade changes. Also, assuming that policy barriers are imposed on the c.i.f. instead of f.o.b. goods' values in the HPPC model actually slightly increases the correlation between the forecasted and actual changes in trade (for $\theta = 3$, the increase is from 0.87 to 0.93 as shown on line 3 of Table 7).

We should also consider the fact that the BDS and HPPC models use different data on pre-NAFTA policy barriers τ, which can be a reason for their different forecasts. We note that the tariff rates used by the BDS model (shown in Brown et al. (1992a)) are highly correlated (0.8) with the tariff rates used by the HPPC model. Using the HPPC model with the BDS tariff levels (keeping $\theta = 3$ and c.i.f. policy barriers) reduces the correlation with the data from 0.93 to 0.88, as shown on line 4 of Table 7.

The tariff equivalents of non-tariff barriers are solved for endogenously by the BDS model and are not shown.[45] However, since the BDS model only considers NTBs imposed by the U.S. on Mexican Food and Textile products, I will simply omit these two trade flows from the analysis to gauge the impact of the BDS's NTB treatment. The correlation between the remaining 30 predicted and actual trade flows for the BDS model is 0.44, which is an increase over 0.32 for all 32 trade flows. So, BDS's treatment of the NTBs may be contributing to the poor quality of its forecasts.

Simulating the effects of NAFTA using the HPPC model with $\theta = 3$, policy-related trade costs imposed on c.i.f. values, BDS's tariff rates, and no NTB removal, the correlation between the predicted and actual changes for the 30 trade flows falls to 0.74, as shown on the last line of

Table 7.[46] This is not as good as using HPPC's own parameter values (0.95), but still substantially better than the BDS's result of 0.44.

However, the gap between the correlations in this case is about a half of the gap that exists when HPPC's own parameter values are used (the gap is 0.3 vs. 0.63). Table 7 shows that of all parameter values, BDS model's treatment of NTBs contribute the most to the poor quality of its forecasts (it explains more than 3/4 of the change in the correlation gap). The values of the Armington elasticities and tariff levels used by the BDS model also deteriorate HPPC model's forecasts, but to a much smaller degree (in terms of correlation, not magnitudes).

The rest of the difference in the performance of the HPPC and BDS models must be explained by the values of other parameters, such as the input-output shares η. Unfortunately, the values of these parameters are not published by the authors of the BDS model. Therefore, a comparison of their values in the BDS and HPPC models is not possible.[47]

In addition to the model properties and parameter values discussed in this section, the gap between the forecasted and actual changes in trade could have been caused by various post-NAFTA events not accounted for by the simulation models. Technological change is one such possible event (Kehoe, 2005). However, technological change affects both trade and GDP, so its effect on the trade-to-GDP ratios is likely to be small. In addition, while by most estimates there was some positive technological change in Mexico in the late 1990s, it was fairly small and not larger than the contemporary technological change in the United States. So the technology of Mexico relative to the U.S. has not changed noticeably during that time.

There may have been differences of technological growth across industries. It is unknown how much these differences have contributed to the variation between predicted and actual changes in trade across industries.

The devaluation of Mexican peso in 1995 is another post-NAFTA event that is not part of the simulations. However, the effects of the peso devaluation have most likely dissipated by the year 2008.

5. Conclusion

Being a major event in recent North American economic history, NAFTA is a natural experiment that is useful for evaluating models of trade. Unfortunately, the currently available computable general equilibrium models of trade have not done a good job forecasting the effects of NAFTA. The changes in trade flows predicted by those models are much smaller than the actual changes that occurred after NAFTA. In addition, the models have done a poor job explaining the variation in trade changes across countries and industries.

While the existing computable models of trade use the Armington (1969) methodology to explain intra-industry trade, this paper presents a new model, called the HPPC model, that uses the Eaton and Kortum (2002) methodology for that purpose. Using this framework on the industry level results in a highly tractable model that has all the usual neoclassical features with room for both Ricardian and Heckscher-Ohlin reasons for trade and asymmetrical industry-level trade costs.

After describing the model, the paper evaluates it by using it to forecast the effects of NAFTA from the point of view of 1989. The results are then compared with the post-NAFTA data and forecasts of other models of trade. The results show that the HPPC model performs better than the existing models of trade. Its forecast is closer in magnitude to the actual data and its ability to predict variation of trade changes across countries and industries is better.

The paper investigates why the HPPC model is able to produce better forecasts than the existing CGE models, focusing specifically on the Brown et al. (1992a) model as an example of an existing CGE model. It finds that the BDS model suffers from using Armington elasticities that are too low. It also finds that the BDS's treatment of the non-tariff barriers has contributed to the poor quality of its forecasts.

Endnotes

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1. Predictions made by politicians varied from significant benefit to the U.S. to significant loss of U.S. jobs to Mexico. For example, President Clinton, who signed NAFTA in 1993, promoted its benefits to the U.S. and the world. Ross Perot, an independent presidential candidate in 1992, predicted significant job losses in the U.S.

2. Factor endowments are fixed in this model. An unpublished appendix (available from the author upon request) presents an extension that allows domestic accumulation (following the Solow model) and international mobility of capital (that equalizes the rates of return across countries). The assumption of fixed capital stock in this paper is motivated by several reasons. First, the existing models of NAFTA that allow capital mobility use various and often ad-hoc closure rules, making a formal comparison with their forecasts difficult. Second, allowing capital accumulation and international mobility has only a small effect on the forecasted changes in trade (see footnote 34).

3. Caliendo and Parro (2010) also have a model that uses the Eaton-Kortum methodology on the industry level. Compared to the HPPC model, their model has only one factor of production and is parametrized differently. Note that this paper and the HPPC model predate their paper and model.

4. Kortum (1997) and Eaton and Kortum (1999) provide microfoundations for this approach. Parameter T_{ij} governs the mean of the distribution, while parameter θ, which is common to all countries and industries, governs the variance. The support of the Fréchet distribution is $(0,\infty)$.

5. To receive \$1 of product in country n requires sending $d_{nij} \geq 1$ dollars of product from country i. By definition, domestic transport costs are set to one: $d_{nnj} \equiv 1$. Trade barriers result in $d_{nij} > 1$.

6. The last equality follows from a known statistical result. These derivations are explained in greater detail in Eaton and Kortum (2002).

7. The technology parameter T is different from the total factor productivity (TFP). Parameter T determines the mean of the Fréchet distribution and is exogenous in this model. TFP, on the other hand, is endogenous. Finicelli, Pagano, and Sbracia (2007) derive the analytic relationship between the T of an industry and the mean productivity of the firms that actually operate in that industry.

8. It obtains as follows: $Z_{nj} = \sum_m Z_{nmj} = \sum_m p_{nj} M_{nmj} = \sum_m \eta_{mj} \rho_{nm} M_{nm}$, where Z_{nmj} is the amount spent by industry m on intermediate goods from industry j, M is the quantity of intermediate goods, and the last equality follows from (2). Then from (1) $\rho_{nm} M_{nm} = w_n L_{nm} (1 - \alpha_m - \beta_m) / \alpha_{gm}$.

9. Consumption C includes private consumption and government consumption.

10. The model has $N^2 J + 5NJ + 3N$ unknowns and the same number of equations. The unknowns in the model are X_{nij}, c_{nj}, p_{nj}, K_{nj}, L_{nj}, Q_{nj}, Y_n, w_n, and r_n.

11. The countries and industries included in the model are chosen because of the availability of data, especially wages and industry-level output and spending. The year 1989 is chosen because the CGE models with which the HPPC model is compared in Section Sect: Evaluation are parametrized with data from 1989 or 1988.

12. The other estimate of θ in Eaton and Kortum (2002), 3.6, results in abnormally large estimates of trade barriers d_{nij} (6.6 average across all countries and industries). The results presented in this paper are affected by the value of θ. See Section 4 for analysis.

13. Following Eaton and Kortum (2002), the physical distance is divided into 6 intervals: $[0,375)$, $[375,750)$, $[750,1500)$, $[1500,3000)$, $[3000,6000)$, and $[6000, \text{maximum})$ to create d_{kj}^{phys}.

14. Note that the estimating equation includes the export and import dummy variables, similarly to the theoretically-derived gravity equation of Anderson and van Wincoop (2003).

15. For some pairs of countries, trade values are missing for 1989. Therefore, δ_{nij}, which are part of the distance measure, could not be estimated for some $n, i,$ and j. There are 19*18*8 =2,736 observations of δ_{nij} possible in the data, of which 105 or 3.8% are missing. Most missing observations are proxied by estimates from neighboring years. Six observations that could not be proxied in this manner were proxied by the estimates of δ_{ni} for total manufacturing.

16. Since Mexico has been liberalizing its trade even before NAFTA, using 1991 instead of 1989 trade barriers in the simulations may have reduced the forecasted growth in Mexican imports.

17. Note that the trade barriers between the U.S. and Canada were not zero in 1989. Even though the U.S.-Canada FTA went into effect in 1988, it called for a gradual removal of all bilateral trade barriers. Therefore, many tariffs and NTBs were still in place in 1989.

18. Section 4 shows the trade forecasts if the NTB barriers are ignored altogether.

19. This procedure is different from the approach used by Eaton and Kortum (2002) to find the technology parameters. They calculate technology parameters from the estimated importer and exporter dummies and data on wages.

20. The rates of return r_i are gross rates. The rate of 20% is obtained by assuming 10% net return and 10% depreciation. The results presented in the paper are not sensitive to these values.

21. The correlation between the calculated industry-level capital stocks and the capital stocks in the data is 0.99. The same number for labor is 0.97.

22. The correlation between the predicted and actual trade flows in the base year is near 1, but it needs to be remembered that the model has very few degrees of freedom. The average Grubel-Lloyd index (it measures the size of intra-industry trade) is 0.443 in the model and 0.438 in the data.

23. The focus will primarily be on the predictions regarding trade, and not GDP, prices, or welfare. The reason is that it is difficult to find data on prices, and GDP and prices were both significantly affected by events other than NAFTA.

24. The HPPC and BDS models were parametrized with data from 1989. The RRS model was parametrized with data from 1988, which should not make noticeable difference for the analysis of this paper because trade data is very slow-moving.

25. Data presented in López-Córdova (2002) shows that the percentage of U.S. manufacturing imports to Mexico that were either not subject to tariff or paid at most 5% tariff was 10 in

1993 and 93 in 2000. The percentage that paid more than 10% tariff was 85 in 1993 and less than 1 in 2000.

26. They include Sobarzo (1992), Roland-Holst, Reinert, and Shiells (1994, Cox and Harris (1992), Brown et al. (1992a), Bachrach and Mizrahi (1992), Shiells and Shelburne (1992), Hunter, Markusen, and Rutherford (1992) (auto industry), and McCleery (1992). The pre-NAFTA studies were initially collected together by the U.S. International Trade Commission (1992). The updated versions of some of these studies, together with the several new ones were later collected in Francois and Shiells (1994) and Kehoe and Kehoe (1995b). Summaries of these studies are presented in Brown, Deardorff, and Stern (1992b), Baldwin and Venables (1995), and Kehoe and Kehoe (1995a).

27. See Baldwin and Venables (1995) for a review and classification of these models.

28. Unfortunately, some studies did not report the size of the trade barriers that were removed during their simulations of NAFTA.

29. The examples include Gould (1998) and Krueger (1999). Unfortunately, many of these studies do not use the theoretically-derived specification of the gravity equation of Anderson and van Wincoop (2003). Romalis (2007) uses a CGE model with the Armington assumption, parametrized with the post-NAFTA data, to study the effects of NAFTA. Reviews of the post-NAFTA literature can be found in Burfisher et al. (2001) and Romalis (2007).

30. Fox (2000) evaluates the performance of CGE models in predicting the effects of U.S.-Canada free trade agreement.

31. Kehoe reviews the forecasts of the Brown-Deardorff-Stern, Cox-Harris and Sobarzo models.

32. The sources for the BDS results are Brown et al. (1992a) and Kehoe (2005); the source for the RRS results is Roland-Holst et al. (1994).

33. Total NAFTA trade is the sum of all bilateral trade flows in NAFTA: $\sum_{n \neq i}^{n,i \in H} \sum_j \left(X_{nij} + X_{inj} \right)$, where H is the set of NAFTA countries. Total trade of the NAFTA countries is $\sum_{n \in H} \sum_j \left(EX_{nj} + IM_{nj} \right)$, where EM_{nj} and IM_{nj} are total exports and imports of industry j goods in country n. Measuring bilateral trade relative to total trade or income helps to control for events other than NAFTA that affected the economies of the NAFTA countries during the post-NAFTA period. See Section 4 for the discussion of such events.

34. As mentioned in footnote 2, an unpublished extension of the HPPC model incorporates domestic accumulation and international mobility of capital. In the simulation of NAFTA, this extension predicts an accumulation of capital stock in the NAFTA countries, mostly due to a transfer from the non-NAFTA countries. It predicts that the capital stocks of Canada, Mexico, and the U.S. would grow 9.1, 10, and 0.65%, respectively. The total NAFTA trade

relative to the total trade of the NAFTA countries in this case is predicted to grow 28.4% and the total NAFTA trade relative to the total income of the NAFTA countries is predicted to grow 66.2%. Therefore, allowing domestic accumulation and international mobility of capital has fairly small effects on these measures of NAFTA trade.

35. The BDS model uses a 21-industry classification. Their results were aggregated to the 8-industry classification used by the HPPC model. The authors of the RRS model do not provide a concordance between their industries classification and SIC. Judging by industry names, some industries in the RRS model have no equivalents in SIC.

36. Trade between U.S. and Canada was 76% of the NAFTA trade in 1989 and 59% in 2008. Trade between U.S. and Mexico was 23% of the NAFTA trade in 1989 and 39% in 2008.

37. Alternatively, the data is correct and the models have trouble making predictions in the vicinity of autarky.

38. The 1989 Mexican Wood exports to Canada are reported at only $8.2M.

39. Correlation is $\sqrt{R^2}$.

40. As in the previous section, the emphasis here will be on the BDS model. As explained earlier, I chose the BDS model because it seems to have made good NAFTA forecasts and because its results (i.e. variables, industrial structure) are readily comparable to the results of the HPPC model.

41. The RRS model sets σ at around 1. Note that setting θ equal to 3 or 1 in the HPPC model would result in very unreasonably high estimates of d .

42. Note that the estimates of total trade costs d_{nij} change when the value of θ changes.

43. More precisely, there is evidence of small overprediction by the model.

44. The percent change in trade costs during trade liberalization is $\theta d\tau/(1+t+\tau)$ in case of the f.o.b. tariffs and $\theta d\tau/(1+\tau)$ in case of the c.i.f. tariffs. For a back-of-the-envelope analysis of this difference, let's take $\sigma=\theta=8$, $t=0.577$, and $\tau=0.166$, which are average for the HPPC model's NAFTA simulation. With these numbers, the percent change in trade costs is about 50% greater in case of the c.i.f. tariff than in case of the f.o.b. tariff.

45. The BDS model incorporates NTBs by "endogenously solving for the ad valorem tariff rate that will hold imports within each product category covered by NTBs at a predetermined level." (Brown et al., 1992a).

46. The overall magnitude of trade changes decreases to be again roughly similar to that of the BDS model.

47. The HPPC and BDS models also have different assumptions regarding the returns to scale. The HPPC model assumes constant returns to scale, while the BDS model assumes increasing returns. However, the forecasts of the constant and increasing returns versions of the RRS model have similar correlations with the data (across countries, see Table 4 - RRS do not present comparable industry-level results for both versions of the model, so I cannot check the similarity of cross-industry correlations.), which suggests that the degree of the returns to scale does not play a big role in determining the variation in trade changes.

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Table 1. Technology parameters relative to the United States

	Food	Textile	Wood	Paper	Chemicals	Nonmet.	Metals	Machinery
Canada	0.266	0.292	0.503	0.753	0.153	0.139	0.914	0.149
Mexico	0.010	0.009	0.001	0.001	0.017	0.010	0.022	0.003
U.S.	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Australia	0.253	0.098	0.018	0.040	0.048	0.045	0.408	0.054
Austria	0.027	0.154	0.029	0.087	0.063	0.201	0.137	0.073
Finland	0.013	0.080	0.089	0.434	0.056	0.048	0.238	0.072
France	0.368	0.702	0.138	0.260	0.372	0.792	0.587	0.318
Germany	0.215	0.676	0.220	0.332	0.522	0.914	0.683	0.521
Greece	0.043	0.044	0.001	0.003	0.008	0.033	0.040	0.002
Italy	0.178	1.435	0.339	0.206	0.249	1.387	0.369	0.356
Japan	0.080	0.776	0.119	0.309	0.571	1.491	1.007	1.228
Korea	0.032	0.319	0.008	0.017	0.069	0.043	0.148	0.061
New Zeal.	0.358	0.058	0.020	0.042	0.031	0.009	0.056	0.015
Norway	0.101	0.032	0.030	0.123	0.084	0.036	0.313	0.053
Portugal	0.018	0.028	0.004	0.011	0.006	0.024	0.011	0.004
Spain	0.117	0.140	0.026	0.058	0.080	0.211	0.193	0.048
Sweden	0.033	0.067	0.076	0.255	0.088	0.092	0.248	0.135
Turkey	0.014	0.019	0.000	0.000	0.007	0.015	0.027	0.001
U.K.	0.232	0.320	0.055	0.166	0.256	0.342	0.352	0.197

Table 2. Policy-related trade barriers

Panel A. Tariffs

Country	Food	Textile	Wood	Paper	Chemicals	Nonmetals	Metals	Machinery	Manuf.
Canada	8.83	17.65	8.48	3.46	8.26	7.78	4.83	5.63	8.51
Mexico	15.93	17.48	15.02	5.84	12.35	15.26	9.86	13.74	13.71
United States	2.14	10.64	2.47	0.62	4.48	7.43	3.04	3.37	4.68

Panel B. Tariff equivalents of non-tariff barriers

Canada	3.23	7.95	12.96	0.00	1.23	0.00	11.82	0.87	3.33
Mexico	26.68	22.89	8.39	11.12	17.09	18.11	4.03	19.21	17.70
United States	11.07	5.81	2.63	0.67	3.28	0.51	0.00	4.05	4.10

Panel C. Total policy-related trade protection

Canada	12.06	25.60	21.44	3.46	9.49	7.78	16.65	6.50	11.84
Mexico	42.61	40.37	23.41	16.96	29.44	33.37	13.89	32.95	31.42
United States	13.21	16.45	5.10	1.29	7.76	7.94	3.04	7.42	8.78

Table 3. Actual vs. predicted percent changes in NAFTA trade

Measure	Predicted HPPC	Actual 1989-2008
NAFTA trade relative to the total trade of the NAFTA countries	25.9	24.8
NAFTA trade relative to the total income of the NAFTA countries	62.2	66.5

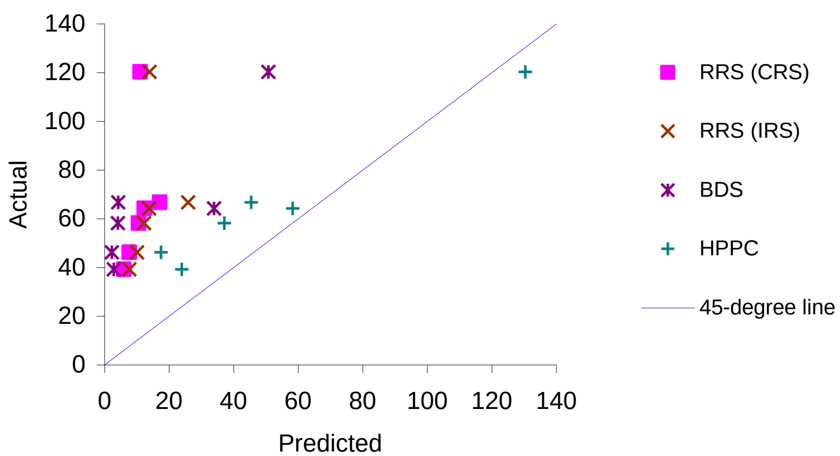
Note: NAFTA trade is the sum of all bilateral trade flows between the NAFTA countries. The total trade of the NAFTA countries is the sum of their exports and imports. The total income of the NAFTA countries is the sum of their GDPs.

Table 4. Actual vs. predicted percent changes in total exports and imports

	Actual	Predicted			
Variable	1989–2008	RRS (CRS)	RRS (IRS)	BDS	HPPC
Canadian exports	66.7	17.1	26.0	4.3	45.4
Canadian imports	58.2	10.5	12.3	4.2	37.1
Mexican exports	120.3	11.1	14.0	50.8	130.4
Mexican imports	64.2	12.4	13.9	34.0	58.3
U.S. exports	39.2	6.0	7.8	2.9	24.0
U.S. imports	46.2	7.7	10.1	2.3	17.5
Correlation with data		0.38	0.29	0.86	0.98

Note: Exports and imports are measured relative to GDP. The model of Ronald-Holst, Reinert and Shiells (RRS) has two versions: one with constant returns to scale (CRS) and another with increasing returns to scale (IRS). The Brown-Deardorff-Stern (BDS) model has increasing returns to scale. The model with heterogeneous producers (HPPC) described in this paper has constant returns to scale.

Figure 1. Actual vs. predicted percent changes in total exports and imports



Note: Exports and imports are measured relative to GDP.

Table 5. Actual vs. predicted changes in bilateral industry-level trade

Panel A. Percent changes in import shares predicted by the HPPC model

Importer	Exporter	Food	Textile	Wood	Paper	Chemicals	Nonmetals	Metals	Machinery
Canada	Mexico	36.3	188.2	21.0	14.9	23.7	21.1	16.0	65.6
Canada	U.S.	16.0	64.5	9.9	2.4	6.9	10.2	17.1	6.5
Mexico	Canada	-9.6	-36.3	-41.8	-24.9	-23.6	-22.9	-3.9	-2.8
Mexico	U.S.	19.6	21.1	2.1	4.0	13.7	25.5	9.0	18.7
U.S.	Canada	32.6	121.0	5.5	-2.8	30.5	26.5	11.3	49.0
U.S.	Mexico	107.1	337.9	60.1	37.2	73.8	69.0	28.9	129.1

Note: Each observation is a share of country *i* in country *n*'s imports of industry *j*.

Panel B. Percent changes in import shares predicted by the BDS model

Importer	Exporter	Food	Textile	Wood	Paper	Chemicals	Nonmetals	Metals	Machinery
Canada	Mexico	10.0	11.0	22.7	15.0	-7.5	5.1	11.2	15.7
Canada	U.S.	7.4	24.3	3.4	3.0	2.2	3.8	2.9	1.6
Mexico	Canada	-7.0	5.6	12.1	0.8	7.0	156.0	6.2	14.4
Mexico	U.S.	7.4	10.5	11.3	2.0	2.2	7.1	5.7	10.8
U.S.	Canada	8.1	23.3	1.4	-0.1	2.8	58.9	8.0	4.2
U.S.	Mexico	10.3	14.7	4.4	4.4	-6.1	-23.6	14.8	41.9

Panel C. Percent changes in import shares found in data (1989-2008)

Importer	Exporter	Food	Textile	Wood	Paper	Chemicals	Nonmetals	Metals	Machinery
Canada	Mexico	92.71	202.83	1580.50	185.78	413.43	208.89	-59.72	254.06
Canada	U.S.	36.15	72.85	16.11	8.95	14.56	25.98	6.83	2.82
Mexico	Canada	20.83	-65.01	846.37	-40.81	5.36	-68.86	-70.19	-35.60
Mexico	U.S.	18.29	22.85	-10.96	-1.35	8.55	3.86	-7.76	4.73
U.S.	Canada	73.45	93.67	-4.37	-11.19	5.78	17.65	-9.06	-5.69
U.S.	Mexico	81.93	291.84	52.06	-1.31	45.92	31.01	19.95	141.12

Table 6. Relationships between actual and predicted changes

		HPPC model			BDS model		
Importer	Exporter	Correlation	Intercept*	Slope	Correlation	Intercept*	Slope
Canada	Mexico	-0.15	423.10	-1.31	0.41	111.09	23.89
Canada	U.S.	0.91	5.71	1.04	0.95	5.54	2.88
Mexico	Canada	-0.57	-185.64	-12.53	-0.14	93.82	-0.81
Mexico	U.S.	0.72	-9.46	1.00	0.10	2.54	0.31
U.S.	Canada	0.77	-7.59	0.81	0.28	12.26	0.58
U.S.	Mexico	0.98	-15.70	0.93	0.44	65.84	2.23

*Note: R^2 for these regressions is correlation^2

Figure 2 Actual vs. predicted percent changes in import shares by industry

Figure 2a HPPC model

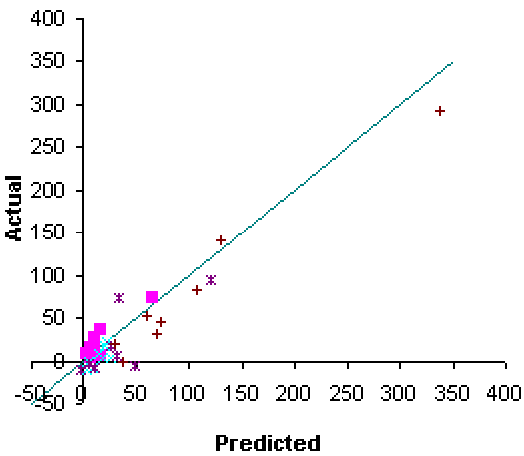
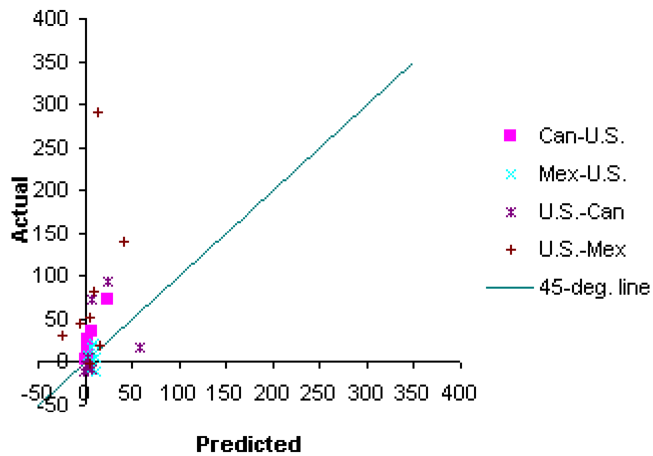


Figure 2b BDS model



Note: Each observation is a share of country *i* in country *n*'s imports of industry *j*. The correlation between the predicted and actual changes is 0.95 for the HPPC and 0.31 for the BDS model.

Figure 2c HPPC model

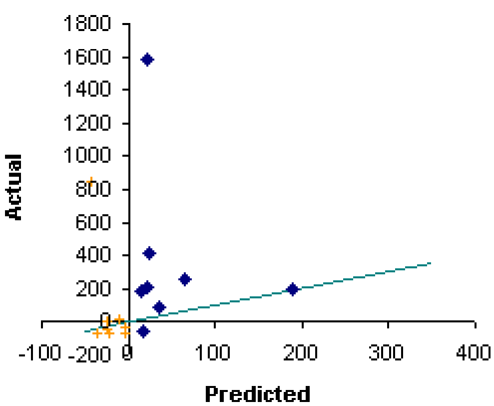
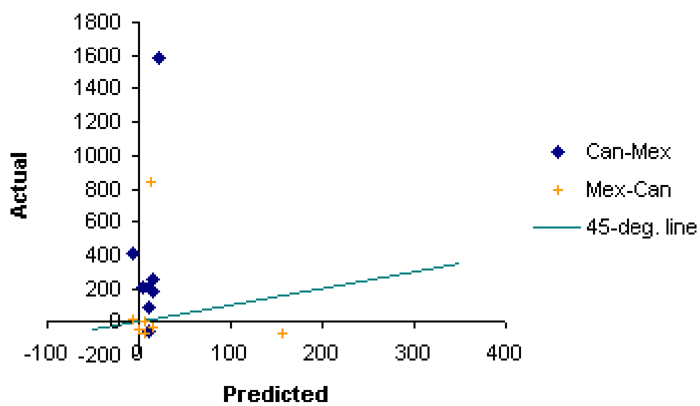


Figure 2d BDS model



Notes: Each observation is a share of country i in country n's imports of industry j. The correlation between the predicted and actual changes is 0.08 for the HPPC and -0.08 for the BDS model.

Table 7. Relationships between predicted and actual changes in industry-level import shares (excluding Canada-Mexico trade)

	HPPC				BDS			
	Correl.	Intercept	Slope	Av(abs)*	Correl.	Intercept	Slope	Av(abs)*
Original	0.95	-4.6	0.87	42.8	0.31	21.23	1.33	10.4
θ=σ=3	0.87	-13.6	4.75	9.9				
θ=σ=3 and c.i.f. barriers	0.93	-16.5	2.2	22.8				
All of the above and BDS tariffs	0.88	-17.1	2.61	19.2				
All of the above and NTBs	0.74	-0.52	2.82	7.8	0.44	13.8	1.1	9.6

Note: Av(abs) is the average absolute percent change in import shares. Its value in the data is 35.9%.

Appendix A. Data sources

Data comes from a variety of sources with the outmost care being taken to make sure that data from various sources are compatible. Industry-level labor shares in output are taken from the UNIDO, and the average of all countries in the sample is used in simulations. Capital shares in output are obtained using ratios of capital to labor shares from the dataset described in. The labor shares are multiplied by these ratios to obtain capital shares.

Data for industry shares η_{jm} is obtained from the OECD input-output tables. These tables exist only for some of the countries in the sample and only for select years. Specifically, the input-output tables for Australia, Canada, France, Germany, Japan, U.K., and the U.S. are available for 1990 (the table for Australia is for 1989). Input-output tables for these countries result in very similar shares η_{jm}. The shares used in simulations are averages across these countries (own intermediate goods always constitute the largest share of all manufacturing intermediate inputs, but never make up more than a half of them).

Bilateral trade data used to estimate equation (gravity equation) is from and. Imports from home X_{iij} are calculated as output minus exports, and spending X_{ij} is calculated as output minus exports plus imports. Industry output and labor compensation are from the UNIDO's statistical database.

For the distance measure d_{kj}^{phys}, the physical distance (in miles) between economic centers of countries is taken from. This distance is the great circle distance between the population-weighted average of the latitude and longitude of major cities. The following free trade agreements are considered for the f_j variable: EC/EU, EFTA, EEA, FTA, NFTA, CER, and a free-trade agreement between Turkey and EFTA.

Post-NAFTA industry-level trade data used for model evaluation purposes is from and the SourceOECD database. Total trade data is from and the SourceOECD database. Post-NAFTA GDP data used in model evaluation is from the UNData database.