Gravity *Redux*: Structural Estimation of Gravity Equations, Elasticities of Substitution, and Economic Welfare under Asymmetric Bilateral Trade Costs*

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Abstract

One of the most notable economic policy accomplishments since World War II has been the large reduction in tariff rates worldwide under several rounds of the GATT. However, *ex ante* estimates of the economic welfare gain to the world have always seemed small – often one-half of one percent of GDP – relative to the political costs of liberalizations, suggesting a puzzle. We provide a general equilibrium comparative static estimate of the economic welfare effect of full elimination of tariffs worldwide that is about *10 times* that of the median traditional estimate, based upon a novel approach using a standard international trade model where the key model parameter – the elasticity of substitution in consumption – as well as all gravity equation coefficients are *estimated simultaneously* and trade costs are allowed to be *bilaterally asymmetric*.

Key words: International trade; Gravity equation; Trade costs; Structural estimation
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1 Introduction

One of the most notable policy accomplishments since World War II has been the enormous reduction in tariff rates worldwide under several rounds initiated by members of the General Agreement on Tariffs and Trade (GATT). Despite the degree of such liberalizations, traditional *ex ante* computable general equilibrium (CGE) analyses of such liberalizations such as *GTAP* have typically yielded seemingly small estimates of the economic welfare gain (as measured by "equivalent variation," or EV) – generally *fractions* of one percent of gross domestic product (GDP). For instance, even though the average tariff cut was 26.2 percent from the Tokyo Round, the estimated worldwide EV-measured welfare gain was 0.1 of 1 percent of GDP, cf., Deardorff and Stern (1985). Even today, CGE-based estimates of complete elimination of remaining tariffs (in 2001) suggest a (median) worldwide economic welfare gain of only 0.7 of 1 percent of GDP; Bouet (2008) evaluates this experiment across 16 alternative CGE models. This suggests a puzzle: Why have governments pursued (and continue to pursue today) such a politically and economically costly policy endeavor with such seemingly small expected economic gains? In this paper, we offer an estimate of the economic welfare gain from full elimination of tariffs worldwide that is about *10 times* that of the median estimate, but still economically plausible.[1]

In contrast to most welfare-effect estimates using traditional CGE models that compute comparative statics using externally-determined parameters, we use recent developments in the empirical international trade literature on the "gravity equation" to estimate *simultaneously* equation coefficients, elasticities of substitution in consumption, *and* welfare gains. Traditionally, the gravity equation in international trade has been used to explain econometrically the *ex post* "partial" (or direct) effects of economic integration agreements, national borders, currency unions, language, and other measures of trade costs on bilateral trade flows, cf., Rose (2004). For instance, one of the most common applications of the gravity equation over the past several decades has been to estimate *ex post* the partial (non-general-equilibrium) effect of the formation of a free trade agreement (FTA) on the bilateral trade of pairs of countries, cf., Frankel (1997), Baier and Bergstrand (2007). *Ex ante* CGE models – so-called, "theory with numbers"

[1] Bouet (2008) offers the most recent, and most comprehensive, analysis of CGE predictions of full tariff liberalizations using the most well-known CGE models. Moreover, he notes that the wide range of estimates depends "crucially" on the elasticity of substitution.

– have been an important part of the trade-policy literature for computing *general-equilibrium* comparative statics, while gravity equations have served in parallel to provide *ex post* empirical estimates of the *partial* effects of FTAs on trade flows. Typically, the two approaches have not intersected. We offer a novel approach to estimate simultaneously coefficients, elasticities, and comparative static trade and welfare effects, and apply our approach to the case of a full liberalization of remaining world tariffs.

Recently, three papers have advanced our understanding of the nexus between estimation of gravity equation parameters and computing general equilibrium estimates of trade-flow and economic welfare effects of eliminating "trade costs." While two early formal theoretical foundations for the gravity equation with trade costs – first Anderson (1979) and later Bergstrand (1985) – addressed the role of "multilateral prices," Eaton and Kortum (2002), Anderson and van Wincoop (2003), and Helpman, Melitz, and Rubinstein (2008) refined the theoretical foundations for the gravity equation to emphasize the importance of accounting properly for the endogeneity of prices in estimation and to conduct general equilibrium comparative statics. While all three approaches generate similar gravity-like equations, the underlying key structural parameter's interpretation is different. Eaton and Kortum (2002), or E-K, developed a structural theoretical foundation for the gravity equation using a Ricardian production framework with perfectly competitive firms, which yielded a gravity equation for which the key structural parameter, $-\theta$, is a measure of product "heterogeneity" on the supply side; a lower θ implies more heterogeneity and a role for comparative advantage. E-K then used three alternative econometric approaches (actual price data, actual wage data, and instruments for prices) to generate estimates of θ to then compute welfare effects; however, the three approaches yielded a wide range of θ estimates from 3.6 to 12.9. Moreover, a concern with the E-K approach is that there are no comparable estimates of their "product heterogeneity" parameter within the international trade policy literature due to their unique production-side approach.[2] The elasticity of substitution *in consumption* plays no role in their final structural system of equations; yet this elasticity has come to play a central role in the literature on the measurement of trade costs and in computing comparative statics and economic welfare effects from trade policies.[3]

[2]However, the E-K approach has strong production-side parallels to our demand-side approach, which we will address later in more detail. Also, Balistreri, Hillberry, and Rutherford (2007) examine simultaneous parameter and comparative-statics estimation using a heterogeneous-productivities model.

[3]There is a very large literature examining empirically elasticities of substitution in consumption, product

The other two papers that have enhanced our understanding of the gravity equation are Anderson and van Wincoop (2003), or A-vW, and Helpman, Melitz, and Rubinstein (2008), or H-M-R. A-vW developed a theoretical foundation for the gravity equation in an endowment economy with Armington preferences and one good per country. H-M-R developed a foundation in a monopolistically-competitive market structure with increasing returns to scale, a descendent of the Helpman and Krugman (1985), or H-K, framework. In both papers, the elasticity of substitution in consumption plays a central role, as in traditional CGE models. However, while both A-vW and H-M-R account for endogenous multilateral price terms, both note that their frameworks cannot *estimate* the key structural parameter, the elasticity of substitution. Consequently, both approaches can only compute general-equilibrium comparative statics under *assumed* values of this elasticity – much like the traditional *ex ante* CGE models. Moreover, both approaches assume bilaterally symmetric trade costs to derive estimable equations, even though in reality many trade costs are bilaterally asymmetric.[4]

This paper presents a novel approach using a standard international trade model to generate a simple structural system where gravity equation coefficients, the elasticity of substitution (in consumption), and economic welfare effects (and other comparative statics) can all be *estimated simultaneously*, and allowing for *bilaterally asymmetric* trade costs. This allows us to estimate the world welfare effect of a complete tariff elimination (of bilaterally asymmetric tariff rates), based upon a consistently estimated elasticity of substitution in consumption that can be compared with the extant literature's estimates.[5] First, for comparability to the trade

variety, and world welfare, cf., Feenstra (1994) and Broda and Weinstein (2006).

[4]The distinguishing emphasis of H-M-R is to introduce heterogeneous firms facing fixed costs to export to markets which yields a two-stage estimation approach and can explain the large number of observed zero aggregate bilateral trade flows. For analytical tractability, we ignore this important distinguishing feature here to focus upon estimation of the elasticity of substitution and economic welfare effects in the context of positive trade flows, such as in E-K, A-vW, and H-K, although the H-M-R elements could be later adopted. Also, A-vW discuss estimation under bilaterally asymmetric trade costs. However, this raises problems of "normalization." They even conclude that "Our analysis suggests that inferential identification of the asymmetry [in bilateral trade costs] is problematic" (p. 175). We address this issue directly so that our results account for proper normalization.

[5]We will see that our approach complements and potentially can be adapted to the E-K Ricardian approach. For this paper, we choose the H-K framework for two primary reasons. First, we can interpret our estimates of the elasticity of substitution in consumption in the context of the large empirical literature on such elasticity estimates (which is not possible for E-K's θ) and show that our estimates are in the middle of the established range. Second, for comparative statics the necessary measure of exporter economic activity in the H-K model is exporter labor/population (which is readily observable) whereas in the E-K framework the exporter activity variable is exporter "efficiency levels" or "states of technology," T_i (which is not readily observable).

policy literature, we can choose a (one-good-per-region) endowment economy as in A-vW or an (endogenously-determined) N-good H-K economy (as in H-M-R). To allow for the observed importance of the "extensive margin" in trade (as in H-M-R), we use the H-K model for illustration, allowing asymmetric bilateral trade costs.[6] Second, since unbiased gravity equation parameters (under A-vW, E-K, or H-K) can be estimated consistently using region fixed effects, we demonstrate that a simple nonlinear solver applied to the multilateral-trade-balance conditions can generate estimates of the elasticity of substitution and comparative statics (given coefficient estimates from a fixed-effects regression). Third, we verify the "consistency" of the elasticity and comparative statics estimates using a simple Monte Carlo approach (to avoid mis-measurement and endogeneity bias). We show using this analysis that – when we know *ex ante* the "true" elasticity of substitution – our approach and A-vW's approach to compute general equilibrium effects yield consistently identical comparative statics to the true ones under symmetric bilateral trade costs. However, only our approach yields *consistently* identical comparative statics to the true ones under asymmetric bilateral trade costs; the average estimation bias of the A-vW technique (properly normalized) under asymmetry is one to two *orders of magnitude* that from our approach. Fourth, we show using a widely-known *empirical* context – McCallum's Canadian-U.S. "border puzzle" – that our approach yields identical (different) comparative statics to A-vW's approach under symmetric (asymmetric) bilateral trade costs using data from Robert Feenstra's website.

Fifth, and finally, we apply our approach to consider the trade and welfare effects of full elimination of remaining world tariffs. We apply our approach empirically to the more general case of trade flows among 67 countries using the *GTAP* data base in the presence of bilaterally *asymmetric* tariff rates. There is large heterogeneity bilaterally in tariff rates. Figure 1 illustrates that only 42 percent of bilateral tariff rates among these 67 countries are symmetric. Also, the figure illustrates that the asymmetry can be as large as 150 percent. We estimate an elasticity of substitution of about 6 – in the range of elasticities (5 to 10) cited in the Anderson and van Wincoop (2004) survey – and the (equivalent-variation) worldwide welfare gain from a complete elimination (in year 2001) of tariff rates among the 67 countries is estimated at 6.9 percent – *10 times* the median estimated welfare effects cited earlier using traditional *ex ante*

[6]However, as shown in H-M-R appendix II, the H-K model can reduce to the A-vW model under more assumptions.

CGE models with pre-specified parameters.

The remainder of this paper is as follows. Section 2 presents the well-known H-K theoretical model and shows how the multilateral-trade-balance conditions along with a nonlinear solver can generate estimates of the elasticity of substitution (given consistently estimated gravity equation parameters) and of welfare effects. Section 3 presents the Monte Carlo analysis to demonstrate the consistency of our elasticity and welfare-effect estimates in the absence of mismeasurement and endogeneity bias and allowing bilaterally symmetric *or asymmetric* trade costs. Section 4 provides two empirical applications. Section 4.1 gives an empirical analysis of the familiar McCallum "border puzzle" to demonstrate the differential estimation effects of assuming symmetric or asymmetric bilateral trade costs. Section 4.2 provides our empirical analysis of simultaneously estimated gravity equation coefficients, elasticity of substitution, and welfare effects from a complete elimination of remaining bilaterally asymmetric tariffs among 67 countries. Section 5 concludes.

2 Gravity ***Redux***

It is now well established that the gravity equation in international trade can be derived from various sets of assumptions. The three major general equilibrium approaches to understanding the determinants of (positive) bilateral trade flows in a gravity framework – E-K's Ricardian approach, A-vW's Armington-endowment economy, and H-K's increasing returns-monopolistic competition model – all generate very similar gravity equations that – once multilateral-price terms are accounted for using (region-specific) fixed effects in estimation – will yield *identical, unbiased* coefficient estimates. Using fixed effects, all three models suggest the following equation for estimation where, for illustration, we assume only two (exogenous bilateral) variables influencing bilateral trade costs:

$$\ln X_{ij} = \psi + [(1-\sigma)\rho]\ln DIST_{ij} + [(1-\sigma)\beta]BORDER_{ij} + \eta_i + \gamma_j + \epsilon_{ij}. \quad (1)$$

where X_{ij} denotes the bilateral trade flow from i to j in some year (or the trade flows scaled by the product of the two countries' GDPs), ψ is a constant, $DIST_{ij}$ is the bilateral distance between i and j, $BORDER_{ij}$ is a dummy variable representing an additional natural or policyrelated barrier to trade between i and j, η_i and γ_j are region-specific fixed effects, and ϵ_{ij} denotes a white noise error term. Note that the coefficients for $DIST_{ij}$ and $BORDER_{ij}$ are the products of some parameter and $(1-\sigma)$, where σ is the elasticity of substitution ($\sigma > 1$).[7] In the E-K, A-vW, and H-K model, $\rho \ln DIST_{ij}$ and $\beta\ BORDER_{ij}$ denote the *ad valorem* equivalents of the trade costs imposed by bilateral distance and, say, a national (political) border, respectively.[8]

However, while estimation of equation (1) yields consistent estimates of $(1-\sigma)\rho$ and $(1-\sigma)\beta$, it does not reveal a unique and consistent estimate of σ (or, in E-K, of θ) – a parameter that is critical for conducting general equilibrium comparative statics in this literature. Consequently, in the absence of a systematic method for identifying σ, A-vW simply assume various values of σ ranging from 2 to 20 for comparative statics. Similarly, in the absence of a systematic method identifying θ, E-K offer three potential econometric/empirical solutions. First, E-K use observed cross-country price data to estimate θ (ignoring potential endogeneity bias), yielding a θ estimate of 8.28. Second, E-K use observed cross-country wage-rate data employing ordinary (two-stage) least squares to generate a θ estimate of 2.86 (3.60). In a third approach, E-K again use price data employing two-stage least squares to generate a θ estimate of 12.86. Thus, using various econometric approaches, they find a range of θ estimates from 3 to 13. As in A-vW, this wide range of parameter estimates implies a wide range of comparative-static effects. Clearly, a method to identify a *unique* and consistent estimate of σ (or θ) would be valuable.

This section has two goals. First, in section 2.1, we summarize the well-known H-K model and gravity equation it implies. While theoretically either the E-K or H-K model can be used to demonstrate our method for using the multilateral-trade-balance conditions to estimate a unique value for θ or σ, respectively, the H-K model is easier to implement empirically (for two such analyses later) since the necessary exporter activity variable is the labor force (or population) in the H-K model, in contrast to the more-difficult-to-measure "efficency level" of the E-K Ricardian framework.[9] In section 2.2, we show how the multilateral-trade-balance

[7]In the A-vW and H-K models, σ is the elasticity of substitution. In the E-K model, $(1-\sigma)$ would be replaced by the productivity heterogeneity parameter, -θ (where $\theta = \sigma - 1$). Everything else is the same.

[8]For clarity, we are assuming as in A-vW that a national (political) border represents a barrier to bilateral trade. This is in contrast with a common *land*, or physical, border in many gravity-equation analyses, which enhances bilateral trade.

[9]We emphasize, however, that with availability of properly measured "efficiency" levels of countries, our method would also work for identifying θ.

conditions can be employed to estimate a unique value of the elasticity of substitution (or productivity heterogeneity parameter, if efficiency-level data were available).

2.1 The Increasing Returns/Monopolistic Competition Model

2.1.1 Utility

Following Krugman (1980), Helpman and Krugman (1985), Baier and Bergstrand (2001), and Feenstra (2004), there exists a single industry where preferences are constant-elasticity-of-substitution (CES). As typical to the Dixit-Stiglitz (1977) class of models, we assume that preferences are determined by a "love of variety." We assume that utility of consumers in country j is given by:

$$U_j = \left[\sum_{i=1}^{N} \sum_{k=1}^{n_i} c_{ijk}^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}}, \tag{2}$$

where c_{ijk} is the consumption of consumers in country j of variety k from country i, n_i is the number of varieties of the single good produced in country i, which is endogenous in the model, N is the number of countries (or regions), and σ is the elasticity of substitution in consumption.[10]

As typical, we assume iceberg transport costs and symmetric firms within each country, and hence all products in country i sell at the same price, p_i. Consequently, the utility function simplifies to:

$$U_j = \left[\sum_{i=1}^{N} n_i c_{ij}^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}}. \tag{3}$$

Maximizing equation (3) subject to the budget constraint:

$$Y_j = \sum_{i=1}^{N} n_i p_i t_{ij} c_{ij}, \tag{4}$$

[10]We begin with utility function (5.21) from Feenstra (2004, p. 152). We could easily introduce a country-specific preference parameter β_i to the function as in A-vW. However, A-vW effectively circumvent estimating β_i by treating prices for each good i as "scaled prices ($\beta_i p_i$)" in their solution, without loss of generality, cf., A-vW (2003, p. 175). Following Krugman (1980), Helpman and Krugman (1985), Baier and Bergstrand (2001), and Feenstra (2004), we assume for simplicity that the β_i are unity for all i. Also, since the gravity equation has almost exclusively been used to explain bilateral *aggregate* trade flows, like A-vW we consider in this paper only the single-industry case. The multiple-industry case is also potentially interesting, but is beyond the scope of this paper and left for future research.

where t_{ij} is one plus the iceberg trade costs (the latter a fraction) and Y_j is national income, yields the demand functions:

$$c_{ij} = \left(\frac{p_i t_{ij}}{P_j}\right)^{-\sigma} \frac{Y_j}{P_j}, \tag{5}$$

where P_j is the CES price index:[11]

$$P_j = \left[\sum_{i=1}^{N} n_i (p_i t_{ij})^{1-\sigma}\right]^{\frac{1}{1-\sigma}}. \tag{6}$$

As in Krugman (1980), Helpman and Krugman (1985), Baier and Bergstrand (2001), and Feenstra (2004), the value of aggregate exports from country i to country j, X_{ij}, equals $n_i p_i t_{ij} c_{ij}$. Substituting equation (5) into this expression for X_{ij} yields:

$$X_{ij} = n_i Y_j \left(\frac{p_i t_{ij}}{P_j}\right)^{1-\sigma}, \tag{7}$$

which is identical to equation (5.26) in Feenstra (2004, p. 153).

2.1.2 Production

The assumption of a monopolistically competitive market with increasing returns to scale in production (internal to the firm) and a single factor (labor) is sufficient to identify the exporting country's number of varieties. The representative firm in country i is assumed to maximize profits subject to the workhorse linear cost function:

$$l_i = \alpha + \phi y_i, \tag{8}$$

where l_i denotes labor used by the representative firm in country i and y_i denotes the output of the firm.

Two conditions characterize equilibrium in this class of models. First, profit maximization ensures that prices are a markup over marginal costs:

$$p_i = \frac{\sigma}{\sigma - 1}\phi w_i, \tag{9}$$

[11] Note that the price of i's good in j, p_{ij}, is assumed (by arbitrage) to equal $p_i t_{ij}$.

where w_i is the wage rate in country i, determining the marginal cost of production.[12] Second, under monopolistic competition, zero economic profits in equilibrium ensures:

$$y_i = \frac{\alpha}{\phi}(\sigma - 1) \equiv \bar{y}, \tag{10}$$

so that the output of each firm is a constant, $\bar{y}$.

An assumption of full employment of labor in each country ensures that the size of the exogenous factor endowment, L_i, determines the number of varieties:

$$n_i = \frac{L_i}{\alpha + \phi \bar{y}}. \tag{11}$$

2.1.3 The Gravity Equation

We can now derive a gravity equation. First, we can show that the trade flow from i to j is a function of GDPs, labor endowments, and trade costs. With labor the only factor of production, $Y_i = w_i L_i$ or $w_i = Y_i / L_i$. Using equations (9) and (11), we can substitute $\sigma \phi w_i / (\sigma - 1)$ for p_i and $L_i / (\alpha + \phi \bar{y})$ for n_i in equation (7) and substitute Y_i / L_i for w_i in the resulting equation to yield:

$$X_{ij} = Y_i Y_j \frac{(Y_i/L_i)^{-\sigma} t_{ij}^{1-\sigma}}{\sum_{k=1}^{N} Y_k (Y_k/L_k)^{-\sigma} t_{kj}^{1-\sigma}}. \tag{12}$$

However, we can easily show that equation (12) is identical to the gravity equation in Feenstra (2004) with GDPs and prices. Using equation (9), we can substitute $p_i / [(\sigma\phi)/(\sigma - 1)]$ for w_i in $L_i = Y_i / w_i$ and then substitute the resulting equation, $Y_i / [(\sigma - 1) p_i / (\sigma \phi)]$, for L_i in equation (11) to yield:

$$n_i = \gamma \frac{Y_i}{p_i}, \tag{13}$$

where $\gamma = \phi\sigma / [(\sigma - 1)(\alpha + \phi \bar{y})]$. Substituting equation (13) into equation (7) yields:

$$X_{ij} = \frac{Y_i Y_j p_i^{-\sigma} t_{ij}^{1-\sigma}}{\sum_{k=1}^{N} Y_k p_k^{-\sigma} t_{kj}^{1-\sigma}}. \tag{14}$$

[12] The wage rate in country 1 serves as the numeraire.

which is identical to equation (5.26') in Feenstra (2004, p. 154).[13]

Equation (14) is a standard representation of the gravity equation. Feenstra (2004) summarized the three methods that have been used up to this point in the literature to address the role of prices. The first approach, used in Bergstrand (1985, 1989), Baier and Bergstrand (2001), and Eaton and Kortum (2002) was to assume that prices are exogenous and use available price or price index data to account for the role of prices. This method is now acknowledged to work poorly for two reasons, the first is that conceptually such prices are endogenous and the second is that available price indexes are crude approximations. The second approach has been to account for the price terms using region-specific fixed effects. While such fixed effects can account for the influence of the price terms in estimation, the shortcoming of this method is that – without estimates of the prices before and after the counterfactual experiment – one cannot calculate the appropriate general equilibrium comparative statics using fixed effects. The third method is to estimate a structural set of nonlinear price equations – under the assumption of symmetric bilateral trade costs (SBTC) – which then generate multilateral price terms before and after the counterfactual experiment to conduct finally the general equilibrium comparative statics, cf., A-vW (2003, eqs. 12 and 13). While this approach provides unbiased estimates and general equilibrium comparative statics, it does so under the SBTC assumption, which also implies bilateral trade balance, cf., A-vW (2003, eq. 13) for x_{ij} and x_{ji}. Both considerations are typically violated in the real world. The next section suggests an alternative approach.

2.2 Estimating Elasticities of Substitution in Consumption and General Equilibrium Comparative Statics

While A-vW (2003) focused on structural estimation of their equations (12) and (13) using a custom nonlinear least squares program, the literature since then has adopted as a norm the estimation of their equation (12) using region-specific fixed effects for the multilateral resistance (MR) terms to avoid the omitted variables bias, and then employed a nonlinear "solver" to conduct comparative statics (which A-vW do in a sensitivity analysis). However, as discussed above, their theoretical foundation assumes SBTC to generate comparative statics and their

[13] To see this, note that – using our notation – the denominator of (14) is identical to $\bar{y}\sum_{k=1}^{N} n_k (p_k t_{kj})^{1-\sigma}$. Moreover, this equation is very similar to equation (10) in E-K (p. 1750).

approach does not allow *estimation* of the elasticity of substitution.

In this section, we suggest a simple method to conduct general equilibrium comparative statics that even allows for bilaterally *asymmetric* trade costs. The idea rests upon upon assuming *multilateral* trade balance, which has a long history in the pure theory of international trade. While also violated in the real world,[14] it is a less restrictive assumption than *bilaterally symmetric* trade costs and bilateral trade balance.[15] Multilateral trade balance is ensured by assuming N equations:

$$\sum_{j=1}^{N} X_{ij} = \sum_{j=1}^{N} X_{ji} \qquad i = 1, ..., N. \tag{15}$$

Hence, our gravity model is equations (12) subject to (15), analogous to A-vW's equations (12) and (13) for SBTC. Our $N(N-1)$ equations (12) along with N equations (15) comprise a system of N^2 equations in $N(N-1)$ endogenous bilateral trade flows, X_{ij} (excluding as in A-vW a country's internal trade), and N GDPs, Y_i. However, unlike A-vW, we do not assume symmetric bilateral trade costs.[16] Rather, we arrive at our system of equations using the H-K market structure to identify n_i combined with the (less restrictive) multilateral trade balance assumption. Like A-vW's equations (12) and (13), our $N(N-1)$ equations (12) along with N equations (15) can be estimated using NLS.

However, as has become the norm, most researchers estimate equation (12) using region-specific fixed effects to obtain consistent gravity equation coefficients. The few that go further and compute general equilibrium comparative statics apply a nonlinear solver by either *assuming* an elasticity of substitution σ (cf., A-vW) or *estimating* it using actual price or wage data (cf., E-K, in the context of their analogue parameter θ). However, our approach allows estimation of σ and of general equilibrium comparative statics. To see this, consider the empirical

[14]While the assumption of bilateral trade balance is very restrictive, some recent evidence that the assumption of multilateral trade balance is not very restrictive is found in Dekle, Eaton and Kortum (2007). In that paper, the authors use a calibrated general equilibrium model of world trade to consider how much wage rates and prices would have to change from current levels if all multilateral trade balances were eliminated (the counterfactual). The authors find that wage rates and prices do not change very much. For instance, elimination of China's and the United States' large multilateral trade imbalances requires wage rate adjustments of less than 10 percent.

[15]The model in H-M-R with heterogeneous firms can explain observed bilaterally imbalanced trade, but still uses the assumption of bilaterally symmetric trade costs. See H-M-R Appendix II.

[16]A-vW's (2003) equations (9)-(11) also comprise a structural system, but allowing asymmetric bilateral trade costs (ABTC). However, as their footnote 11 explains, if bilateral trade costs are asymmetric across countries, the interpretation of their border barrier's effect is restricted to be only an "average" of the barrier's effects in both directions. We will contrast the implications of our model with those of A-vW's equations (12) and (13) assuming SBTC and A-vW's equations (9)-(11) allowing ABTC using Monte Carlo analyses in section 3.

analogue to equation (12), replacing t_{ij} by $\hat{t}_{ij}$. For instance, with one bilaterally asymmetric trade impediment d_{ij}, we could write $t_{ij} = d^{\rho}$, where ρ is an unknown parameter relating the bilateral trade impediment to the bilateral (economic) *ad valorem* trade cost. Then, we could write $\hat{t}_{ij} = d^{\hat{\rho}}$ and the empirical analogue to equation (12) would be:

$$X_{ij} = Y_i Y_j \frac{(Y_i/L_i)^{-\sigma} d_{ij}^{\widehat{(1-\sigma)\rho}}}{\sum_{k=1}^{N} Y_k (Y_k/L_k)^{-\sigma} d_{kj}^{\widehat{(1-\sigma)\rho}}}. \tag{16}$$

Fixed-country-effects estimation of the empirical counterpart to gravity equation (16) will yield a consistent estimate of $(1-\sigma)\rho$, irrespective of whether d_{ij} is correlated with the country-specific error terms or not.[17] With fixed effects, σ can not be directly estimated but can be retrieved in the following way. We can substitute an estimate of $(1-\sigma)\rho$ and data about GDPs (Y_i), populations (L_i), and trade impediments (d_{ij}) in the N countries' multilateral-trade-balance conditions (15) and, with asymmetric trade costs, solve for σ by minimizing the sum of the squared deviations of these equations. Formally, we solve for σ by minimizing $\sum_{i=1}^{N}\left[\sum_{j=1}^{N} X_{ij} - \sum_{j=1}^{N} X_{ji}\right]^2$ after substituting X_{ij} and X_{ji} with the expression in equation (16) and its analogue, respectively.

Alternatively, we can use equation (12) to determine relative aggregate bilateral demand of consumers in market j:

$$\frac{X_{ij}}{X_{kj}} = \frac{Y_i}{Y_k}\left(\frac{Y_i/L_i}{Y_k/L_k}\right)^{-\sigma}\left(\frac{t_{ij}}{t_{kj}}\right)^{1-\sigma}. \tag{17}$$

The latter provides an alternative way of estimating the elasticity of substitution among varieties with symmetric or asymmetric trade costs by using the expression:

$$\widehat{\sigma} = -\frac{1}{N^2(N-1)}\sum_{i=1}^{N}\sum_{j=1}^{N}\sum_{k\neq j}\left[\left(\ln\frac{X_{ij}}{X_{kj}} - \ln\frac{Y_i}{Y_k} - \ln\frac{\widehat{t_{ij}^{1-\sigma}}}{\widehat{t_{kj}^{1-\sigma}}}\right)/\ln\left(\frac{Y_i/L_i}{Y_k/L_k}\right)\right]. \tag{18}$$

Consequently, the comparative-static effects of trade-cost changes can be estimated using the estimated elasticities that surface from our approach. Using the estimated elasticities of

[17] Of course, the approach is also applicable with more than a single trade cost variable. Then, d_{ij}^{ρ} is a single element in a product which is represented by t_{ij} in the main text.

substitution, we provide estimates of two comparative statics. One is the change in trade relative to the products of GDPs, $X_{ij}/(Y_i Y_j/Y_W)$. The other is the welfare effect due to a change in trade costs, based on the equivalent variation for country i (EV_i), defined as:

$$EV_i = 100 \cdot \left[\frac{Y_i^c}{Y_i} \left(\frac{\sum_{k=1}^{N} Y_k (Y_k/L_k)^{-\sigma} (t_{ki})^{1-\sigma}}{\sum_{k=1}^{N} Y_k^c (Y_k^c/L_k)^{-\sigma} (t_{ki}^c)^{1-\sigma}} \right)^{\frac{1}{1-\sigma}} - 1 \right], \tag{19}$$

where superscript c indicates counterfactual values of trade costs and GDPs.

The remainder of our paper demonstrates our approach under both symmetric and asymmetric bilateral trade costs. In the following section, we provide a Monte Carlo analysis to demonstrate our approach relative to A-vW's (to avoid data-measurement bias and specification bias). Section 4 applies our approach to two widely-recognized empirical contexts.

3 Monte Carlo Analysis

We conduct a large-scale Monte Carlo study to evaluate our approach relative to several alternatives: A-vW, a traditional OLS gravity specification without multilateral resistance terms (labeled, for brevity, OLS), and a recent linear-approximation approach suggested by Baier and Bergstrand (2006, 2008) (described below and referred to henceforth, for brevity, as BV-OLS). The purpose of the Monte Carlo analysis (before applying our approach in an empirical context) is the following. First, both our approach and A-vW's can obtain identical (unbiased) gravity-equation parameters using fixed effects estimation. However, we provide an *estimate* of the elasticity of substitution (in consumption) between varieties using the multilateral-trade-balance conditions. One goal of the Monte Carlo analysis is to demonstrate the consistency of the elasticity estimates in the absence of measurement or specification bias. Second, the Monte Carlo analysis can demonstrate that our approach and A-vW's can generate virtually identical trade-flow comparative static effects and average absolute biases under symmetric bilateral trade costs (in the absence of measurement and specification bias). Third, in the presence of asymmetric bilateral trade costs, the Monte Carlo framework reveals that our approach yields comparative static effects whose average absolute errors are less than *5 percent* those estimated using A-vW's approach – assuming *either* bilaterally symmetric *or* asymmetric trade costs. While under asymmetry proper normalization of the A-vW approach allows unbiased estimates of comparative statics, our approach can yield *consistently* unbiased comparative static estimates. The reason is that – in the presence of a log-normally distributed error term in the bilateral trade-flow equation – the greater number of non-linear conditions imposed using A-vW's approach under asymmetric bilateral trade costs (notably, estimating P_i's *and* Π_i's simultaneously) compared with our approach can raise the average absolute biases of the A-vW technique relative to ours by one to two *orders of magnitude*. The Monte Carlo setting *ensures* that none of the differences in the biases could be attributed to omitted variables or to measurement error.

The Monte Carlo analysis proceeds in two steps. First, we use alternative sets of parameter values described in detail below to generate sets of all endogenous variables of the theoretical model (Y_i, p_i, w_i, n_i, X_{ij}) as functions of the model's exogenous variables, L_i, and t_{ij}, in a baseline general equilibrium. Then, we change exogenous bilateral trade costs t_{ij}, holding the model parameters and all L_i constant to obtain counterfactual values for all the endogenous variables.

In a second step, we use these generated general equilibrium data and add a stochastic error term as in traditional Monte Carlo studies.[18] The major advantage of this procedure is that the true parameters *and* the comparative static effects are known so that one can infer the biases of alternative estimation strategies and the consequent comparative statics in a "laboratory" setting.

For robustness, we consider three alternative configurations of the world to capture the typical contexts for gravity equations – analyzing world trade flows. We consider three alternative sizes of the number N of countries in the world equal to 10, 20 and 40; this allows us to study the performance of alternative techniques for estimation and comparative statics as sample size increases. There are only three parameters in the theoretical model (σ, α, and ϕ); without loss of generality, we set the fixed cost (α) and marginal cost (ϕ) parameters equal

[18]An additive log-linear error term is conventional to the general-equilibrium-based literature on gravity-model estimation, cf., Anderson and van Wincoop (2003). In particular, it seems to be a suitable assumption in the absence of zero trade flows, as in our application. We have chosen to add the stochastic error term in only the trade flow equation. GDP (and also n_i) could potentially have measurement error as well. However, because we estimate the trade flow equation with country-specific fixed effects, country-specific measurement error will not bias our parameter estimates.

to unity ($\alpha = \phi = 1$). However, we will consider three alternative values for the elasticity of substitution (σ) – 3, 5, and 10 – to allow us to study the role of "curvature" for estimation and comparative statics. Hence, with three alternative elasticity values and three alternative numbers of countries, we have nine alternative combinations of N and σ. For each of these nine, we use 10 different draws from the set of empirical values for populations, L_i, and observable (symmetric and asymmetric) bilateral trade costs – bilateral cif-fob factors, denoted d_{ij} – where we assume $t_{ij} = d_{ij}^{\rho}$, with ρ denoting an (arbitrary) parameter for d_{ij} which is assumed to be $\rho = 2$.[19] Population endowments (L_i) are drawn from the empirical realizations of population data for the year 2003 across 207 economies covered by the World Bank's *World Development Indicators* (2005).[20] Bilateral cif-fob factors are drawn from the empirical realizations of the cif-fob factors in the 25th-75th percentiles of the distribution using the cif and fob bilateral trade flows from the International Monetary Fund's *Direction of Trade Statistics* (2003).[21] The purpose of using actual population and cif-fob data in the Monte Carlo simulations is to generate simulated results in a setting similar to that used in most empirical gravity applications, such as will be pursued in the second empirical application in the last substantive section of the paper. These data generate 90 (9 scenarios $\times$ 10 draws) alternative *baseline* equilibria of bilateral trade flows, GDPs, prices, wage rates and numbers of varieties consistent with general equilibrium (before any counterfactuals are introduced).

In general, we summarize the findings from our Monte Carlo analysis along two lines and organized in a pair of tables (labeled "a" and "b" after the table number, respectively). A table denoted with an "a" provides information about the true and estimated parameters, $(1-\sigma)\rho$ and σ, where we report the mean, standard deviation, and average absolute bias of each estimate of the two parameters (biases are reported as a percent of the true parameter value). A table denoted with a "b" focuses on comparative static effects. Each of these tables provides

[19] In general, t_{ij} is a function of multiple observable variables, such as bilateral distance, adjacency, etc., whose relationships with t_{ij} would be a set of corresponding parameters, such as ρ_1, ρ_2, etc., which convert the underlying variables to "*ad valorem* (or tariff)" equivalents. In the case of d_{ij}, ρ is set arbitrarily to 2. The simulations below are insensitive qualitatively to using instead, say, bilateral distances with a value of ρ set equal to 0.25, common to many empirical gravity analyses. However, the use of bilateral cif-fob factors allows for observations on bilaterally symmetric *and asymmetric* trade costs, which bilateral distances do not permit.

[20] Average population size across the 207 economies is 30,042,094, the standard deviation is 119,909,488, and the minimum and maximum are 20,000 and 1,290,000,000, respectively.

[21] The average cif-fob ratio is $\frac{1}{N(N-1)} \sum_i^N \sum_{j \neq i} d_{ij} = 1.196$, the standard deviation of that measure is 0.067, and the corresponding minimum and maximum are 1.010 and 1.455, respectively.

information about the true and estimated changes of trade flows and of equivalent variations (in percent). Since the true comparative static effects are already expressed in percent, the biases are measured as an average absolute percentage point deviation from the true comparative static percent change for the representative country-pair. As with parameter estimates, we also report the mean and standard deviation of the true and estimated comparative static effects across all country-pairs using 2,000 Monte Carlo runs per draw from the set of empirical populations and cif-fob factors, or 20,000 runs per value of N and σ.

3.1 Symmetric Bilateral Trade Costs (SBTC)

The purpose of this section is twofold. First, under the assumption of SBTC, our approach and A-vW's approach provide coefficient estimates and comparative-static estimates that are virtually identical to the true values. Second, our approach provides additionally *estimates* of the elasticity of substitution that are consistently identical to the true elasticities.

Initially, we evaluate our approach (denoted the "Suggested model") relative to the approaches of A-vW, BV-OLS (to be explained shortly), and traditional OLS under the case of symmetric bilateral trade costs. Hence, for each of the 90 alternative baseline equilibria, we *ensure* that the restriction $d_{ij} = d_{ji}$ (and, hence, $t_{ij} = t_{ji}$) holds in the draws from the empirical distribution of bilateral cif-fob factors. Also, we ensure the same restriction holds when altering the trade cost for the counterfactual exercise.

We consider two alternative error structures in the Monte Carlo simulations. We assume that the error terms, u_{ij}, are given by $u_{ij} = \mu_i + \nu_j + \xi_{ij}$. In all cases, ξ_{ij} is drawn from a normal distribution with $\mathcal{N}(0, s_\xi^2)$ and $s_\xi = 0.35 s_x$, where s_x denotes the standard deviation of true log bilateral exports.[22] First, we assume that the error terms (u_{ij}) are uncorrelated with the right-hand-side variables. In the tables, this error structure is labeled "uncorrelated." In this case, μ_i and ν_j are each distributed as $\mathcal{N}(0, s_\mu^2)$ with $s_\mu = 0.15 s_x$. Then, A-vW's iterated approach is as consistent as fixed effects estimation but fixed effects estimates are less efficient. We made 2,000 draws for the error terms under this structure. Second, we also consider an error structure where we know the u_{ij} are correlated with the bilateral trade cost variable, t_{ij}. To do

[22] We scale the variance of the error term (ξ) to a fraction of the variance of exports (0.35) in order for the Monte Carlo simulations of the gravity equations to have R^2 values of approximately 0.65.

this, we add ten times the average exporter-specific trade cost variable ($(1/N)\sum_{j=1} t_{ij}$) to the respective μ_i and ten times the average importer-specific trade cost variable ($(1/N)\sum_{i=1} t_{ij}$) to the respective ν_j. In the tables, this error structure is labeled "correlated." In the latter case A-vW's iterated approach is inconsistent but fixed effects is consistent. We made 2,000 draws for the error terms under this structure also.

Tables 1a and 1b (assuming $\sigma = 5$) provides the Monte Carlo results for three alternative world configurations of 10, 20, and 40 countries. Each of the tables has three panels top to bottom corresponding to alternative configurations of 10, 20, and 40 countries, respectively. Each panel in Table 1a is associated with the corresponding one in Table 1b. Each panel in Table 1a has two blocs of rows which correspond to estimates of key gravity-equation parameters. The first bloc in each panel of Table 1a provides the true value and estimates of the coefficient of $\ln d_{ij}$, $(1-\sigma)\rho$. The second bloc shows the true value and estimates of σ. Each panel in Table 1b has two blocs of rows corresponding to comparative static effects. The first bloc of Table 1b is for estimates of the general equilibrium comparative-static effects on bilateral trade flows relative to GDP products, or "scaled trade flows," of changing trade costs exogenously. The second bloc of this table is for the comparative-static change in welfare (measured by equivalent variation) of the same change in trade costs. Values in Table 1b in each panel of these tables are the results of a change in trade costs represented by two random draws from the world distribution of cif-fob factors described earlier.[23] Recall that the mean effects, their standard deviations, and their average absolute bias are based on $20,000$ draws (10 draws from the empirical distribution of L_i and d_{ij} times $2,000$ error-structure draws).

Tables 1a and 1b have 12 columns. The first column in each provides the names of the two estimates of interest for each panel (corresponding to the two blocs of rows). The second column indicates the "true" values. For $(1-\sigma)\rho$ and σ, the "mean" is simply the true value specified a priori (hence, no standard deviation or bias exists). For the bilateral trade-flow-effect and equivalent-variation estimates, the "true" values are the means and standard deviations of the comparative statics in response to the change in trade costs based upon the calibrated general equilibrium model (with no stochastic component). The remaining columns (3) – (12) present the estimates from five alternative techniques, with each technique applied twice: first with

[23]Note that this implies that some country-pairs will have larger and others smaller trade barriers in the counterfactual situation than in the benchmark equilibrium.

our uncorrelated error structure (odd-numbered columns) and second with correlated errors (even-numbered columns).

Columns (3) and (4) present the estimates using our "suggested" model. For consistent parameter estimates of $(1 - \sigma)\rho$ in the first stage, we use fixed effects, as has become the standard in the literature.[24] Given a consistent estimate of $(1-\sigma)\rho$, we then use this parameter estimate with the N (nonlinear) multilateral trade balance equations to obtain estimates of N GDPs, and then obtain estimates of σ. Using exogenous changes in bilateral cif-fob factors $d_{ij} = d_{ji}$, we can then generate the counterfactual GDPs and trade flows to estimate the two comparative statics.

Columns (5) and (6) present the estimates using the A-vW technique. In this case, we use the same "structural" (iterative) estimation technique as in A-vW, under both error structures, from which N multilateral resistance terms are estimated. Then using exogenous changes in $d_{ij} = d_{ji}$, we can generate the counterfactual multilateral resistance terms and trade flows to estimate the scaled trade-flow comparative statics, given an assumed value of σ (say, 5). Finally, one can estimate the equivalent variation based on the same set of assumptions. In the case of uncorrelated errors, coefficient estimates using fixed effects in the first stage will generate asymptotically identical parameter estimates of $(1-\sigma)\rho$ to A-vW; this is not the case for correlated errors.

Columns (7) and (8) present the estimates using one of two techniques described in Baier and Bergstrand (2006, 2008), referred to here as BV-OLS-1. Columns (9) and (10) present the estimates using the other of the two techniques described in Baier and Bergstrand (2006, 2008), referred to here as BV-OLS-2. Baier and Bergstrand (2006, 2008) present two techniques for estimating gravity equation parameters and comparative statics accounting for the endogenous price terms by using a first-order log-linear Taylor-series expansion of the nonlinear price equations. The method results in estimating the coefficients using a (reduced-form) gravity equation and calculating the MR terms without having to solve a structural system of nonlinear equations. In the case of BV-OLS-1 (BV-OLS-2), the MR terms are exporter and importer simple (GDP-share-weighted) averages of underlying bilateral trade costs.

Finally, columns (11) and (12) present the estimates using the traditional OLS gravity

[24] Recall that both the iterative non-linear least-squares procedure as well as the fixed effects procedure provide consistent parameter estimates with uncorrelated errors.

equation ignoring the role of endogenous prices.

Tables 1a and 1b provide the results for a true elasticity of substitution of $\sigma = 5$ (which is chosen specifically to correspond to the σ *assumed* in A-vW) and $\rho = 2$. Several points are worth noting. First, with a true value of $(1 - \sigma)\rho = -8$, our suggested approach (both error structures), A-vW (with uncorrelated errors), and BV-OLS-1 (both error structures) provide coefficient estimates for d_{ij} that are virtually identical to the true value (see all panels in Table 1a). Moreover, both our approach and BV-OLS-1 share the minimum average absolute bias. Both BV-OLS-2 and traditional OLS gravity equations have notably larger biases.[25] We note that these same *relative* results hold as sample size grows from 10 to 20 to 40 countries, although as expected average absolute biases of $(1 - \sigma)\rho$ decline with N (from 3.22 to 1.55 to 0.76).

The second bloc of rows of each panel in Table 1a provides estimates of the elasticity of substitution, but only for our approach. As discussed earlier, the A-vW approach cannot provide an elasticity of substitution *estimate*, and neither can the BV-OLS or OLS specifications. Across sample sizes of N countries, our approach provides very accurate estimates of σ.

The first row in Table 1b provides estimates of the comparative-static effect on scaled trade flows of a common trade-cost change, using the parameter estimates from Table 1a. The most notable result is that in all three panels our suggested approach provides the *lowest biases* for the general equilibrium trade-effect estimates. We note three further results. First, the trade-effect comparative-static biases for our suggested approach and for A-vW are not notably different; this is to be expected since – under assumed symmetric bilateral trade costs – the two approaches should yield similar results. Second, BV-OLS-2 biases are much smaller than BV-OLS-1 biases (or OLS biases) for $N = 40$, since the former uses a GDP-weighted approach whereas the latter does not. Third, while the comparative-static estimates using BV-OLS-2 are considerably higher than using either our suggested approach or A-vW, they are also considerably less than those from ignoring multilateral resistance terms – as is typically done by empirical researchers.

In the second bloc of rows of each panel of Table 1b, we provide two pieces of information. For our approach, we use the *estimated* elasticities of substitution to generate estimates of welfare-effect comparative statics. These are very close to the true values, not surprisingly,

[25] BV-OLS-1 tends to have less bias because it uses approximations around the "mean," consistent with least squares estimation, cf., Baier and Bergstrand (2006, 2008).

since the elasticity estimates using our approach are precise. The second piece of information is that – assuming $\sigma = 5$ (as in A-vW) – A-vW estimates of the welfare effects are also accurate. Again, this is not surprising because these estimates are based upon *assuming* the true value of σ, 5.

For robustness, we also ran the same Monte Carlo analysis for true values of σ of 3 and 10. These estimates are provided in Appendix Tables A1a to A2b. For brevity, we note three key findings. Most importantly, the overall findings summarized above hold also for the cases of $\sigma = 3$ and $\sigma = 10$. Second, the estimated welfare effects using our approach are now considerably less biased than those using A-vW. There is a simple explanation. Our approach uses *estimated* values of σ *and* our method generates precise estimates of σ. By contrast, A-vW welfare estimates use the assumed value of $\sigma = 5$. If the assumption for σ is incorrect – in both tables for A-vW, σ is assumed to equal 5, as in A-vW, but the true values are different – the estimated welfare effects are very biased. This is another advantage of our approach.

In summary, we note two important conclusions regarding the comparative-static estimates from this Monte Carlo analysis. First, under the assumption of symmetric bilateral trade costs, neither our approach nor A-vW provides trade-effect estimates that are economically different from the true values. However, under *asymmetric* bilateral trade costs, we will see that things change. Second, our approach provides precise *estimates* of the true elasticity of substitution, so that our welfare-effect estimates are also very precise. By contrast, A-vW assume a value of σ, so that if the σ assumption is considerably different from the true value, A-vW welfare-effect estimates will be considerably biased.

3.2 Asymmetric Bilateral Trade Costs (ABTC)

The purpose of this section is twofold. First, we show that under ABTC, our approach and the A-vW approach yield unbiased estimates of the coefficient estimates and comparative-static estimates. Second, our approach, however, provides *consistently* identical comparative static estimates compared with the true ones, whereas the A-vW approach assuming ABTC – even when "properly normalized" – does not. We show that the average trade-flow comparative-static estimation bias of the A-vW approach is *20 to 100 times* that using our approach. The rationale for the difference is attributable to the presence of a stochastic error term in the bilateral trade-flow equation. Our approach retains the same number of nonlinear conditions as in the A-vW approach under SBTC; however, under ABTC, the A-vW approach introduces additional nonlinearities (P_i *and* Π_i).

We performed the same set of Monte Carlo simulations as before except now we admit *asymmetric* bilateral trade costs in the draws from the empirical distributions for cif-fob factors. Every other aspect was identical in these simulations as before, including the alternative error structures, configurations of countries, and parameter values.

We summarize the results in Tables 2a and 2b for the case of $\sigma = 5$ (where A-vW assume the correct value); similar results hold for the two other elasticities (not reported, for brevity). Tables 2a and 2b are structured similarly to Tables 1a and 1b. Moreover, for brevity we focus more on the results for our approach versus A-vW (2003), mentioning only briefly the results for the two BV-OLS techniques and traditional OLS. Also for brevity, we report the results only for uncorrelated errors. Columns (3), (4) and (5) in Tables 2a and 2b provide estimates from our approach and two versions of A-vW's, respectively. The results in column (4) are based on A-vW's equations (12) and (13) assuming SBTC, whereas those in column (5) are based upon A-vW's equations (9)-(11) *allowing ABTC*. The results in columns (6), (7), and (8) are for BV-OLS-1, BV-OLS-2, and OLS, respectively.

Several points are worth noting regarding coefficient estimates in Table 2a. First, our method, A-vW's approach assuming asymmetric bilateral trade costs (henceforth, ABTC-AvW), and BV-OLS-1 provide unbiased estimates of $(1 - \sigma)\rho$ in the presence of ABTC; only our approach provides an unbiased estimate of σ. Second, while OLS is expected to provide biased coefficient estimates, and BV-OLS-2 is not expected to perform as well as BV-OLS-1 (for the reason discussed earlier), the largest absolute coefficient estimate biases arise from using A-vW's approach (in the 20- and 40-country cases) assuming symmetric bilateral trade costs (henceforth, SBTC-AvW), when in fact the trade costs are bilaterally asymmetric – as one might expect.

Consider next the comparative static estimates in Table 2b. First, our method and ABTC-AvW both provide similar average effects on trade flows – especially for world sizes of 20 or 40 countries. However, the average absolute biases using ABTC-AvW for this comparative static is one to two *orders of magnitude* greater than those using our suggested method. For instance, in the 40-country-world in the bottom panel of Table 2b, the average absolute bias for estimating the trade-flow comparative static effect of a change in trade costs is 63.94 percentage points using ABTC-AvW compared with only 0.59 percentage points using our approach (a difference of *100 times*). Not surprisingly, the trade-flow comparative static biases using SBTC-AvW are also worse than those using ABTC-AvW in the presence of ABTC, and consequently are also worse than those using our model.

The stark difference between comparative static estimation biases under ABTC using either A-vW technique relative to those using our method can be explained by the stochastic error term in the bilateral trade-flow equation. As we saw in the case of SBTC, the comparative-statics average absolute estimation bias was only slightly larger than that using our approach. For instance, in Table 1b's top panel, for uncorrelated errors the trade-flow effect's average bias was 2.60 (1.85) percent of the true value using A-vW's (our) approach. The similarity reflects the similar degree of nonlinearity of the two approaches. However, the difference between A-vW under SBTC and under ABTC is that the degree of nonlinearity is higher under the latter because of the need to estimate P_i *and* Π_i, not just P_i (as under SBTC). For instance, in Table 2b's top panel (uncorrelated errors), the trade-flow effect's average bias was 61.27 percent using the ABTC-AvW approach under ABTC, whereas the trade-flow effect's average bias was 2.60 using the SBTC-AvW approach under SBTC (Table 1b, top panel).[26] Hence, the higher degree of nonlinearity of the A-vW approach under ABTC magnifies the estimation bias. However, our approach has the same degree of nonlinearity under either SBTC or ABTC. Consequently, the average estimation biases using our same approach under SBTC and ABTC are 1.85 (Table 1b, top panel) and 2.22 (Table 2b, top panel), respectively, in the 10-country case assuming SBTC and ABTC, respectively. This explanation is corroborated empirically. We estimated the correlation coefficients between the absolute error of the trade-flow equation and the absolute bias of the comparative-static trade flow effect across the 20,000 Monte Carlo runs for the three world sizes of 10, 20, and 40 countries. In every case, the correlation coefficient between the absolute error and the absolute bias is much higher for ABTC-AvW than for our suggested

[26] In Table 2b's top panel, note that the average estimation bias using the SBTC-AvW approach under ABTC is 72.15, which is larger than that using the ABTC-AvW approach under ABTC. This makes sense as the restriction of the SBTC-AvW approach is severe and causes large estimation biases when the world actually has ABTC.

model, implying that that the error terms are correlated with a higher estimation biases for ABTC-AvW relative to our approach. For instance, in the 10-country world, the correlation coefficient for ABTC-AvW was 0.18 versus that for our approach of only 0.06.[27]

Finally, we note that the reason for the bias under asymmetric A-vW estimation is *not* rooted in multiple equilibria or an improper normalization of the exporter and importer multilateral resistance terms. To illustrate this point, we provide a three-country example in the Appendix, where we solve the model without adding a stochastic error term. Then, we obtain exact predictions both with our approach and with the asymmetric A-vW procedure (properly normalized). The reason for the bias of the comparative static results in Table 2b consequently lies in the greater sensitivity of A-vW's approach to stochastic error terms in the trade-flow equations. This is confirmed in $20,000$ Monte Carlo runs and is obvious from a density plot of the biases of comparative static effects across these runs, cf., Figure 2. This figure shows that the average absolute biases in the asymmetric A-vW model are not influenced by just a few outliers. Rather, the biases using ABTC-AvW under asymmetric bilateral trade costs are systematically larger than those from our model.

4 Empirical Evidence

We now apply our technique and A-vW's technique to actual trade flow data. We consider two popular contexts: the U.S.-Canadian "border puzzle" case and a traditional gravity-equation case of world trade flows in the presence of asymmetric trade costs (in particular, asymmetric bilateral tariff rates).

4.1 The U.S.-Canadian Border Puzzle

McCallum (1995) inspired a cottage industry of gravity-equation analyses of the effects of a national border on the trade of Canadian provinces and U.S. states, including the seminal A-vW (2003). This section has two parts. We re-estimate the same specifications addressed in that literature, initially assuming SBTC (as assumed there). We show that – if coefficient

[27] The corresponding correlation coefficients for the 20(40)-country world are 0.31 (0.19) for ABTC-AvW and 0.09 (0.08) for our approach.

estimates are identical from the first stage (say, from fixed-effects parameter estimation) – then our approach and SBTC-AvW's approach lead to identical comparative static effects, if the elasticity of substitution is assumed to be the same. If one uses the estimated elasticity generated by our approach, slightly different comparative statics result. In the second part, we assume *asymmetric* national border barriers for Canada and the United States, resulting in some notably different findings.

4.1.1 Symmetric Canadian-U.S. National Border Barriers

In this section, we present the results of re-evaluating the empirical analysis of A-vW using their nonlinear estimation technique (NLS), fixed effects, and our ("suggested") approach. Note that our approach uses fixed effects to obtain coefficient estimates, but then uses the multilateral-trade-balance conditions to obtain an estimate of the elasticity of substitution. The top panel of Table 3 presents the coefficient estimates (standard errors in parentheses) under the three alternative estimation procedures. First, we confirm in the second column of the top panel of Table 3 the A-vW (2003) coefficient estimates of -0.79 for bilateral distance and -1.65 for the border variable using their NLS structural model.[28] Second, we confirm the fixed effects estimates of -1.25 and -1.55 found in that study; estimates that follow in column (3) use the A-vW approach to solve for MR terms, but based upon coefficient estimates using fixed effects. Third, our approach yields identical coefficient estimates (cf., column (4)) to those in column (3), as we use fixed effects also to estimate gravity-equation parameters; however, estimates that follow parameter estimates in column (4) are based upon our suggested approach for determining σ (using the multilateral-trade-balance conditions). Of course, fixed effects estimation avoids coefficient estimate bias introduced using the SBTC-based A-vW method on actual trade data (which likely suffers from correlation of country-specific errors with explanatory variables in the model). Fourth, the top panel of Table 3 reminds one that our method also generates an *estimate* of σ from the data. Our method implies an estimate of σ equal to approximately 12. While such an estimate is at the higher end of the range of recent estimates of σ, we will show shortly that – by allowing for *asymmetric* Canadian and U.S. national border coefficient estimates – the estimate of σ falls right in the middle of the

[28]The border dummy takes a value of 1 (0) if trade is between a U.S. state and a Canadian province.

range of recent cross-country estimates of σ.

The middle panel of Table 3 summarizes the trade-effect comparative-static estimates for pairings of provinces-provinces, states-states, and provinces-states. The important conclusion to draw from this panel is that — under the restriction that the border effect is symmetric — the standard deviation of the trade effects of border barriers is high using all three estimation procedures.

The bottom panel of Table 3 presents the welfare-effect estimates of symmetric border barriers. Note that our method generates much smaller welfare effects of national barrier eliminations than A-vW or fixed effects. Our overall welfare effect is 2.070 whereas that from fixed-effects is 6.660; the reason is that our estimated elasticity of substitution is 12, whereas estimates in column (3) use A-vW's *assumed* elasticity of 5. The overall effect using A-vW's NLS-estimated coefficient and A-vW's assumed elasticity of 5 are presented in column (2). This overall welfare effect of 10.984 is larger than that in column (3) owing to the different coefficient estimates using NLS, which generate a larger partial effect of a border on trade (-1.65) compared with fixed effects (-1.55).

For completeness, we also estimated the average values of the $P^{1-\sigma}$ terms and the impacts of border barriers on trade flows, as explored in A-vW. For brevity, we summarize the results (provided in Appendix Tables A4a and A4b). First, since our approach uses fixed-effects to obtain gravity-equation parameters, we obtain virtually identical average $P^{1-\sigma}$ values and border impacts to those estimated using SBTC-AvW, based upon the same coefficient estimates, as expected. If the average $P^{1-\sigma}$ values and border impacts use gravity-equation coefficients from A-vW NLS estimation (border coefficient of -1.65), the average $P^{1-\sigma}$ values and border impacts depart somewhat as expected from those obtained using fixed-effects gravity-equation coefficient estimates (border coefficient of -1.55).

4.1.2 Asymmetric Canadian-U.S. National Border Barriers

Table 4 reports the empirical results under the more plausible assumption that Canadian and U.S. national borders have *asymmetric* effects on trade. We introduce separate dummy variables for a Canadian national border and a U.S. national border. In this case, the estimate of $(1-\sigma)\ln b_{US}$ measures the effect of the Canadian-U.S. border on a flow from a Canadian province to a U.S. state. The estimate of $(1-\sigma)\ln b_{CA}$ measures the effect of the national border on a trade flow from a U.S. state to a Canadian province. Note that the coefficient estimates for the two dummy variables are economically and statistically significantly different from one another. The effect of a national border is asymmetric according to the flow's direction. The top panel indicates also that, as in the previous case, our method provides identical parameter estimates for the trade-cost variables' coefficients to fixed effects. However, note that with ABTC, the estimate of the elasticity of substitution from our model is equal to 6.4. This value is well within the range of recent estimates of this elasticity using cross-section trade data, cf., Baier and Bergstrand (2001), Head and Ries (2001), and Anderson and van Wincoop (2004).

The middle panel of Table 4 confirms that – under an assumption of ABTC – our method yields border barrier effects that are quite different from and have lower standard deviations than the ones using the A-vW approach which assumes ABTC. First, compare our approach's border effects in column (4) versus those estimated using ABTC-AvW for comparative statics, but using the same fixed-effects coefficient estimates, cf., column (3). Using the same coefficient estimates (from top panel, columns (3) and (4)), our method yields slightly higher average trade effects with occasionally higher standard deviations. Our method uses the estimated elasticity of 6.4, whereas column (3) uses the assumed elasticity of 5; consequently, our method generates larger trade effects on average. If one uses coefficient estimates generated by A-vW's NLS estimation technique in column (2)'s top panel, which are considerably different, the trade effects are much different of course; however, the coefficient estimates based upon NLS are likely biased.

The bottom panel of Table 4 provides welfare-effect estimates of border barriers. In this panel, recall that A-vW and fixed effects assume an elasticity of 5, whereas our approach estimates the elasticity at 6.4. The higher welfare effects using our approach in column (4) compared with those in column (3) are explained by our procedure's calculation of (much less biased) comparative statics relative to the ABTC-AvW approach for comparative statics (used for columns (2) and (3)), despite our estimate of σ of 6.4 compared with A-vW's assumed value of 5; see discussion in section 3.2. Note that the estimates of the welfare gain from eliminating the national border are *considerably* higher in our approach, even when using coefficient estimates generated with fixed effects. Using A-vW's custom nonlinear estimation, the estimated comparative-static effect of eliminating the national border is to reduce welfare by 7.9 percent as shown in column (2). This considerably different estimate is likely attributable to correlated errors causing bias in the estimated gravity-equation parameters using NLS (rather than fixed effects).

4.2 World Trade Flows and Asymmetric Bilateral Tariffs

In this final substantive section, we apply our estimation procedure to the case of world trade flows, tariffs, and dummy variables for the year 2001. Thus, we apply our approach to the most common context for the gravity equation, world trade flows (from the *UN COMTRADE* data set). We compile a data base for 67 countries with GDPs and asymmetric bilateral tariff rates (from *GTAP*), populations (from *World Development Indicators*), and numerous dummy variables (from *CEPII*) to conduct parameter estimation and general equilibrium comparative statics. This data set provides an excellent context in order to examine the usefulness of our procedure.

We run a country-fixed-effects gravity equation on "scaled" bilateral trade flows including, on the right-hand-side, the log of the gross bilateral tariff rate (*Tar*), the log of bilateral distance (*Dist*), and dummy variables for common language (*Comlang*), contiguity (*Contig*), former colony (*Colony*), and common colonial heritage (*Comcol*), often included in gravity specifications, cf., Rose (2004).[29] Then, we employ the N multilateral trade balance conditions to conduct the trade-effect and welfare-effect comparative statics.

As conventional to the gravity-equation literature, we assume that the log of the gross trade-cost variable (t) is a linear function of the log of the gross bilateral tariff rate, log bilateral distance, and various dummies:

$$
\begin{aligned}
(1-\sigma)\ln t_{ij} &= -\sigma\kappa \ln(Tar_{ij}) + (1-\sigma)\rho \ln Dist_{ij} + (1-\sigma)\ln b_1 Comlang_{ij} \\
&+ (1-\sigma)\ln b_2 Contig_{ij} + (1-\sigma)\ln b_3 Colony_{ij} \\
&+ (1-\sigma)\ln b_4 Comcol_{ij}.
\end{aligned}
$$

The parameter of log gross import tariffs of importer j from exporter i, $-\sigma\kappa$, has two compo-

[29] Recall that "scaled" trade flows are trade flows divided by the product of the countries' GDPs.

nents. The use of $-\sigma$, rather than $1-\sigma$, reflects an assumption of tariff-revenue redistribution to consumers. The term κ reflects the influence of measurement error of *de jure* tariff rates.[30]

Table 5 presents the results. The top panel in Table 5 provides the coefficient estimates. Column (2) shows that convergence was not achieved using the iterative non-linear A-vW procedure for ABTC to obtain coefficient estimates. Columns (3) and (4) show that we obtain plausible parameter estimates and statistically significant coefficients using fixed effects. The R^2 for the fixed-effects regressions are 0.65, typical of gravity equations using world trade flows. Recall, our suggested model uses parameter estimates combined with the multilateral-trade-balance conditions to obtain a consistent estimate of σ. Column (4) in the top panel reports an estimate of σ of 6.07 from our approach, which is in the range of plausible estimates discussed earlier and in Anderson and van Wincoop (2004).

The middle panel reports the general equilibrium comparative-static "trade-effect" estimates from a complete elimination of bilateral tariff rates. Not surprisingly, given the sizable negative shock on tariffs, the increase in trade relative to GDPs on average is fairly large, 167 percent. Also the standard deviation of the effects is quite large relative to the mean effect, indicating that the variation in tariffs among the 67 developed and the developing economies is quite large.

The bottom panel reports the comparative-static welfare-effect estimate of a complete elimination of bilateral tariff rates. In column (3), we *assume* an elasticity of substitution of 6.07 (as found empirically using our approach). However, column (3) calculates the welfare effects using the ABTC-AvW approach with P_i's and Π_i's. The tariff elimination raises welfare by 10.7 percent using the ABTC-AvW approach and by 6.9 percent using our approach. The reason for the discrepancy is *not* associated with the value of σ, as we assume the same value for σ in column (3) as estimated in column (4) with our approach. Rather, the ABTC-AvW approach and ours provide different comparative-static estimates (even when using the same estimated coefficients). However, as shown in the earlier Monte Carlo analysis (in the absence of measurement and specification errors), the average estimation bias of ABTC-AvW can be *10 to 100 times* that of our approach. We consider our approach more accurate based upon the earlier Monte Carlo results. However, the interesting finding is that our 6.9 percent of

[30] The impact of high *de jure* tariffs tends to be dampened by the misclassification of goods. Hence, we would expect that $\kappa < 1$. Evidence on this issue has been provided by Fisman and Wei (2004) and, more recently, by Javorcik and Narciso (2007).

GDP welfare improvement is *10 times* that of the median effect of a complete elimination of remaining tariffs found in standard *ex ante* CGE models, cf., Bouet (2008). Our 6.9 percent increase in economic welfare seems more in line with the gains needed for the political pursuit of full tariff liberalization.

5 Conclusions

Theoretical foundations for estimating gravity equations were enhanced recently in Eaton and Kortum (2002), Anderson and van Wincoop (2003), and Helpman, Melitz, and Rubinstein (2008). Though elegant, the approaches do not provide consistent estimates of elasticities of substitution in consumption and general equilibrium comparative statics. We use the simple workhorse Helpman-Krugman increasing returns-monopolistic competition model of trade (used recently in Helpman, Melitz, and Rubinstein, 2008) along with the multilateral-trade-balance conditions to motivate estimating simultaneously gravity equation coefficients, the elasticity of substitution in consumption, and general equilibrium trade-flow and economic welfare effects – in the presence of bilaterally symmetric *or asymmetric* trade costs. In an empirical example of our approach, we show that complete elimination of remaining (bilaterally asymmetric) tariffs among 67 countries (in 2001) would yield an estimated (equivalent-variation) improvement of world welfare of 6.9 percent – *10 times* the median estimated impact from traditional *ex ante* CGE models.

However, the paper has not addressed several issues, which are plausibly examined in future research. Notably, we use a one-sector, one-factor trade model. Our future work will extend the analysis to multiple sectors, such as typically addressed in traditional CGE models. However, different estimation issues surface, such as the treatment of extensive zero trade flows – which is even an issue to be dealt with for aggregate bilateral trade flows. Moreover, future work should extend the framework to multiple factors, a subject also beyond the scope of the present paper.

A1 Appendix

A-vW's approach is mainly developed for symmetric trade costs. For instance, the GAUSS-routine posted at http://www2.bc.edu/∼anderson/Research.htm is designed for symmetric countries but, to the best of our knowledge, no such routine is available in public domain for asymmetric trade costs.

A-vW, Anderson and van Wincoop (2004), and Anderson (2007) point out that, for asymmetric trade costs, the multilateral resistance terms need to be properly "normalized." As A-vW (2003, footnote 11) point out explicitly, "There are many equilibria with asymmetric barriers that lead to the same equilibrium trade flows as with symmetric barriers, so that empirically they are impossible to distinguish" (p. 175). It is important for our analysis of comparing our approach for comparative statics to those using ABTC-AvW's approach to show that the differing results are not attributable to multiple-equilibria/normalization issues, as opposed to our more precise Monte Carlo estimates being attributable to a lower degree of nonlinearity. We have identified a proper normalization that implies estimates for the comparative static trade-flow effects using the ABTC-AvW approach under asymmetry that are *identical* to the "true" values in the absence of stochastic errors.

This can be seen from a three-country example which we summarize in Table A3. We distinguish between two cases in the table, one with symmetric trade barriers (on the left-hand side of the table) and one with asymmetric trade barriers (on the right-hand side). The chosen parameters and values for trade costs and country size are given in the corresponding footnote to the table. In the table, we provide true and predicted values for bilateral trade flows between all country-pairs for both cases. Predicted values are obtained from A-vW's procedures for symmetric and asymmetric trade costs, respectively. Notably, either procedure predicts true bilateral trade flows (scaled by the product of GDPs) between all country-pairs equally well for symmetric trade costs. However, the procedure for symmetric trade barriers obtains biased results if trade costs are in fact asymmetric, while the procedure for asymmetric trade barriers works as well as under symmetric trade costs.

Table A3 is important because it informs us that the ABTC-AvW technique obtains identical comparative statics to the true ones (in the absence of stochastic errors), when properly normalized. Consequently, the imprecision of the comparative statics using ABTC-AvW shown in Table 2b relative to the precision of comparative statics using our method must reflect the role of the stochastic errors in the trade-flow equations causing less precision of the ABTC-AvW comparative-static estimates due to the increase in the degree of nonlinearity in the asymmetric case (i.e., estimating P_i's and Π_i's) relative to the symmetric case, an increase which does not occur under our method in going from bilaterally symmetric to asymmetric trade costs.

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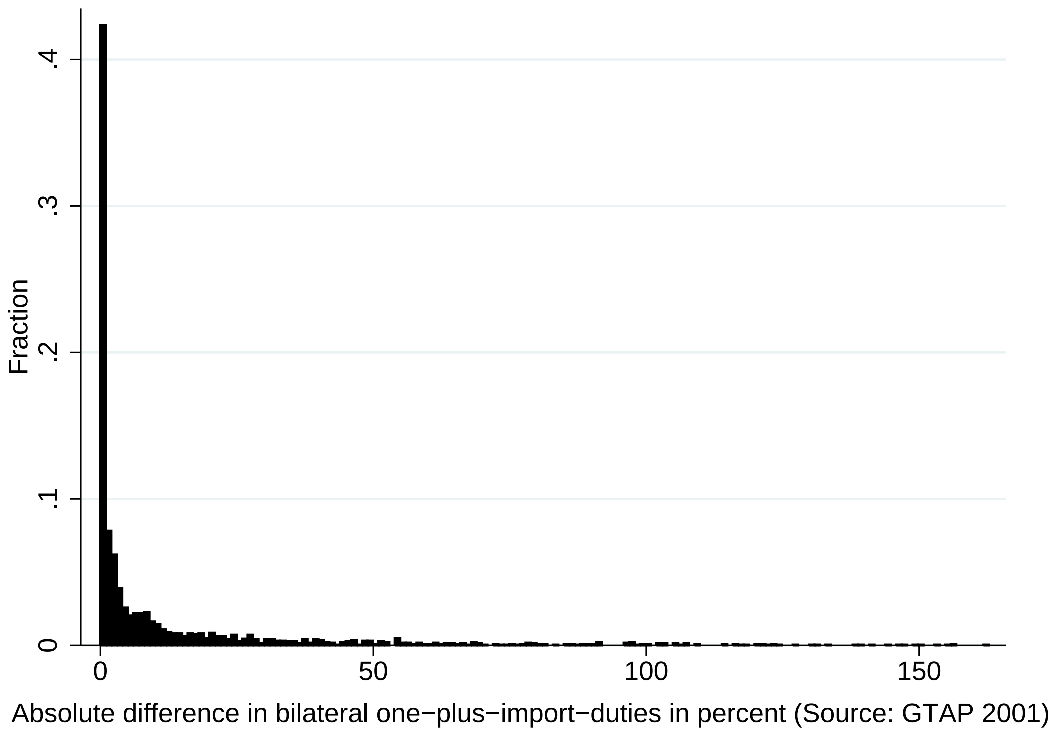

Figure 1: Asymmetry of bilateral import duties

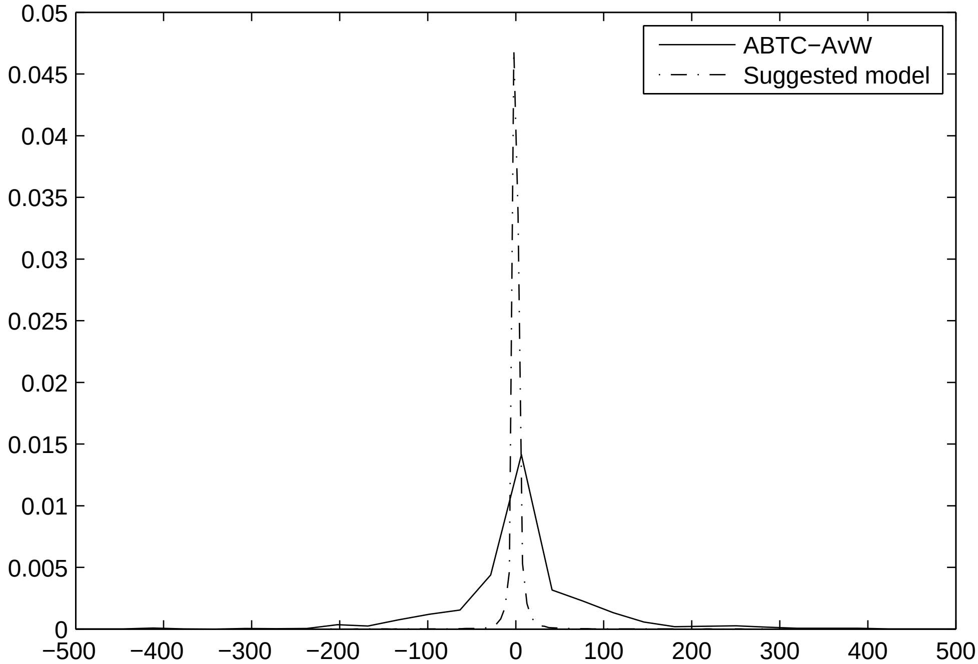

Figure 2: Distribution of trade prediction biases for Table 2a, top panel, i.e., for the 10-country-world and $\sigma = 5$ (in percentage points)

Table 1a: Monte Carlo results for gravity-equation parameters in the case of a $\sigma = 5$ and symmetric trade costs

Estimates	True	Suggested model		A-vW		BV-OLS-1		BV-OLS-2		OLS	
		uncorr.	corr.	uncorr.	corr.	uncorr.	corr.	uncorr.	corr.	uncorr.	corr.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
					10-country-world, $\sigma = 5$						
$\rho(1-\sigma)$											
mean	-8	-8.0214	-8.0354	-8.0149	-7.5514	-8.0214	-8.0354	-7.7444	-7.8193	-7.6241	-6.8319
std.	-	0.3232	0.3205	0.4738	0.5197	0.3232	0.3205	0.6343	0.6395	0.5502	0.6785
bias	-	3.2207	3.2069	4.6685	6.7944	3.2207	3.2069	6.6943	6.5789	6.7748	14.7083
σ											
mean	5	5.0177	5.0264	-	-	-	-	-	-	-	-
std.	-	0.2487	0.2467	-	-	-	-	-	-	-	-
bias	-	3.7163	3.7071	-	-	-	-	-	-	-	-
					20-country-world, $\sigma = 5$						
$\rho(1-\sigma)$											
mean	-8	-8.0107	-8.0087	-8.0107	-7.6167	-8.0107	-8.0087	-7.8510	-7.7691	-7.7905	-7.2060
std.	-	0.1558	0.1559	0.2570	0.2333	0.1558	0.1559	0.2712	0.2235	0.2655	0.3237
bias	-	1.5518	1.5545	2.5415	4.8903	1.5518	1.5545	3.0960	3.2839	3.5705	9.9623
σ											
mean	5	5.0092	5.0078	-	-	-	-	-	-	-	-
std.	-	0.1249	0.1248	-	-	-	-	-	-	-	-
bias	-	1.8199	1.8232	-	-	-	-	-	-	-	-
					40-country-world, $\sigma = 5$						
$\rho(1-\sigma)$											
mean	-8	-8.0029	-8.0026	-8.0106	-7.8565	-8.0029	-8.0026	-7.7537	-7.7207	-7.7949	-7.4301
std.	-	0.0764	0.0776	0.1359	0.1305	0.0764	0.0776	0.1944	0.2150	0.1205	0.1547
bias	-	0.7633	0.7733	1.3514	2.0033	0.7633	0.7733	3.2803	3.5994	2.5981	7.1239
σ											
mean	5	5.0008	5.0003	-	-	-	-	-	-	-	-
std.	-	0.0780	0.0789	-	-	-	-	-	-	-	-
bias	-	1.0884	1.1039	-	-	-	-	-	-	-	-

Notes: The (absolute) bias is expressed in percent of the true value.

Table 1b: Monte Carlo results for predicted trade flow and welfare comparative statics in the case of a $\sigma = 5$ and symmetric trade costs

Estimates	True	Suggested model		A-vW		BV-OLS-1		BV-OLS-2		OLS	
		uncorr.	corr.	uncorr.	corr.	uncorr.	corr.	uncorr.	corr.	uncorr.	corr.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
					10-country-world, $\sigma = 5$						
$\Delta \frac{X_{ij} y_w}{y_i y_j}$											
mean	15.6348	15.7586	15.8197	15.7720	13.7475	14.6863	14.7388	20.9057	21.2467	21.2083	16.9485
std.	67.7946	68.2929	68.4372	68.4578	62.1077	63.0199	63.1647	81.6642	82.1467	73.8767	61.3019
bias	-	1.8482	1.8396	2.5982	3.7948	19.0619	19.0723	22.7052	22.8996	26.4978	24.1339
EV_i											
mean	1.7030	1.7011	1.6972	1.7038	1.6365	-	-	-	-	-	-
std.	9.1959	9.1915	9.1818	9.1918	9.0527	-	-	-	-	-	-
bias	-	0.2234	0.2213	0.1483	0.2054	-	-	-	-	-	-
					20-country-world, $\sigma = 5$						
$\Delta \frac{X_{ij} y_w}{y_i y_j}$											
mean	23.3920	23.4703	23.4569	23.4934	21.2079	19.0991	19.0883	26.1341	25.4988	24.3130	20.7552
std.	90.5346	90.8372	90.7944	90.9789	83.7935	80.1990	80.1646	96.5163	94.8488	84.9751	75.3124
bias	-	1.1651	1.1674	1.8146	3.3970	17.9046	17.9053	14.7770	14.2352	22.2170	21.7635
EV_i											
mean	0.8988	0.8984	0.8986	0.8997	0.8486	-	-	-	-	-	-
std.	7.2242	7.2194	7.2202	7.2294	7.0372	-	-	-	-	-	-
bias	-	0.0788	0.0789	0.0903	0.1692	-	-	-	-	-	-
					40-country-world, $\sigma = 5$						
$\Delta \frac{X_{ij} y_w}{y_i y_j}$											
mean	23.8155	23.8488	23.8473	23.8913	22.944	19.2797	19.2779	25.0291	24.7589	18.9762	17.066
std.	89.7503	89.8462	89.841	90.0318	87.0564	78.7351	78.731	92.7942	91.6696	78.7336	73.0796
bias	-	0.71597	0.726	0.9867	1.4566	20.6474	20.6487	11.3734	11.2878	23.504	23.5699
EV_i											
mean	-0.0880	-0.0906	-0.0909	-0.0878	-0.0941	-	-	-	-	-	-
std.	7.7841	7.7875	7.7880	7.7914	7.6844	-	-	-	-	-	-
bias	-	0.0658	0.0668	0.0587	0.0878	-	-	-	-	-	-

Notes: The bias is expressed in percentage points of the true value (as scaled trade flows and EVs are in percent already).

Table 2a: Monte Carlo results for model parameters in the case of a $\sigma = 5$ and asymmetric trade costs

Estimates	True	Suggested model uncorr.	SBTC-AvW uncorr.	ABTC-AvW uncorr.	BV-OLS-1 uncorr.	BV-OLS-2 uncorr.	OLS uncorr.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
				10-country-world, $\sigma = 5$			
$\rho(1-\sigma)$							
mean	-8	-8.0344	-7.5450	-8.0189	-8.0344	-7.7706	-7.3985
std.	-	0.3379	0.7194	0.5350	0.3379	0.5602	0.6601
bias	-	3.3576	7.9758	5.1400	3.3576	6.0316	8.8690
σ							
mean	5	5.0192	-	-	-	-	-
std.	-	0.1999	-	-	-	-	-
bias	-	3.0146	-	-	-	-	-
				20-country-world, $\sigma = 5$			
$\rho(1-\sigma)$							
mean	-8	-8.0115	-7.4819	-8.0056	-8.0115	-7.6672	-7.6695
std.	-	0.1675	0.3399	0.3095	0.1675	0.3714	0.3067
bias	-	1.6740	6.6555	2.9432	1.6740	4.9601	4.7580
σ							
mean	5	5.0060	-	-	-	-	-
std.	-	0.0944	-	-	-	-	-
bias	-	1.4972	-	-	-	-	-
				40-country-world, $\sigma = 5$			
$\rho(1-\sigma)$							
mean	-8	-8.0049	-7.6258	-8.0037	-8.0048	-7.7128	-7.7428
std.	-	0.0780	0.1863	0.1308	0.0780	0.3349	0.1148
bias	-	0.7763	4.6963	1.1463	0.7762	3.9769	3.2360
σ							
mean	5	5.0029	-	-	-	-	-
std.	-	0.0480	-	-	-	-	-
bias	-	0.7609	-	-	-	-	-

Notes: The (absolute) bias is expressed in percent of the true value.

Table 2b: Monte Carlo results for predicted trade flow and welfare changes in the case of a $\sigma = 5$ and asymmetric trade costs

Estimates	True	Suggested model uncorr.	SBTC-AvW uncorr.	ABTC-AvW uncorr.	BV-OLS-1 uncorr.	BV-OLS-2 uncorr.	OLS uncorr.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
				10-country-world, $\sigma = 5$			
$\Delta \frac{X_{ij} y_w}{y_i y_j}$							
mean	22.3160	22.5329	24.3033	29.8790	15.4115	31.4988	13.4523
std.	86.8816	87.8055	94.8674	118.1064	70.4919	105.6992	70.1517
bias	-	2.2204	72.1455	61.2726	27.0623	19.7823	32.7729
EV_i							
mean	-0.5329	-0.6103	-1.3676	3.2516	-	-	-
std.	7.9587	8.3275	12.3080	14.6215	-	-	-
bias	-	0.1395	5.4040	10.2616	-	-	-
				20-country-world, $\sigma = 5$			
$\Delta \frac{X_{ij} y_w}{y_i y_j}$							
mean	26.8187	26.9274	20.4911	27.1922	18.4374	32.2394	16.7067
std.	96.5832	96.9327	85.9832	96.3771	75.5212	107.0587	75.7831
bias	-	1.3808	82.3099	65.7077	30.7412	16.2714	33.5192
EV_i							
mean	-0.4670	-0.4689	-1.1426	3.6342	-	-	-
std.	7.1483	7.5979	11.8526	14.7043	-	-	-
bias	-	0.0529	6.4617	11.3423	-	-	-
				40-country-world, $\sigma = 5$			
$\Delta \frac{X_{ij} y_w}{y_i y_j}$							
mean	22.1344	22.1696	25.2088	22.9877	19.3464	22.8142	18.6620
std.	89.3596	89.4665	88.3751	88.7845	79.3079	90.4984	78.6963
bias	-	0.5884	81.5856	63.9398	21.9361	10.9886	25.0806
EV_i							
mean	0.1282	0.1276	3.0281	-2.2186	-	-	-
std.	6.3510	5.7522	10.4759	36.4761	-	-	-
bias	-	0.0201	6.0811	15.2836	-	-	-

Notes: The bias is expressed in percentage points of the true value.

Table 3: Estimation results for the A-vW data-set

Estimates (1)	A-vW NLS (2)	Fixed Effects (3)	Suggested model (4)
Parameters			
$(1-\sigma)\rho$	-0.788	-1.252	-1.252
	(0.032)	(0.037)	(0.037)
$(1-\sigma)\ln b_{US,CA}$	-1.646	-1.551	-1.551
	(0.077)	(0.059)	(0.059)
σ	–	–	11.892
R^2	0.435	0.664	0.664
σ^2	1.062	0.841	0.841
Trade effects of border barrier abolition			
Overall			
mean	42.806	61.388	72.157
min	-82.823	-71.685	-64.820
max	211.487	277.512	293.530
std.	79.300	99.307	112.366
Intra-US trade			
mean	5.924	10.430	58.541
min	-51.746	-35.178	-20.036
max	208.110	274.571	292.052
std.	39.599	52.280	103.419
Intra-CA trade			
mean	19.055	51.503	67.459
min	-82.823	-71.685	-63.599
max	209.755	263.328	293.530
std.	102.968	116.319	136.396
Inter trade			
mean	98.533	134.879	92.108
min	-82.823	-71.685	-64.820
max	211.487	277.512	293.530
std.	84.758	101.426	117.374
Welfare effects of border barrier abolition (equivalent variation)			
Overall	10.984	6.660	2.070
US	1.428	1.179	0.535
CA	39.654	23.105	6.675

Table 4: Estimation results for the A-vW data-set allowing for asymmetric border barrier effects

Estimates (1)	ABTC-AvW (2)	Fixed Effects (3)	Suggested model (4)
Parameters			
$(1-\sigma)\rho$	-0.788	-1.252	-1.252
	(0.008)	(0.037)	(0.037)
$(1-\sigma)\ln b_{US}$	-0.264	-0.470	-0.470
	(0.173)	(0.046)	(0.046)
$(1-\sigma)\ln b_{CA}$	-3.028	-0.825	-0.825
	(0.104)	(0.047)	(0.047)
σ	–	–	6.3593
R^2	0.435	0.664	0.664
σ^2	1.062	0.841	0.841

Trade effects of border barrier abolition

Overall			
mean	113.150	11.308	15.516
min	-92.615	-51.370	-46.389
max	594.230	62.785	141.719
std	114.440	27.419	43.880
Intra-US trade			
mean	86.928	-1.235	-0.289
min	-43.567	-10.892	-11.411
max	520.710	62.278	18.666
std	73.124	13.571	5.470
Intra-CA trade			
mean	34.354	-3.678	28.664
min	-92.615	-51.370	-45.454
max	440.210	62.602	141.719
std	145.430	42.622	73.806
Inter trade			
mean	162.220	31.316	35.833
min	-92.615	-51.370	-46.389
max	594.230	62.785	141.150
std	135.950	27.093	57.208

Welfare effects of border barrier abolition
(equivalent variation)

Overall	-7.900	0.651	2.374
US	0.074	-0.260	0.593
CA	-31.820	3.382	7.719

Table 5: Estimation results for the GTAP data-set

Estimates (1)	ABTC-AvW (2)	Fixed Effects (3)	Suggested model (4)
Parameters			
$-\sigma\kappa$	no convergence achieved	-1.865	-1.865
		(0.059)	(0.059)
$(1-\sigma)\rho$		-1.056	-1.056
		(0.027)	(0.027)
$(1-\sigma)\ln b_{\text{comlang}}$		0.442	0.442
		(0.070)	(0.070)
$(1-\sigma)\ln b_{\text{contig}}$		0.658	0.658
		(0.104)	(0.104)
$(1-\sigma)\ln b_{\text{colony}}$		0.416	0.416
		(0.117)	(0.117)
$(1-\sigma)\ln b_{\text{comcol}}$		0.284	0.284
		(0.100)	(0.100)
σ		-	6.072
R^2		0.645	0.645
σ^2		1.185	1.185

Trade effects of world wide abolition of import duties

Overall			
mean	–	166.470	167.470
min	–	-94.594	-94.677
max	–	111690.000	78315.000
std	–	2709.600	2291.700

Welfare effects of world wide abolition of import duties
(equivalent variation)

Overall	–	10.701	6.948

Table A1a: Monte Carlo results for model parameters in the case of a $\sigma = 3$ and symmetric trade costs

Estimates	True	Suggested model		A-vW		BV-OLS 1		BV-OLS 2		OLS	
		uncorr.	corr.	uncorr.	corr.	uncorr.	corr.	uncorr.	corr.	uncorr.	corr.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
					10-country-world, $\sigma = 3$						
$\rho(1-\sigma)$											
mean	-4	-4.0136	-4.0194	-4.0119	-4.0035	-4.0136	-4.0194	-3.9321	-4.0462	-3.7571	-3.2041
std.	-	0.1698	0.1690	0.3167	0.2881	0.1698	0.1690	0.3235	0.3411	0.2799	0.3539
bias	-	3.3738	3.3803	6.2824	5.8070	3.3738	3.3803	6.5394	7.0723	7.5737	19.9271
σ											
mean	3	3.0080	3.0129	-	-	-	-	-	-	-	-
std.	-	0.1153	0.1153	-	-	-	-	-	-	-	-
bias	-	3.0183	3.0335	-	-	-	-	-	-	-	-
					20-country-world, $\sigma = 3$						
$\rho(1-\sigma)$											
mean	-4	-4.0034	-4.0043	-4.0033	-3.8925	-4.0034	-4.0043	-3.9528	-3.9859	-3.7878	-3.1911
std.	-	0.0787	0.0785	0.1926	0.1841	0.0787	0.0785	0.2024	0.1871	0.1631	0.2800
bias	-	1.5676	1.5565	3.7673	4.3525	1.5676	1.5565	4.0657	3.7943	5.5451	20.2220
σ											
mean	3	3.0032	3.0044	-	-	-	-	-	-	-	-
std.	-	0.0926	0.0919	-	-	-	-	-	-	-	-
bias	-	2.1690	2.1483	-	-	-	-	-	-	-	-
					40-country-world, $\sigma = 3$						
$\rho(1-\sigma)$											
mean	-4	-4.0021	-4.0017	-4.0011	-3.9242	-4.0021	-4.0017	-3.9462	-3.9459	-3.8842	-3.5452
std.	-	0.0380	0.0382	0.0868	0.0997	0.0380	0.0382	0.0975	0.0972	0.0694	0.1030
bias	-	0.7595	0.7626	1.7105	2.6967	0.7595	0.7626	2.1731	2.2230	2.9590	11.3697
σ											
mean	3	3.0016	3.0013	-	-	-	-	-	-	-	-
std.	-	0.0286	0.0288	-	-	-	-	-	-	-	-
bias	-	0.7539	0.7585	-	-	-	-	-	-	-	-

Notes: The (absolute) bias is expressed in percent of the true value.

Table A1b: Monte Carlo results for predicted trade flow and welfare changes in the case of a $\sigma = 3$ and symmetric trade costs

Estimates	True	Suggested model		A-vW		BV-OLS 1		BV-OLS 2		OLS	
		uncorr.	corr.	uncorr.	corr.	uncorr.	corr.	uncorr.	corr.	uncorr.	corr.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	10-country-world, $\sigma = 3$										
$\Delta \frac{X_{ij} y_w}{y_i y_j}$											
mean	6.6662	6.7489	6.7416	6.6014	6.8860	3.5120	3.5190	8.2709	9.3040	3.2435	2.3500
std.	36.9948	37.2688	37.2623	37.1356	38.1079	27.7128	27.7392	41.0057	44.4533	27.8818	23.5375
bias	-	0.9934	0.9887	1.6633	1.5481	15.2644	15.2651	4.4485	5.3880	17.8267	17.6405
EV_i											
mean	0.2351	0.2304	0.2317	-0.0611	-0.0875	-	-	-	-	-	-
std.	14.1707	14.1729	14.1630	7.4562	7.5313	-	-	-	-	-	-
bias	-	0.1355	0.1352	4.3464	4.3028	-	-	-	-	-	-
	20-country-world, $\sigma = 3$										
$\Delta \frac{X_{ij} y_w}{y_i y_j}$											
mean	5.4797	5.4923	5.4933	5.4408	5.1722	4.4173	4.4194	6.0417	6.0668	3.7566	2.5930
std.	35.3275	35.3767	35.3852	35.4044	34.3500	31.3472	31.3551	36.6611	36.8558	31.1362	25.9515
bias	-	0.4772	0.4750	1.0460	1.1888	11.3259	11.3260	3.7866	3.7163	13.1648	13.4517
EV_i											
mean	0.1196	0.1184	0.1187	-0.0231	-0.0290	-	-	-	-	-	-
std.	9.8557	9.8611	9.8581	5.2396	5.1146	-	-	-	-	-	-
bias	-	0.1346	0.1339	3.4358	3.5203	-	-	-	-	-	-
	40-country-world, $\sigma = 3$										
$\Delta \frac{X_{ij} y_w}{y_i y_j}$											
mean	4.7364	4.7431	4.7416	4.6834	4.5225	4.4345	4.4335	4.7299	4.7390	4.5261	3.7749
std.	33.7559	33.7794	33.7748	33.7530	33.0860	31.4914	31.4874	34.1411	34.1706	31.2879	28.2547
bias	-	0.2050	0.2058	0.4662	0.7302	9.0524	9.0524	2.2595	2.2712	9.8183	9.9459
EV_i											
mean	0.4752	0.4748	0.4749	0.1975	0.1907	-	-	-	-	-	-
std.	7.0784	7.0774	7.0777	3.7986	3.7388	-	-	-	-	-	-
bias	-	0.0190	0.0191	2.5146	2.5626	-	-	-	-	-	-

Notes: The bias is expressed in percentage points of the true value.

Table A2a: Monte Carlo results for model parameters in the case of a $\sigma = 10$ and symmetric trade costs

Estimates	True	Suggested model		A-vW		BV-OLS 1		BV-OLS 2		OLS	
		uncorr.	corr.	uncorr.	corr.	uncorr.	corr.	uncorr.	corr.	uncorr.	corr.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
					10-country-world, $\sigma = 10$						
$\rho(1-\sigma)$											
mean	-18	-18.1151	-18.0950	-18.0302	-17.3963	-18.1151	-18.0950	-16.4232	-16.3901	-18.0739	-17.4395
std.	-	0.7788	0.7756	0.8402	0.7863	0.7788	0.7756	2.6003	2.5866	1.0715	1.1069
bias	-	3.4823	3.4579	3.7112	4.4491	3.4823	3.4579	13.1853	13.1519	4.7878	5.4869
σ											
mean	10	10.0318	10.0207	-	-	-	-	-	-	-	-
std.	-	0.5865	0.5889	-	-	-	-	-	-	-	-
bias	-	4.1089	4.0843	-	-	-	-	-	-	-	-
					20-country-world, $\sigma = 10$						
$\rho(1-\sigma)$											
mean	-18	-18.0253	-18.0327	-18.0037	-17.5787	-18.0253	-18.0327	-15.6098	-15.5545	-17.6570	-17.0613
std.	-	0.3721	0.3759	0.4886	0.5454	0.3721	0.3759	2.1116	2.0400	0.6485	0.6821
bias	-	1.6554	1.6777	2.1710	3.1475	1.6554	1.6777	14.1517	13.9282	3.3918	5.6584
σ											
mean	10	10.0001	9.9912	-	-	-	-	-	-	-	-
std.	-	0.7965	0.7933	-	-	-	-	-	-	-	-
bias	-	4.3285	4.3509	-	-	-	-	-	-	-	-
					40-country-world, $\sigma = 10$						
$\rho(1-\sigma)$											
mean	-18	-18.0035	-18.0024	-17.7132	-17.4493	-18.0035	-18.0024	-15.4103	-15.4223	-17.5999	-17.2310
std.	-	0.1831	0.1838	0.3260	0.3568	0.1831	0.1838	0.8177	0.8364	0.3311	0.3615
bias	-	0.8119	0.8141	1.9529	3.1321	0.8119	0.8141	14.3872	14.3203	2.3740	4.2745
σ											
mean	10	9.9974	10.0029	-	-	-	-	-	-	-	-
std.	-	1.0969	1.0989	-	-	-	-	-	-	-	-
bias	-	5.5566	5.5380	-	-	-	-	-	-	-	-

Notes: The (absolute) bias is expressed in percent of the true value.

Table A2b: Monte Carlo results for predicted trade flow and welfare changes in the case of a $\sigma = 10$ and symmetric trade costs

Estimates	True	Suggested model		A-vW		BV-OLS 1		BV-OLS 2		OLS	
		uncorr.	corr.	uncorr.	corr.	uncorr.	corr.	uncorr.	corr.	uncorr.	corr.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
					10-country-world, $\sigma = 10$						
$\Delta \frac{X_{ij} y_w}{y_i y_j}$											
mean	123.3248	127.7351	127.5996	125.6036	113.0115	91.1245	90.9670	227.5535	233.1863	129.9514	116.2394
std.	469.3185	494.9210	495.4916	485.1469	432.9379	293.4474	293.1617	1128.8546	1204.7017	521.3890	453.9210
bias	-	17.5295	17.4202	15.3387	16.9658	74.4546	74.4805	214.5082	219.7298	92.7117	85.5440
EV_i											
mean	0.1390	0.1034	0.1056	0.9072	0.9780	-	-	-	-	-	-
std.	7.0641	7.0674	7.0776	15.5048	15.6467	-	-	-	-	-	-
bias	-	0.3054	0.3043	5.4158	5.6047	-	-	-	-	-	-
					20-country-world, $\sigma = 10$						
$\Delta \frac{X_{ij} y_w}{y_i y_j}$											
mean	137.9529	139.7014	139.9970	139.2621	129.7217	129.4379	129.5752	136.3740	133.9121	139.7465	125.7076
std.	509.0532	516.9189	517.5073	516.0786	476.7905	471.1198	471.2312	531.6067	509.3490	536.1079	474.6907
bias	-	11.2513	11.3483	10.0604	13.7876	80.4346	80.4387	116.1598	114.3426	79.3370	76.5853
EV_i											
mean	0.5568	0.5251	0.5120	1.6953	1.6870	-	-	-	-	-	-
std.	6.5455	7.0969	6.6141	14.3039	14.3381	-	-	-	-	-	-
bias	-	0.2931	0.2868	5.5801	5.6378	-	-	-	-	-	-
					40-country-world, $\sigma = 10$						
$\Delta \frac{X_{ij} y_w}{y_i y_j}$											
mean	192.7730	196.6792	196.5124	185.2525	177.1900	154.7657	154.7352	177.6109	177.6029	160.0134	149.9590
std.	714.2798	736.2606	735.6959	686.9376	652.4061	574.5780	574.4365	787.0798	792.4892	574.2420	532.3568
bias	-	19.2990	19.1996	11.3912	17.6107	112.1997	112.2014	146.8040	146.9326	111.2852	111.3648
EV_i											
mean	0.2995	0.1826	0.1867	1.2536	1.2613	-	-	-	-	-	-
std.	7.4031	7.6870	7.6855	16.2158	16.1786	-	-	-	-	-	-
bias	-	0.5404	0.5367	6.5144	6.5101	-	-	-	-	-	-

Notes: The bias is expressed in percentage points of the true value.

Table A3: Monte Carlo results for predicted trade flow changes due to changing trade frictions in the case of a $\sigma = 5$, $N = 3$ and no stochastic error

	Symmetric trade barriers			Asymmetric trade barriers		
Estimates	True	SBTC-AvW $\tilde{P}_i = \tilde{\Pi}_i$	ABTC-AvW $\tilde{P}_i \neq \tilde{\Pi}_i$	True	SBTC-AvW $\tilde{P}_i = \tilde{\Pi}_i$	ABTC-AvW $\tilde{P}_i \neq \tilde{\Pi}_i$
(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Model prediction: $X_{ij}Y_w/(Y_iY_j) = t_{ij}^{1-\sigma}/(P_i^{\sigma-1}\Pi_j^{\sigma-1})$					
$X_{11}Y_w/(Y_1Y_1)$	3.8093	3.8093	3.8093	4.6027	5.5712	4.6027
$X_{12}Y_w/(Y_1Y_2)$	0.7133	0.7133	0.7133	0.9171	1.4798	0.9171
$X_{13}Y_w/(Y_1Y_3)$	0.3178	0.3178	0.3178	0.0985	0.1879	0.0985
$X_{21}Y_w/(Y_2Y_1)$	0.7133	0.7133	0.7133	0.1735	0.1238	0.1735
$X_{22}Y_w/(Y_2Y_2)$	2.4692	2.4692	2.4692	1.8988	1.8060	1.8988
$X_{23}Y_w/(Y_2Y_3)$	0.1414	0.1414	0.1414	0.6547	0.7366	0.6547
$X_{31}Y_w/(Y_3Y_1)$	0.3178	0.3178	0.3178	0.5651	0.3399	0.5651
$X_{32}Y_w/(Y_3Y_2)$	0.1414	0.1414	0.1414	0.4579	0.3672	0.4579
$X_{32}Y_w/(Y_3Y_2)$	1.7640	1.7640	1.7640	1.4553	1.3803	1.4553
	Model prediction: $X_{ij}^cY_w^c/(Y_i^cY_j^c) = (t_{ij}^c)^{1-\sigma}/((P_i^c)^{\sigma-1}(\Pi_j^c)^{\sigma-1})$					
$X_{11}^cY_w^c/(Y_1^cY_1^c)$	3.1974	3.1974	3.1974	3.4995	5.2534	3.4995
$X_{12}^cY_w^c/(Y_1^cY_2^c)$	1.2224	1.2224	1.2224	0.1493	0.3268	0.1493
$X_{13}^cY_w^c/(Y_1^cY_3^c)$	0.1626	0.1626	0.1626	0.8826	1.2918	0.8826
$X_{21}^cY_w^c/(Y_2^cY_1^c)$	1.2224	1.2224	1.2224	1.2118	0.6200	1.2118
$X_{22}^cY_w^c/(Y_2^cY_2^c)$	2.1475	2.1475	2.1475	1.8135	1.3528	1.8135
$X_{23}^cY_w^c/(Y_2^cY_3^c)$	0.1783	0.1783	0.1783	0.3453	0.1723	0.3453
$X_{31}^cY_w^c/(Y_3^cY_1^c)$	0.1626	0.1626	0.1626	0.1091	0.1080	0.1091
$X_{32}^cY_w^c/(Y_3^cY_2^c)$	0.1783	0.1783	0.1783	0.6585	0.9511	0.6585
$X_{33}^cY_w^c/(Y_3^cY_3^c)$	1.8018	1.8018	1.8018	1.5112	1.4596	1.5112
	Model prediction: $(X_{ij}^cY_w^c/(Y_i^cY_j^c) - X_{ij}Y_w/(Y_iY_j))/(X_{ij}Y_w/(Y_iY_j)) \times 100$					
$\Delta X_{11}Y_w/(Y_1Y_1)$	-16.0629	-16.0629	-16.0629	-23.9679	-5.7042	-23.9679
$\Delta X_{12}Y_w/(Y_1Y_2)$	71.3850	71.3851	71.3851	-83.7187	-77.9150	-83.7187
$\Delta X_{13}Y_w/(Y_1Y_3)$	-48.8194	-48.8194	-48.8194	796.4271	587.4731	796.4271
$\Delta X_{21}Y_w/(Y_2Y_1)$	71.3850	71.3851	71.3851	598.5824	400.9362	598.5825
$\Delta X_{22}Y_w/(Y_2Y_2)$	-13.0289	-13.0289	-13.0289	-4.4933	-25.0947	-4.4933
$\Delta X_{23}Y_w/(Y_2Y_3)$	26.0804	26.0804	26.0804	-47.2567	-76.6128	-47.2567
$\Delta X_{31}Y_w/(Y_3Y_1)$	-48.8194	-48.8194	-48.8194	-80.6998	-68.2174	-80.6998
$\Delta X_{32}Y_w/(Y_3Y_2)$	26.0804	26.0804	26.0804	43.8058	159.0113	43.8058
$\Delta X_{33}Y_w/(Y_3Y_3)$	2.1438	2.1438	2.1438	3.8436	5.7435	3.8436

Notes: The model predictions are obtained in the absence of any stochastic term. To keep notation simple in the table, we suppress hat-notation to indicate estimated parameters.

Table A4a: Estimation results for the A-vW data-set

Estimates (1)	A-vW NLS (2)	Fixed Effects (3)	Suggested model (4)
Average of $P^{(1-\sigma)}$			
With border barrier (BB)			
US	0.773	0.530	0.530
	(0.015)	(0.020)	(0.020)
CA	2.451	1.787	1.787
	(0.060)	(0.062)	(0.062)
Borderless trade (NB)			
US	0.754	0.519	0.518
	(0.015)	(0.019)	(0.019)
CA	1.179	1.136	1.147
	(0.004)	(0.013)	(0.013)
Ratio (BB/NB)			
US	1.025	1.022	1.022
	(0.001)	(0.001)	(0.001)
CA	2.079	1.573	1.558
	(0.057)	(0.037)	(0.036)
Impact of border barriers on bilateral trade			
Ratio (BB/NB)			
US-US	1.050	1.044	1.045
	(0.002)	(0.002)	(0.002)
CA-CA	4.321	2.475	2.428
	(0.237)	(0.115)	(0.113)
US-CA	0.411	0.341	0.322
	(0.023)	(0.018)	(0.017)
Due to bilateral resistance			
US-US	1.000	1.000	1.000
	(0.000)	(0.000)	(0.000)
CA-CA	1.000	1.000	1.000
	(0.000)	(0.000)	(0.000)
US-CA	0.193	0.212	0.202
	(0.015)	(0.012)	(0.012)
Due to multilateral resistance			
US-US	1.050	1.044	1.045
	(0.002)	(0.002)	(0.002)
CA-CA	4.321	2.475	2.428
	(0.237)	(0.115)	(0.113)
US-CA	2.130	1.608	1.592
	(0.060)	(0.039)	(0.038)

Table A4b: Estimation results for the A-vW data-set

Estimates	A-vW NLS	Fixed Effects	Suggested model
(1)	(2)	(3)	(4)
Impact of border barriers on intranational trade relative to international trade			
Theoretically consistent estimate			
US	2.557	3.061	3.249
	(0.146)	(0.159)	(0.162)
CA	10.524	7.258	7.551
	(1.048)	(0.526)	(0.520)
McCallum parameter implied by theory			
US	1.635	1.398	1.469
	(0.103)	(0.074)	(0.074)
CA	16.455	15.899	16.705
	(1.485)	(1.042)	(1.042)