Structural Estimation of Gravity Models with Market Entry Dynamics

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Abstract

This paper develops a structural empirical general equilibrium model with path dependence of the role of fixed costs of bilateral market entry for the aggregate extensive margin of bilateral trade. This leads to path dependence of that margin. We embed the theoretical model into a dynamic stochastic model of bilateral selection into import markets and apply it to a data-set of aggregate bilateral exports among 171 countries over the period 1992-2004. In particular, we disentangle the role of changes in trade costs, in labor endowments, and in total factor productivity for trade, bilateral market entry, numbers of firms active, and welfare.

Keywords: Bilateral trade flows; Gravity equation; Dynamic random effects model; Sample selection

JEL codes: R11; C31; O47

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1 Introduction

Whether two countries trade with each other in a given year or not – referred to as an *extensive margin of bilateral trade* – can be explained with great success in terms of a function of whether they did so in prior periods or not. For a cross section of the major 171 countries in terms of their GDP over the time period 1992-2004, Table 1 suggests that 44% of the country-pairs display bilateral exports when they did so 3 years prior to that, 41% do not report exports when they did not have any exports 3 years prior to that, and 16% change their activity within 3 years on average. Moreover, 21% of the country-pairs display bilateral exports in 2004 and they did so in 1992, 36% do not report exports in 2004 and they did not have any exports in 1992, and 44% change their activity from 1992 to 2004. There is a strong role for persistence to play both unconditional and, in qualitative terms, conditional on exogenous determinants of the extensive margin of trade.

This paper delivers a structural empirical model which is capable of analyzing both the *extensive* and the *intensive margin* of aggregate bilateral goods trade with a path-dependent extensive margin of trade (e.g., due to learning of firms about fixed market entry costs). In particular, the work by Evenett and Venables (2002), Albornoz, Calvo Pardo, Corcos, and Ornelas (2010), and others points to such path dependence at the extensive margin of trade. The model we propose is based on a dynamic model for bilateral selection-into-import-markets and a demand equation for bilateral goods exports which are interrelated through deterministic and stochastic data-generating processes. This model fully respects general equilibrium constraints at both margins of trade and, unlike earlier work, pursues iterated estimation of a general-equilibrium-consistent panel data model with dynamic selection into import markets.

– Table 1 –

By virtue of the chosen approach, the paper stands on the shoulders of previous research on structural modeling of bilateral trade flows. With the seminal papers of Eaton and Kortum (2002), Anderson and van Wincoop (2003), and Helpman, Melitz, and Rubinstein (2008), it became possible to to infer empirically comparative static effects of determinants of bilateral trade flows which are consistent with general equilibrium, taking into account repercussions of changes of exogenous drivers of trade on endogenous product and, eventually, factor prices. Beyond earlier work, the structural models of Eaton and Kortum (2002) and Helpman, Melitz, and Rubinstein (2008) can explain zero trade flows and, hence, deliver answers to the question as to which extent trade responds to changes in fundamental variables through the *extensive* versus the *intensive* margins of bilateral trade.[1]

A salient feature of the aforementioned general equilibrium models is that they are designed for empirical cross section analysis. Hence, they do not distinguish between short-run and long-run responses of outcome to changes in fundamental variables. In principal, it is of course possible with such models to simply index endogenous and exogenous variables by time and analyze empirically a series of cross sections. Yet, there is no salient role for history to play in the sense that, conditional on the contemporaneous exogenous variables, those cross sections would be independent of each other. Hence, such theoretical work suggests that the analysis of time series data on bilateral trade matrices can be performed for each period separately without any loss of insight.

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[1]This paper is mostly concerned with dynamic entry of markets at the aggregate bilateral level. Hence, it is only loosely related to recent work on the (static) determinants and effects of growth of product variety in new trade theory models along the lines of Broda and Weinstein (2006) and Feenstra and Kee (2008).

In line with recent structural empirical work on aggregate bilateral trade flows, we model nominal bilateral goods trade as a function of an exporting country's supply potential, an importing country's demand potential, and trade barriers. In line with Melitz (2003), Chaney (2005), or Helpman, Melitz, and Rubinstein (2008), the latter contain elements which are tied to the quantity of goods shipped (*variable trade costs*) and ones that entail fixed import market access costs (*fixed trade costs*). Apart from contemporaneous fundamentals, we allow the extensive margin of bilateral trade to depend on bilateral export status prior to a given point in time. For instance, this is consistent with a firms' learning about fixed market access costs for a given importing country. This leads to a dynamic model of import market selection which is stochastically related to export demand.

We formulate a deterministic and a stochastic version of that model and apply it to data on bilateral aggregate trade flows of the aforementioned 171 countries in three-year intervals between 1992 and 2004. We ask the question about the main drivers of world trade for that period, which in the context of the model are (fixed and variable) trade costs, labor endowments, and total factor productivity.[2] In particular, we shed light on the short-run and the long-run responses – and hence, of path-dependence – of trade in general equilibrium to the changes of these fundamentals. We do so in a fully nonlinear model as well as linearized versions which represent generalizations of the framework of Baier and Bergstrand (2009) for the case of zero trade

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[2]In a different context, Baier and Bergstrand (2001) have asked a similar question in a non-structural model with tariffs, non-tariff trade costs, and GDP growth as the main drivers of trade in a static model. They found that 67% of total growth of trade flows for 16 OECD countries over 1958-1960 and 1986-1988 could be explained by GDP growth, 26% by tariff reductions, and 8% by changes in non-tariff trade costs. Hence, the lion's share is attributed to GDP growth, the latter being exogenous there but endogenous in general equilibrium models of trade and itself a function of tariffs and trade costs among other factors (such as total factor productivity and factor endowments).

flows. Our findings suggest that the average three-year change in (fixed and variable) trade costs – a reduction thereof – per country-pair between 1992 and 2004 triggered positive short-run and long-run effects on nominal bilateral exports. Similarly, the increases in labor endowments and total factor productivity raised bilateral exports in the short run and the long run, respectively.

The remainder of the paper is organized as follows. The next section formulates a parsimonious endowment model with import market entry dynamics. While we chose an endowment model à la Anderson (1979), such a model could easily be cast in the context of theoretical models à la Krugman (1979), Eaton and Kortum (2002), or Helpman, Melitz, and Rubinstein (2008). Section 3 embeds this model in a stochastic framework for dynamic selection into import markets and aggregate export demand. Also, that section provides details about the implementation of such a model for parameter estimation and comparative static analysis. Section 4 describes features of the data-set of 171 countries and three-year intervals for 1992-2004 we apply this model to, and it summarizes estimation results. Section 5 describes the findings about the short-run (three-year) and long-run (thirty-year) comparative static effects of changes in drivers of trade flows as observed over the period 1992-2004. The last section concludes with a summary of the most important findings.

2 An aggregate gravity equation with entry dynamics – theory

Consider a world with J countries indexed by $j = 1, ..., J$ and consumers with a love for variety for goods consumption in a single sector à la Dixit

and Stiglitz (1977). It will be useful to introduce a time index and set out that model for two periods, say t and $t-1$. It will suffice to focus mostly on the exposition of the model for period t, but, as will become clear below, the equilibrium in t will depend on the export status (of firms) of country i with j in period $t-1$. Let us assume that all varieties in country i and period t are produced by using one factor of production, labor, at unit input costs of $w_{it}a_{it}$, where w_{it} denotes the wage rate and a_{it} the corresponding input coefficient. Then, monopolistic competition and non-segmentation of consumer markets by firms implies mark-up pricing with mill price[3]

$$p_{it} = \tfrac{\sigma}{\sigma-1} w_{it}a_{it}. \tag{1}$$

An important consequence of the assumption of homogeneous technologies within countries is that, through (1), all firms in country i – of which there is a mass n_{it} in period t – behave in the same way so that we can write utility-maximizing demand in j per i-borne variety in period t, c_{ijt} and the price index for the consumer basket in j and year t, P_{jt}, respectively, as

$$c_{ijt} = \frac{\widehat{p}_{ijt}^{-\sigma}}{P_{jt}^{1-\sigma}} Y_{jt}, \quad P_{jt}^{1-\sigma} = \sum_{i=1}^{J} n_{it}\widehat{p}_{ijt}^{1-\sigma} V_{ijt}, \tag{2}$$

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[3]Notice that the chosen approach follows closely Krugman's (1979) and Redding and Venables' (2004) framework. Alternatively, one could allow for heterogeneous firms by assuming a fixed distribution of total factor productivity as in Melitz (2003) or Helpman, Melitz, and Rubinstein (2008). The latter approach would support comparative static results for trade costs which run through an additional channel, namely adjustment of the import market-specific lower cutoff level of productivity of active producers. While the latter may be important to consider for an analysis at the level of firms or individual sectors (see Das, Roberts, and Tybout, 2007; Kee and Krishna, 2008; Cherkashin, Demidova, Kee, and Krishna, 2009; for examples), selection-induced productivity effects tend to be negligible in estimated general equilibrium models at the aggregate (country) level (see Egger, Larch, Staub, and Winkelmann, 2009). Therefore, we suppress the less parsimonious outline for a model with heterogeneous firms, here.

where $\sigma > 1$ is the (time-invariant) elasticity of substitution between varieties, $\widehat{p}_{ijt} \geq p_{it}$ is the consumer price per unit of c_{ijt}, $\widehat{Y}_{jt}$ is income (GDP) in country j in that period, and V_{ijt} is an indicator variable which takes the value 1, if i-borne varieties are sold at market j in t and zero otherwise.

Each variety is assumed to be internationally tradable, but importing is subject to variable transportation costs. Hence, with variable iceberg-type trade costs for shipping goods from i to j in period t of $\tau_{ijt} - 1 \geq 0$, $\widehat{p}_{ijt} = p_{it}\tau_{ijt}$. Moreover, we follow Melitz (2003) and Helpman, Melitz, and Rubinstein (2008) in assuming that a firm's profits are additively separable into import market specific profits. Accessing a particular import market j for i-borne firms in period t is associated with fixed sunk costs (incurred in the first year of entry of that import market) plus fixed period-specific costs.

Suppose i-borne firms did not deliver goods to market j in period $t-1$ but they start doing so in period t. Let us denote the sum of set-up and maintenance fixed costs per i-borne firm for serving market j for the first time in t by $w_{it}f_{ijt}$, where f_{ijt} measures the units of labor used for set-up and maintenance.[4] To capture dynamics through, e.g., learning about market fixed costs, in a very parsimonious way, assume that prior exporting (in $t-1$) of any i-borne firms to that market results in proportionately lower fixed costs of $w_{it}f_{ijt}e^{-\delta}$ with $\delta \geq 1$. Then, fixed costs of i-borne firms from serving market j in year t may be written as $e^{-\delta V_{ij,t-1}}$, where $V_{ij,t-1} = 1$ if market j had been served by i-borne firms in the previous period and zero else. The fixed costs are assumed to be proportional to and depend on $w_{it}f_{ijt}$. Most importantly, the presence of $e^{-\delta V_{ij,t-1}}$ in the fixed costs entails

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[4]To avoid complicated dynamics at the firm level which are not observable in aggregate data for multiple countries, we assume that each firm lives one period only (see Cherkashin, Demidova, Kee, and Krishna, 2009, for a similar assumption). However, there is a dynamic process of aggregate market entry in each period accruing to new firms' inheritance of public knowledge about exports markets from previous periods by previous exporters.

state-dependence in export status at the country-pair level.

In equilibrium, bilateral shipments per variety, x_{ijt}, equal τ_{ijt} times bilateral demand per variety, c_{ijt}, for positive exports so that per-firm real shipments and aggregate exports at market prices including cost, insurance, and freight (cif), respectively, are determined as[5]

$$x_{ijt} = \tau_{ijt}c_{ijt} = \frac{p_{it}^{-\sigma}\tau_{ijt}^{1-\sigma}}{P_{jt}^{1-\sigma}}Y_{jt}V_{ijt}, \tag{3}$$

$$X_{ijt} \equiv n_{it}p_{it}x_{ijt} = n_{it}\left(\frac{p_{it}^{1-\sigma}\tau_{ijt}^{1-\sigma}}{P_{jt}^{1-\sigma}}\right)Y_{jt}V_{ijt}. \tag{4}$$

We assume that production in i and set-up of business relationships with consumers in market j only require a single factor in i and t, labor, whose aggregate endowment we denote by L_{it}. Assuming full employment, the labor constraint consistent reads

$$L_{it} = n_{it}\sum_{j=1}^{J}V_{ijt}\left(a_{it}x_{ijt} + e^{-\delta V_{ij,t-1}}f_{ijt}\right), \tag{5}$$

where $\sum_{j=1}^{J}V_{ijt}\left(a_{it}x_{ijt}\right) = a_{it}\sum_{j=1}^{J}x_{ijt}$ is the amount of labor used for production, and $\sum_{j=1}^{J}\left(V_{ijt}e^{-\delta V_{ij,t-1}}f_{ijt}\right)$ is the amount of labor used for set-up of business contacts in $\sum_{j=1}^{J}V_{ijt} \leq J$ markets.

Market j-specific profits of i-borne firms in period t are given by

$$\pi_{ijt} = \frac{w_{it}a_{it}x_{ijt}}{\sigma} - w_{it}f_{ijt}e^{-\delta V_{ij,t-1}}, \tag{6}$$

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[5]As long as $\tau_{ijt}^{1-\sigma}$ is of an iceberg-type and only based on non-tariff measures, the distinction between aggregate nominal exports at cif (i.e., gross of tariffs) and ones measured at free on board (fob; i.e., net of tariffs) is irrelevant in a model as ours. However, outlining the model for aggregate outcomes at cif with tariffs among non-tariff factors behind $\tau_{ijt}^{1-\sigma}$ reduces the notation significantly.

where $V_{ij,t-1} = 1$ if $i = j$.[6] For domestic sales, $\pi_{iit} = \frac{w_{it}a_{it}x_{iit}}{\sigma} - w_{it}f_{iit}$.

The requirement of non-negative profits in (6) for exports per firm from i to j in period t suggests that positive exports at free market entry require $x_{ijt}^* = \frac{f_{ijt}e^{-\delta V_{ij,t-1}}}{a_{it}}(\sigma - 1)$. Hence, i-borne firms will only start exporting to j in t, if $\tau_{ijt}c_{ijt} \geq \frac{f_{ijt}}{a_{it}}(\sigma - 1)$ and, in case of prior exports between i and j, they will only continue exporting, if $\tau_{ijt}c_{ijt} \geq \frac{f_{ijt}e^{-\delta}}{a_{it}}(\sigma - 1)$. No matter of whether they start or continue exporting in t, an i-borne firm's exports to j in t are at free entry determined by x_{ijt}^*. In equilibrium, usage of x_{ijt}^* in (5) determines the number of firms active in country i at time t as

$$n_{it} = \frac{L_{it}}{\sigma \sum_{j=1}^{J} V_{ijt}e^{-\delta V_{ij,t-1}}f_{ijt}}. \tag{7}$$

Since market j is only served in t by i-borne firms if this is profitable, we may introduce a latent variable which is proportional to the associated net profits. For this, multiply (6) by n_{it} to obtain for aggregate profits $\frac{n_{it}p_{it}x_{ijt}}{\sigma} - n_{it}w_{it}f_{ijt}e^{-\delta V_{ij,t-1}} \geq 0$. We may now introduce a latent variable V_{ijt}^* which reflects aggregate potentially realizable profits of firms in i for serving consumers in j in period t as

$$V_{ijt}^* = \frac{n_{it}p_{it}x_{ijt}}{\sigma w_{it}f_{ijt}e^{-\delta V_{ij,t-1}}} \geq 1, \quad \text{or} \tag{8}$$

$$\widetilde{V}_{ijt}^* \equiv \frac{V_{ijt}^*}{V_{iit}^*} = \frac{\tau_{ijt}^{1-\sigma}}{\tau_{iit}^{1-\sigma}} \frac{m_{jt}}{m_{it}} \frac{f_{iit}}{e^{-\delta V_{ij,t-1}}f_{ijt}} \geq 1. \tag{9}$$

Since $V_{iit}^* \geq 1$ by both assumption and observation (consumption from domestic producers is generally positive at the aggregate level), both V_{ijt}^* and

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[6]Hence, we assume that f_{iit} is small enough to ensure that active firms always serve consumers at least in the country they produce in at any period t.

$\widetilde{V}_{ijt}^*$ generate the same indicator variable V_{ijt} according to

$$V_{ijt} = \begin{cases} 1 & if \quad \ln \widetilde{V}_{ijt}^* \geq 0 \\ 0 & else. \end{cases} \tag{10}$$

In general equilibrium, total sales to all markets gross of ad-valorem tariffs charged by importers (referred to as including cost, insurance and, freight; cif) add up to GDP so that

$$Y_{it} = \sum_{h=1}^{J} X_{iht} = n_{it}p_{it}^{1-\sigma} \sum_{h=1}^{J} \left[V_{iht} \left(\frac{\tau_{iht}}{P_{ht}} \right)^{1-\sigma} Y_{ht} \right]$$

or, after defining $Y_t \equiv \sum_{h=1}^{J} Y_{ht}$, $\theta_{it} \equiv Y_{it}/Y_t$, and $\Pi_{it}^{1-\sigma} = \sum_{h=1}^{J} V_{iht} \left(\frac{\tau_{iht}}{P_{ht}} \right)^{1-\sigma} \theta_{ht}$, as in Anderson and van Wincoop (2003) and Anderson (2010), we obtain

$$Y_{it} = n_{it}p_{it}^{1-\sigma} Y_t \Pi_{it}^{1-\sigma} \Rightarrow n_{it}p_{it}^{1-\sigma} = \theta_{it}\Pi_{it}^{\sigma-1}. \tag{11}$$

The latter expressions illustrate that the adopted version of a Dixit and Stiglitz (1977) or Krugman (1979) model is isomorphic to the one of Anderson and van Wincoop (2003). Replacing $n_{it}p_{it}^{1-\sigma}$ by the expression in (11) and Y_{jt} by $Y_t\theta_{jt}$ in (4) and recalling the definition of $P_{jt}^{1-\sigma}$ from (2), the generalized system of trade resistance equations à la Anderson and van Wincoop (2003) with possible zero trade flows is then given by

$$\Pi_{it}^{1-\sigma} = \sum_{h=1}^{J} V_{iht}\tau_{iht}^{1-\sigma}b_{iht}^{1-\sigma}P_{ht}^{\sigma-1}\theta_{ht}, \quad P_{jt}^{1-\sigma} = \sum_{h=1}^{J} V_{hjt}\tau_{hjt}^{1-\sigma}b_{hjt}^{1-\sigma}\Pi_{ht}^{\sigma-1}\theta_h. \tag{12}$$

After defining $\mu_{it} \equiv \theta_{it}\Pi_{it}^{\sigma-1}$ and $m_{jt} \equiv \theta_{jt}P_{jt}^{\sigma-1}$, we can rewrite aggregate

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nominal exports at cif from i to j in t as

$$X_{ijt} = Y_t \tau_{ijt}^{1-\sigma} V_{ijt} \mu_{it} m_{jt}, \quad \text{with} \tag{13}$$

$$\theta_{it} = \mu_{it} \sum_{h=1}^{J} V_{iht} \tau_{iht}^{1-\sigma} m_{ht}, \quad \theta_{jt} = m_{jt} \sum_{h=1}^{J} V_{hjt} \tau_{hjt}^{1-\sigma} \mu_{ht}. \tag{14}$$

3 From theory to an empirical model: Implementation and estimation

To derive an econometric specification of the above gravity model with panel data, it is useful to allow time indices to be $t = 1, ..., T$. Furthermore, we need to specify the stochastic processes that arise from measurement error about or random shocks on exports. Finally, we ought to comment on some issues with the implementation of the model.

3.1 Adding a stochastic process

Let us take logs of the gravity equation in (13) and add a log-additive stochastic term $u_{X,ijt}$ to obtain

$$\ln X_{ijt}^{fob} = \begin{cases} \ln Y_t + \ln \tau_{ijt}^{1-\sigma} + \ln m_{it} + \ln \mu_{jt} + u_{X,ijt} & \text{if } \widetilde{V}_{ijt} = 1 \\ \text{unobserved} & \text{if } \widetilde{V}_{ijt} = 0 \end{cases}, \tag{15}$$

where $u_{X,ijt}$ is the stochastic disturbance term. The trade resistance terms $\ln \mu_{it}$ and $\ln m_{jt}$ are determined as implicit solutions to the system of $2J$ equations (14) in $2J$ unknowns μ_{it} and m_{jt} for each period t following from the requirement of multilaterally balanced trade for each economy.

The unobserved latent variable for the propensity to export from i to j in year t is based on (9) is log-transformed and augmented additively by the

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stochastic $u_{V,ijt}$ term so that it can be written as

$$\ln \widetilde{V}^*_{ijt} = \ln \frac{\tau^{1-\sigma}_{ijt}}{\tau^{1-\sigma}_{iit}} + \ln \frac{m_{jt}}{m_{it}} + \delta V_{ij,-1} + \ln \frac{f_{iit}}{f_{ijt}} + u_{V,ijt}, \quad \text{with} \quad (16)$$

$$V_{ijt} = 1[\ln \widetilde{V}^*_{ijt} \geq 0]. \quad (17)$$

We will talk about the assumptions regarding $u_{X,ijt}$ and $u_{V,ijt}$ in the next subsection. With respect to variable trade costs and fixed import market access costs, our specification follows the literature (see, e.g., Helpman, Melitz, and Rubinstein, 2008) assuming

$$\ln \tau^{1-\sigma}_{ijt} = \sum_{k=1}^{K} \alpha_k \ln \zeta_{k,ijt}, \quad \ln f_{ijt} = \sum_{l=1}^{L} \beta_l \ln \chi_{l,ijt}, \quad (18)$$

where $\zeta_{k,ijt}$ and $\chi_{l,ijt}$ are variables related to variable and fixed trade costs, respectively. In practice, K may equal L and all factors determining $\ln \tau^{1-\sigma}_{ijt}$ may also affect $\ln f_{ijt}$. As long as the parameters α_k differ from the respective β_l, $\ln \tau^{1-\sigma}_{ijt}$ may still differ from $\ln f_{ijt}$. However, there is no requirement for these terms to differ at all.

Obviously, even in the absence of zero trade flows (i.e., $V_{ijt} = 1$ for all ijt) and at known σ, Y_{it}, $\tau^{1-\sigma}_{ijt}$, the system in equation (14) could only be solved numerically. For that case, Baier and Bergstrand (2009) derived a linear approximation which is based on the first step of a Gauss-Newton iteration of the solution to the system of trade resistance equations (14). We generalize this procedure here for the case of some zero trade flows and provide a detailed derivation in Appendix 1. Using the approximated solutions for the multilateral resistance terms with zero trade flows, the econometric specification of the approximated model à la Baier and Bergstrand (2009) is

based on

$$
\begin{aligned}
\ln \widetilde{X}_{ijt} &= \ln X_{ijt} - \ln Y_{it} - \ln Y_{jt} - \ln Y_t - d_{X,ijt} \\
&\approx \begin{cases} \ln \tau_{ijt}^{1-\sigma} + \ln \left(\Pi_{it}^{\sigma-1} \right)^* + \ln \left(P_{jt}^{\sigma-1} \right)^* + u_{X,ijt} & \text{if } V_{ijt} = 1 \\ 0 & \text{if } V_{ijt} = 0 \end{cases}
\end{aligned} \tag{19}
$$

where expressions for the approximated trade resistance terms $\ln \left(\Pi_{it}^{\sigma-1} \right)^*$, $\ln \left(P_{jt}^{\sigma-1} \right)^*$, and $d_{X,ijt}$ are derived in Appendix 1. $d_{X,ijt}$ is a correction term that comes in because in general $\sum_{h=1}^{J} V_{h1t} \theta_{ht} \neq 1$ in the presence of zero trade flows. Even more importantly, with some zero trade flows, the first-order approximation does not result in the simple approximation of $\ln \tau_{ijt}^{1-\sigma} + \ln \Pi_{it}^{\sigma-1} + \ln P_{jt}^{\sigma-1}$ as derived in Baier and Bergstrand (2009). Hence, a potentially important insight from this paper is that the computational gain from linearly approximating the non-linear model vis-à-vis the non-linear iterative estimator is marginal with some zero trade flows.[7] The approximated selection equation then reads

$$
\begin{aligned}
V_{ijt} &= 1[\ln \widetilde{\widetilde{V}}_{ijt}^* \geq 0], \tag{20} \\
\ln \widetilde{\widetilde{V}}_{ijt}^* &= \frac{\tau_{ijt}^{1-\sigma}}{\tau_{iit}^{1-\sigma}} + \left(\ln \frac{\theta_{jt}}{\theta_{it}} + d_{V,ijt} \right) \\
&\quad + \ln \frac{\left(P_{jt}^{\sigma-1} \right)^*}{\left(P_{it}^{\sigma-1} \right)^*} + \delta V_{ij,t-1} + \ln \frac{f_{iit}}{f_{ijt}} + u_{V,ijt} \tag{21}
\end{aligned}
$$

where $d_{V,ijt}$ is another correction factor which is derived in Appendix 1 along with solutions for $\ln \left(\Pi_{it}^{\sigma-1} \right)^*$ and $\ln \left(P_{jt}^{\sigma-1} \right)^*$. Notice that we fully respect cross-equation restrictions of parameters in the empirical models (15)-(17)

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[7]To see this, consider the fact that the approximation of the multilateral resistance terms $\ln \left(\Pi_{it}^{\sigma-1} \right)^* + \ln \left(P_{jt}^{\sigma-1} \right)^*$ in Appendix 1 is based on elements of a relatively complicated inverse matrix.

as well as the corresponding approximation in (19)-(21).[8]

3.2 Specification of the stochastic process and estimation

The actual implementation of the above model rests upon the equations (15)-(17) or, when resorting to linear approximation, upon the equations (19)-(21). Notice that export status at the country-pair level, V_{ijt}, is observed at any point in time t, but the underlying latent processes $\ln \widetilde{V}_{ijt}^*$ or $\ln \widetilde{\widetilde{V}}_{ijt}^*$ are not. The latter latent variables measure the net log benefits from exporting at all from i to j at time t. Hence, V_{ijt} measures and $\widetilde{V}_{ijt}^*$ determines what we may refer to as the *extensive margin* of exports at the aggregate country-pair level. The variable $\ln X_{ijt}$ is only observed if $\ln \widetilde{V}_{ijt}^* > 0$ and operating profits earned in country j are large enough to cover the fixed exporting (or import market access) costs.

The disturbances $u_{V,ijt}$ and $u_{X,ijt}$ in the models of $\widetilde{V}_{ijt}^*$ in (16) and $\ln X_{ijt}$ in (15), respectively, are specified as

$$u_{V,ijt} = \eta_{V,ij} + \lambda_{V0} V_{ij,0} + \varepsilon_{V,ijt} \tag{22}$$

$$u_{X,ijt} = \eta_{X,ij} + \varepsilon_{X,ijt}, \tag{23}$$

where $\eta_{V,ij}$ and $\eta_{X,ij}$ are time-invariant, country-pair-specific effects that are assumed to be uncorrelated with the other determinants of $\widetilde{V}_{ijt}^*$ (including $V_{ij,0}$) and of $\ln X_{ijt}$, respectively. $\eta_{V,ij}$ and $\eta_{X,ij}$ are identically and independently distributed normal random effects which may be correlated with each other, and λ_{V0} captures the (time-invariant) initial conditions, which are in-

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[8]If the corresponding restrictions are not imposed, the comparative static results are, in fact, not interpretable and inconsistent with general equilibrium in the underlying theoretical model.

cluded to acknowledge the market entry dynamics introduced before. Moreover, $\varepsilon_{V,ijt}$ and $\varepsilon_{X,ijt}$ are identically and independently distributed normal disturbances which may be correlated with each other but are independent of $\eta_{V,ij}$ and $\eta_{X,ij}$ and the other determinants of $\widetilde{V}_{ijt}^*$ (including $V_{ij,0}$) and of $\ln X_{ijt}$.[9]

Regarding the distribution of the disturbances, we assume specifically that $(\eta_{V,ij}, \eta_{X,ij}) \sim i.i.d.N(\mathbf{0}, \mathbf{V}_\eta)$ and $(\varepsilon_{V,ijt}, \varepsilon_{X,ijt}) \sim i.i.d.N(\mathbf{0}, \mathbf{V}_\varepsilon)$, where

$$
\mathbf{V}_\eta = \begin{bmatrix} \sigma_{V,\eta}^2 & \rho_\eta \\ \rho_\eta & \sigma_{X,\eta}^2 \end{bmatrix}, \quad \mathbf{V}_\varepsilon = \begin{bmatrix} 1 & \rho_\varepsilon \\ \rho_\varepsilon & \sigma_{X,\varepsilon}^2 \end{bmatrix}.
$$

Since the variance of the remainder disturbances is not identified, we normalized it to unity without loss of generality (see the upper left cell of $\mathbf{V}_\varepsilon$). In that model, $\rho_\eta \neq 0$ and/or $\rho_\varepsilon \neq 0$ implies selection into export status, so that the stochastic process may be termed a generalized random effects sample selection model which allows for (export) state dependence.

For the sake of simplicity of the notation, let us collect the determinants of the indicator function V_{ijt} (the *extensive margin* of aggregate bilateral exports) and of continuous $\ln X_{ijt}$ (the *intensive margin* of aggregate bilateral

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[9]In principal, it would be possible to allow not only $u_{V,ijt}$ (as we do) but even $\eta_{V,ij}$ to be correlated with some of the determinants of $\widetilde{V}_{ijt}^*$ and $\eta_{X,ij}$ with some of the determinants of $\ln X_{ijt}$. For instance, one could follow the so-called Mundlak-Chamberlain-Wooldridge device and include means of all determinants of $\widetilde{V}_{ijt}^*$ and $\ln X_{ijt}$ in the respective equations across time in addition to the original variables in the model. However, this requires enough time variation in the data and that approach is infeasible with numerous time-invariant variables (such as bilateral distance or common borders, etc.) whose coefficients estimates are vital to the comparative statics of the model. Accordingly, we have to resort to the somewhat stronger assumption of $\eta_{V,ij}$ and $\eta_{X,ij}$ as well as $\varepsilon_{V,ijt}$ and $\varepsilon_{X,ijt}$ to be generally uncorrelated with other determinants of the extensive and the intensive margin of exports. Moreover, the findings of Baier and Bergstrand (2007) suggest that, e.g., the endogeneity of trade regionalism is much less an issue in panel data models than in cross section models.

exports) for observation ijt into the following vectors

$$
\begin{aligned}
\mathbf{w}_{V,ijt} &= \left[\ln \frac{\zeta_{1,ijt}}{\zeta_{1,iit}}, ..., \ln \frac{\zeta_{K,ijt}}{\zeta_{K,iit}}, \ln \frac{m_{jt}}{m_{it}}, V_{ij,t-1}, \ln \chi_{1,ijt}, ..., \ln \chi_{L,ijt}, V_{ij,0}, 1 \right] \\
\mathbf{w}_{X,ijt} &= [\zeta_{1,ijt}, ..., \ln \zeta_{K,ijt}, \ln \mu_{it}, \ln m_{jt}, Y_t, 1],
\end{aligned}
$$

where $V_{ij,0}$ is included by following Wooldridge (2005) in $\mathbf{w}_{V,ijt}$ to model the initial condition of the dynamic process for the extensive margin (selection into import markets), and a constant is included at the end of both $\mathbf{w}_{V,ijt}$ and $\mathbf{w}_{X,ijt}$ for proper centering of the data. Taking into account the parametrization in (18), the parameter vectors corresponding to $\mathbf{w}_{V,ijt}$ and $\mathbf{w}_{X,ijt}$, respectively, are

$$
\begin{aligned}
\beta_V &= [\alpha_1, ..., \alpha_K, 1, \delta, \beta_1, ..., \beta_L, \lambda_{V0}, \beta_0] &&(24) \\
\beta_X &= [\alpha_1, ..., \alpha_K, 1, 1, 1, \alpha_0], &&(25)
\end{aligned}
$$

where β_0 and α_0 are the coefficients of the constants in the two models. Notice that, for comparative static analysis, the coefficients on $\ln \frac{\zeta_{1,ijt}}{\zeta_{1,iit}}, ..., \ln \frac{\zeta_{K,ijt}}{\zeta_{K,iit}}$ in the specification of the latent process (16) underlying the extensive margin of aggregate bilateral trade have to equal the ones on $\zeta_{1,ijt}, ..., \ln \zeta_{K,ijt}$ in the specification of the intensive margin of exports (15). Moreover, general-equilibrium-consistent comparative static analysis requires that the coefficients on $\frac{m_{jt}}{m_{it}}$ in (16) as well as the ones on $\ln \mu_{it}$, $\ln m_{jt}$, and Y_t in (15) are unity each. Similar restrictions apply for the linearly approximated model akin to Baier and Bergstrand (2009).

Then, we can write the models to be estimated as follows:

$$V_{ijt} = 1[\ln \widetilde{V}_{ijt}^* = \mathbf{w}_{V,ijt}\beta_V + \eta_{Vij} + \varepsilon_{V,ijt} > 0] \qquad (26)$$

$$= 1[A_{ijt} + \eta_{Vij} + \varepsilon_{V,ijt} > 0]$$

$$\ln X_{ijt} = \mathbf{w}_{X,ijt}\beta_X + \eta_{Xij} + \varepsilon_{X,ijt} \qquad (27)$$

$$= B_{ijt} + \eta_{Xij} + \varepsilon_{X,ijt}$$

Recently, Raymond, Mohnen, Palm and Schim van der Loeff (2007a,b) analyzed such models which allow to test and correct for sample selection in a dynamic model.[10] Following Wooldridge (2005) and Raymond, Mohnen, Palm, and Schim van der Loeff (2007a,b), we specify the likelihood of country-pair ij, starting in $t = 1$ conditional on the regressors in $\mathbf{w}_{V,ijt}$ (including the initial conditions) and $\mathbf{w}_{X,ijt}$ and integrate out the country-pair-specific random effects $\eta_{V,ij}$ and $\eta_{X,ij}$ as

$$\mathcal{L}_{ij} = \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} \Pi_{t=1}^T L_{ijt}\phi(\eta_{V,ij}, \eta_{X,ij})d\eta_{V,ij}d\eta_{X,ij}, \qquad (28)$$

$$L_{ijt} = \Pi_{t=1}^T \left\{ \Phi\left(-A_{ijt} - \eta_{V,ij}\right)^{1-V_{ijt}} \left[\frac{1}{\sigma_{X,\varepsilon}}\phi\left(\frac{\ln X_{ijt} - B_{ijt} - \eta_{X,ij}}{\sigma_{X,\varepsilon}}\right) \times \right. \right.$$
$$\left. \left. \Phi\left(\frac{A_{it} + \eta_{V,ij} + \frac{\rho_\varepsilon}{\sigma_{X,\varepsilon}}\left(\ln X_{ijt} - B_{ijt} - \eta_{X,ij}\right)}{\sqrt{1-\rho_\varepsilon}}\right) \right]^{V_{ijt}} \right\}, \qquad (29)$$

where $\phi(\eta_{V,ij}, \eta_{X,ij})$ denotes the density of the bivariate normal of the random country-pair effects as defined above, and $\Phi(\cdot)$ and $\phi(\cdot)$ in the expression for L_{ijt} denote the cumulative distribution function and the density, respectively,

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[10]In contrast to previous sample selection models for panel data (e.g., Wooldridge, 1995), this model permits accounting for state dependence in the selection equation for the extensive margin of exports. In contrast to earlier work on endogenous selection into exporting and the problem of zeros in trade matrices, this model is applicable with panel data and allows entertaining the time variation in trade with path dependence at the extensive margin data.

of the univariate normal distribution.

The likelihood in (28)-(29) can be numerically maximized to estimate the model parameters – namely the elements in $\mathbf{w}_{V,ijt}$ and $\mathbf{w}_{X,ijt}$ as well as those in $\mathbf{V}_\eta$ and $\mathbf{V}_\varepsilon$ – using a two-step Gauss-Hermite quadrature for integrating out the random country-pair effects (see Appendix 4 for details). For this, one chooses a (not too large) number of sample points. The procedure is computationally demanding, since, with a bivariate normal, the number of sample points implies a number of evaluation points of that number squared. We use seven sample points of the Hermite polynomial and a weight for each of them to approximate the density of the bivariate normal distribution in the likelihood function (see Appendix 4 for further details).[11]

Since (5) for observation ijt depends on $\ln\mu_{it}$, $\ln m_{it}$, and $\ln m_{jt}$ which themselves depend on the estimated model parameter estimates, we pursue an iterative approach to parameter estimation and solving for $\ln\mu_{it}$, $\ln m_{it}$, and, $\ln m_{jt}$ for all ijt. Hence, at each iteration point of the likelihood optimization, the multilateral resistance terms are solved iteratively. More precisely, we use starting values of θ_{it}, $\ln\mu_{it}$, $\ln m_{it}$ for all it and jt in Step 1 and optimize (28) to obtain estimates of the elements of β_V and β_X as well as those of $\mathbf{V}_\eta$ and $\mathbf{V}_\varepsilon$. Then, we solve for all $\ln\mu_{it}$ and $\ln m_{it}$ from the $2JT$ equations in (14) through nonlinear least squares in Step 2. With the new values for all $\ln\mu_{it}$ and $\ln m_{it}$ at hand, one obtains new values of the latent variable $\ln\widetilde{V}_{ijt}^*$, etc. We iterate Steps 1 and 2 until convergence to obtain theory-consistent parameter estimates from maximum likelihood estimation.[12] With the chosen grid of 49 evaluation points (based on seven

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[11]Hence, with seven sample points and a bivariate normal, there are 49 points at which the likelihood has to be evaluated iteratively.

[12]As an alternative, we generalize the approach of Baier and Bergstrand (2009) to linearize the system of equations of multilateral resistance terms $\ln\Pi_{it}^{\sigma-1}$ and $\ln P_{it}^{\sigma-1}$ to the case with zero trade flows (see Appendix 2). Then, we employ three versions of that

sample points) with a bivariate normal for the stochastic process, parameter estimation of a random effects model cum dynamic sample selection and endogenous multilateral resistance terms takes roughly two days on a modern multi-core computer for a data-set as large as ours. There is virtually no gain in estimating the linearly approximated model à la Baier and Bergstrand (2009).

Overall, the model accounts for three types instantaneous effects of increasing trade costs on bilateral trade flows similar to Eaton and Kortum (2002), Melitz (2003), Chaney (2008), or Helpman, Melitz, and Rubinstein (2008). First, there is a direct effect due to the adjustment at the intensive margin as in (27) through higher (variable) trade costs on consumer prices in the destination country. Second, higher (variable as well as fixed) trade costs, eventually, may lead to zero bilateral trade flows as captured by the extensive margin relationship in (26). Finally, these direct consequences of higher trade costs at the extensive and intensive margins cause multilateral effects through trade by virtue of the price index effects captured by (14).[13] In contrast to previous structural empirical work on bilateral trade flows, our model generates dynamic effects of changes in trade barriers through dynamic adjustment at the extensive margin of aggregate bilateral trade. In our empirical analysis, we aim at fleshing out the instantaneous versus the long run effects of changes in country size versus trade costs on the extensive and intensive margin of trade and, taking general equilibrium feedback

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model as described in Appendix 3 in the optimization of (28). However, in Appendix 2 we show that the approach of Baier and Bergstrand (2009) reduces complexity only marginally with zero trade flows, since the linearization involves the inverse of a fairly complicated matrix.

[13]As said before, by focusing on homogeneous firms within countries, we rule out effects of higher trade costs on average productivity of firms exporting from a given country to a specific destination country. However, previous evidence suggests that this effect is of minor importance in aggregate data (see Egger, Larch, Staub, and Winkelmann, 2009).

effects and implied parameter constraints in the model fully into account for
both estimation and comparative static analysis.

4   Data and estimation results

4.1   Data

Our panel is based on three-year averages of bilateral trade among 171 coun-
tries in six periods (see Appendix 5 for a list of countries by continent): 1989
($t = 0$), 1992 ($t = 1$), 1995 ($t = 2$), 1998 ($t = 3$), 2001 ($t = 4$), 2004 ($t = 5$).
We use three-year intervals so as to keep the number of time periods, T,
small enough, since maximum likelihood estimation of the stochastic model
is computationally quite demanding. Both X_{ijt} and V_{ijt} are based on nomi-
nal aggregate bilateral export flows in current US dollars as published in the
United Nations' COMTRADE database. Figures on exporter and importer
nominal GDP in current US dollars for the respective years come from the
World Bank's World Development Indicators).

Furthermore, we employ three types of trade barriers: ones related to
geographical distance between countries' economic centers from the Centre
d'Études Prospectives et d'Informations Internationales' Geographical Data-
base; ones related to cultural distance in terms of a absence of a common
official language indicator variable from the same source; and ones related to
tariffs. For the latter, we pursue two models, one which involves an indicator
variable for the absence of preferential trade agreements as notified to the
World Trade Organization (WTO) and such agreements outside the WTO
information about which has been collected by Egger, Larch, Staub, and
Winkelmann (2009) and Egger and Larch (2010). Alternatively, we use in-
formation on average trade-weighted tariff rates as provided by the TRAINS

Database (available from the World Bank's WITS). Since the source data on weighted tariffs exhibit a large number of missing values, we interpolated and estimated missing tariff data using exogenous predictors (see the Appendix 6 for details). Since such a procedure (and even trade weighting alone) leads to measurement error, we follow Wansbeek and Meijer (2000, p. 29) by constructing indicator variables so as to capture quantiles of the distribution of tariffs. Using a rough approximation of the distribution of measurement error-prone tariff data, e.g., from trade weighting or imputation, through discrete variables helps reducing measurement error and is a valid alternative to instrumental variables estimation (see Wansbeek and Meijer, 2000). For this, we generate five indicator variables, which are associated with quintiles of the imputed tariff levels. We use zero tariff rates (as charged within preferential trade agreements) as the base which fully captures preferential trade agreement membership. In this way we are able to obtain a maximum coverage of countries and time periods, which is a prerequisite for both sample selection model estimation and solution of trade resistance terms.

Denote average applied bilateral tariff levels charged by country j on varieties from i in year t in quintile $\kappa = 2, ..., 5$ by $1 \geq b_\kappa - 1 \geq 0$. Average applied bilateral tariff levels percent are $100(b_\kappa - 1)$. In the second, third, fourth, and fifth quintile of tariffs, the latter is 2.96%, 7.07%, 11.62%, and 21.42%, respectively, for the average pair ij and year t. This information is important for interpretation of the parameter estimates. We choose a notation so that $\zeta_2, ..., \zeta_5$ (e.g., in Table 4 below) correspond to quintiles two to five of the tariff distribution. Given that tariffs in the lowest quintile are $b_1 = 1$, the estimated coefficients $\widehat{\alpha}_2, ..., \widehat{\alpha}_5$ on the indicators $\zeta_2, ..., \zeta_5$ can be interpreted as follows: $\widehat{\alpha}_\kappa = -\widehat{\sigma} \ln b_\kappa$ for $\kappa = 2, ..., 5$ so that $\widehat{\sigma} = -\frac{\widehat{\alpha}_\kappa}{\ln b_\kappa}$.

Hence, the model principally permits estimation of σ.[14]

<center>– Table 2 –</center>

Table 2 summarizes features of the data on nominal exports in logs GDP, and the geographical (bilateral distance in logs and a non-contiguity binary indicator), cultural (binary indicator variables on no common language, no past colonial relationships between exporter and importer, and the two countries not having had a common colonizer), and political trade barriers (binary indicator variables on common preferential trade agreement non-membership of exporter and importer and quintiles for tariff rates).[15] While the bloc on the left-hand side of Table 2 provides information on average levels of these variables over the information period and their standard deviation, the bloc on the right-hand side provides average three-year changes for the time-variant subset of variables (i.e., except for the geographical and cultural indicators).

According to Table 2, 87% of the covered observations represent country-pair-time dyads outside of a preferential trade agreement. About 22% of the observations fall into the lowest quintile of the tariff distribution (zero tariffs), while about 20% of the observations fall into the second and the fifth quintile, respectively, and about 19% fall into the third and fourth quintile, respectively. In the average three-year period, more than 3% of the observations enter the lowest quintile of tariffs (from wherever) and less than 1%

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[14]However, since there are four levels of κ which we can use, the estimates for σ may differ. In general, there are various ways of estimating σ which eventually will give different point estimates. See Eaton and Kortum, 2002, for a similar finding in an isomorphic index where what we refer to as an estimate of σ corresponds to an estimate of comparative advantage.

[15]We use binary indicators on non-contiguity, absence of a common language, etc., so that the parameter on these binary elements of $\ln \tau_{ijt}^{1-\sigma}$ and $\ln f_{ijt}$ always measure the role of higher barriers associated with an absence of the respective trade facilitation through contiguity, common language, etc., on the extensive and intensive margins of exports.

<center>22</center>

enter the second quintile. Anyone of the upper three quintiles looses more than 1% of the observations in the average three-year period between 1992 and 2004. The majority of observations does not have a common land border or a common language, and did not have a colonial relationship of any kind considered in the past. About 22% of the country-pairs did have positive exports in 1989. In the average period, about 56% of the country-pairs had positive exports and about 48% of the country-pairs had positive exports three years earlier.

In terms of the notation in the previous section, we have up to $K = L = 10$ elements $\alpha_k \ln \zeta_{k,ijt}$ for $k = 1, ..., 10$ in $\ln \tau_{ijt}^{1-\sigma}$ and $\beta_l \ln \chi_{l,ijt}$ for $l = 1, ..., 10$ in $\ln f_{ijt}$, namely the aforementioned geographical, cultural, and tariff barriers to trade times the unknown parameters relating them to $\ln \tau_{ijt}^{1-\sigma}$ and $\ln f_{ijt}$. Recall that we impose the restriction that the estimate of $\ln \tau_{ijt}^{1-\sigma}$ is identical between the extensive $(\ln \widetilde{V}_{ijt}^*)$ and intensive margin equations $(\ln X_{ijt})$, but the inclusion of $\ln f_{ijt}$ along with $\ln \tau_{ijt}^{1-\sigma}$ allows for identification of the parameters β_l apart from α_k.

4.2 Estimation results

In this subsection, we summarize the estimation results of dynamic selection models for both the fully non-linear and the linearly approximated model as introduced in the previous sections. In any case, the parameters have to be estimated iteratively, since the multilateral resistance terms in (14) and, eventually, their linearly approximated counterparts in logs based on $\ln \left(\Pi_{it}^{\sigma-1} \right)^*$ and $\ln \left(P_{jt}^{\sigma-1} \right)^*$ depend on the endogenous V_{ijt}.

Tables 3 and 4 summarize parameter estimates, their standard errors, numbers of both positive-exports and all observations, and the values of the log-likelihood for both the estimated model as well as the constant-only model

along with information about the net model degrees of freedom (i.e., the number of parameters estimated minus the number of constraints imposed) for four models each. While Table 3 is based on a specification which only employs a binary preferential trade agreement dummy (PTA), which we refer to as Model 1, Table 4 uses quintiles of bilateral tariff rates the lowest of which corresponds to zero tariffs and, hence, covers the case of PTA membership. We refer to the specification in Table 4 as Model 2.

On the left-hand side of each table, we summarize the results for both the latent process underlying the extensive margin ($\widetilde{V}_{ijt}^*$) and the intensive margin ($\ln X_{ijt}$). We refer to this as Model 1A in Table 3 and Model 2A in Table 4. Due to the parameter restrictions imposed, the estimates of α_k are identical for all determinants of $\ln \tau_{ijt}^{1-\sigma}$ in either equation. However, parameter estimates of β_l for the same trade cost variables as components of $\ln f_{ijt}$. Moreover, only the extensive margin equation includes (endogenous) $V_{ij,t-1}$ and $V_{ij,0}$ and, hence, delivers parameter estimates for δ and λ_{V0}, respectively. For convenience, we put the parameter estimates for the extensive and intensive margin models underneath each other. To the right of Model 1A and 2A we report the corresponding results for the variant of that model à la Baier and Bergstrand (2009), referred to as Models 1B and 2B, respectively. Models 1C and 1D in Table 3 and Models 2C and 2D in Table 4 are estimated for comparison only and treat V_{ijt} in the intensive margin equation for $\ln X_{ijt}$ not as Bernoulli response variable to $\widetilde{V}_{ijt}^*$ but as an exogenous determinant. Accordingly, the parameters of the latent process $\widetilde{V}_{ijt}^*$ are not estimated in these models but the multilateral resistance terms in (14) are solved by conditioning on the observed contemporaneous bilateral export status V_{ijt}. Model 1C is based on nonlinear terms (14) and should be compared to Model 1A, while Model 1D is based on linear approximations

of the multilateral resistance terms $\ln \left(\Pi_{it}^{\sigma-1} \right)^*$ and $\ln \left(P_{jt}^{\sigma-1} \right)^*$ and should be compared to Model 1B. Similarly, Models 2C and 2D should be compared to Models 2A and 2B, respectively. For the sake of brevity, we do not repeat the parameters for the elements of $\ln \tau_{ijt}^{1-\sigma}$ in the extensive margin equation at the top of each table, but it should be borne in mind that the same variables enter with the parameters as in the intensive margin equation also there as elements of $\ln \tau_{ijt}^{1-\sigma}$, according to the theoretical model.

– Tables 3 and 4 –

The results in Tables 3 and 4 suggest the following conclusions. First, the positive and highly significant coefficient of previous exporting clearly points to the importance of dynamics and path-dependence at the extensive margin of bilateral exports, irrespective of whether we consult the fully nonlinear (Models 1A and 2A) or the linearized specifications (Models 1B and 2B). PPP A Hausman test statistic suggests that the linearized models (Models 1B and 2B) are rejected against their fully nonlinear counterparts (Models 1A and 2A, respectively). The reason is that linearization of the multilateral resistance terms in (14) leads to correlation between the disturbances of the equations for the extensive and intensive margins of exports and the elements of $\ln \tau_{ijt}^{1-\sigma}$ and $\ln f_{ijt}$ and, hence, to an endogeneity bias in the estimated parameter vector. Finally, the point estimates and standard errors on ρ_η and ρ_ε – i.e., correlation of the disturbances between the processes of $\widetilde{V}_{ijt}^*$ and $\ln X_{ijt}$ – suggests that contemporaneous export status V_{ijt} should not be treated as exogenous (as in Models 1C, 1D, 2C, and 2D) but as a Bernoulli response variable (as in the other models). PPP

Regarding the role of variable trade costs for the extensive and the intensive margin, we find that all elements of $\ln \tau_{ijt}^{1-\sigma}$ display negative parameters

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(α_k) which are highly significantly different from zero. Hence, variable trade barriers of any kind specified deter both the probability to export at all for country-pairs and, at positive exports, the volume of exports shipped. However, most but not all of the elements of $\ln \tau_{ijt}^{1-\sigma}$ are also important obstacles to trade in terms of fixed costs (elements of $\ln f_{ijt}$): only absence of a PTA membership (in Table 3) or higher tariff levels (in Table 4), log distance, and absence of a common language are found to raise fixed costs to bilateral trade; lack of adjacency or lack of colonial relationships rather seems to reduce fixed trade costs than to raise them, according to the estimates in Tables 3 and 4.

5   Comparative static analysis

5.1   Preliminaries for counterfactual analysis

With (13)-(14), (5)-(7), and the expression for the equivalent variation in (5.1), we can now conduct comparative static effects of changes in the variables underlying $\tau_{ijt}^{1-\sigma}$ and f_{ijt} as well as of changes in factor endowments L_{it} and (the inverse of) total factor productivity a_{it}. Moreover, we will consider comparative static effects of changes in inverse total factor productivity a_{it}. For this, note that the level of a_{it} is hard to measure. However, defining real output as $\Upsilon_{it} = n_{it}\bar{y}_{it}$, with $\bar{y}_{it} \equiv \sum_j^J x_{ijt}$, and aggregate tariff income of country i in year t as Ξ_{it}, and using these terms in the definition of nominal GDP, $Y_{it} = \frac{\sigma}{\sigma-1} w_{it} a_{it} \Upsilon_{it} = w_{it} L_{it} + \Xi_{it}$, we obtain

$$a_{it} = \frac{\sigma - 1}{\sigma} \frac{L_{it}}{\Upsilon_{it}} \left(1 + \frac{\Xi_{it}}{Y_{it}}\right).$$

Now, the ratio counterfactual to baseline inverse total factor productivity is

$$\frac{a_{it}^c}{a_{it}} = \frac{\Upsilon_{it}/L_{it}}{\Upsilon_{it}^c/L_{it}^c} \frac{1 + \Xi_{it}^c/Y_{it}^c}{1 + \Xi_{it}/Y_{it}}.$$

Hence, while the level of a_{it} is hard to measure, we can measure, for instance, the change of a_{it} over time, $\frac{a_{i,t+1}}{a_{it}}$, by the inverse change in real output per worker, $\left(\frac{\Upsilon_{it}/L_{it}}{\Upsilon_{i,t+1}/L_{i,t+1}}\right)$, which can be measured by the inverse change of real output per worker (using GDP at constant producer prices) from period t to $t+1$, together with the change of the trade-weighted ad-valorem tariff factor, $\frac{1+\Xi_{it}^c/Y_{it}^c}{1+\Xi_{it}/Y_{it}}$.[16]

Using $P_{it} \equiv m_{it}^{\frac{1}{\sigma-1}} \theta_{it}^{\frac{1}{1-\sigma}}$, the equivalent variation in percent associated with a comparative static effect on Y_{it} and P_{it} as a measure of welfare change can be calculated as

$$EV_{it} \equiv 100 \cdot \left(\frac{Y_{it}^c/P_{it}^c}{Y_{it}/P_{it}} - 1\right).$$

In general, we calculate changes between baseline and counterfactual equilibria based on the estimates of both Model 2A and Model 2B in Table 3 for each experiment.

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[16]In their model of the determinants of export variety, Feenstra and Kee (2008) allow total factor productivity to be determined endogenously in a nonlinear systems estimation approach. While we do not consider heterogeneous firms or responses of total factor productivity to endogenous variables, this would be principally possible also with our general equilibrium model. One could even allow tariff indicators to be endogenous and analyze a system of equations where only geographical (distance and absence of a common land border) and cultural trade barriers (absence of a common language, of a past colonial relationship, or of a common colonizer) along with factor endowments L_{it} would be exogenous. However this would push the importance of the adopted structural assumptions quite far, and we resort to stronger assumptions about exogeneity at the advantage of simplicity of an already complicated structural empirical general equilibrium model with path dependence at the extensive margin.

5.2 Description of counterfactual experiments

Recall that, by design of our data-set, $t = 0$ corresponds to the initial year of 1989, while $t = 1, ..., 5$ correspond to $1992, 1995, 1998, 2001, 2004$. Hence, $V_{ij,t-1}$ refers to three years prior to t. For the comparative static analysis, we will compute equilibria which are based on $\tau_{ijt}^{1-\sigma}$, f_{ijt}, L_{it}, and a_{it} as observed or estimated from data used for estimation. Using estimated parameters from the data, we then consider three counterfactual equilibria for all countries and country-pairs for the years in the short run and the long run. For this, we shock alternatively $\tau_{ijt}^{1-\sigma}$ together with f_{ijt}, L_{it}, and a_{it} in the year 2004 by the three-year change a country-pair (for $\tau_{ijt}^{1-\sigma}$ and f_{ijt}) or country (for L_{it} and a_{it}) experienced in the average three-year period between 1992 and 2004. We refer to the short-run response of outcome as the contemporaneous one in 2004 and to the corresponding long-run response as the one after reaching a new equilibrium. The three experiments considered are the following.

Changing bilateral tariffs: For this experiment, we change the five indicator variables for quintiles of tariffs, which Models 2A-2D are based upon, in 2004 which alters $\tau_{ijt}^{1-\sigma}$ and f_{ijt} but use L_{it} and a_{it} as of 2004.

Changing labor endowments: For this experiment, we change L_{it} but use $\tau_{ijt}^{1-\sigma}$, f_{ijt}, and a_{it} as of 2004.

Changing total factor productivity: For this experiment, we change a_{it} but use $\tau_{ijt}^{1-\sigma}$, f_{ijt}, and L_{it} as of 2004.

Then, for each experiment we calculate counterfactual trade flows X_{ijt}^c, GDP Y_{it}^c, μ_{it}^c and m_{jt}^c (or linearized $\left(\Pi_{it}^{\sigma-1}\right)^{*c}$ and $\left(P_{jt}^{\sigma-1}\right)^{*c}$), endogenous export status V_{ijt}^c, and equivalent variation EV_{it} for the short run (in 2004) and the long run as described in Appendices 2 and 3.

5.3 Summary of comparative static results

Table 5 summarizes average three-year changes between 1992 and 2004 of the dummy variables as employed in Models 2A-2D in Table 3, capturing quintiles of the distribution of tariff levels. Even though we will not report comparative static effects at that level, we report such changes not only for the average country-pair and three-year period (in the first column) within 1992-2004, but also for country-pairs within the continents Africa, Americas, Asia, Europe, and Pacific.[17] The distinction of continents in Table 5 is one way to indicate that there is variation in changes of tariff quintile indicators (as well as in $\tau_{ijt}^{1-\sigma}$, f_{ijt}, L_{it}, and a_{it}) across the observations. Hence, the comparative static analysis rests on heterogeneous changes of heterogeneous levels of variables across country-pairs. Underneath these changes of tariff quintile indicators, we report the implied changes of $\tau_{ijt}^{1-\sigma}$ and f_{ijt}. Underneath those, we give average three-year changes in L_{it} and a_{it}. Changes of $\tau_{ijt}^{1-\sigma}$, f_{ijt}, L_{it}, and a_{it} are expressed in percent, while those of the tariff quintile indicators should be interpreted as changes in hundredths of percent.

– Table 5 –

In Table 6, we summarize the associated results with the mentioned comparative static experiments on a number of endogenous variables of interest, namely, equivalent variation EV_{it}, nominal trade flows X_{ijt}, endogenous export status V_{ijt}, and the number of firms active for three alternative levels of the elasticity of substitution, $\sigma \in [4; 7; 10]$.[18] Akin to the change in the

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[17]When imagining a cross-tabulation of changes in quintiles across continents, the information provided by continent corresponds to the diagonal blocs of the cross-tabulation.

[18]Since $\widehat{\alpha}_\kappa < 0$ and log ad-valorem tariff factors $\ln b_\kappa > 0$ for all quintiles $\kappa = 2, ..., 5$, this leads to $\widehat{\sigma} > 1$ throughout, which is consistent with the corresponding model assumption. However, there is variation about $\widehat{\sigma}$ across $\kappa = 2, ..., 5$, as expected, and the corresponding point estimates are in the range $\widehat{\sigma} \in [3.46, ..., 10.30]$. Since the observations in each of the

exogenous $\tau_{ijt}^{1-\sigma}$, f_{ijt}, L_{it}, and a_{it}, all comparative static effects are expressed as percentage changes.

– Table 6 –

TO BE COMPLETED

6   Conclusions

TO BE COMPLETED

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upper four quintiles is about the same, the average value of $\widehat{\sigma} \simeq 7.86$. The latter seems plausible against the background of previous work at the aggregate level of bilateral trade (see Anderson and van Wincoop, 2003; or Bergstrand, Egger, and Larch, 2009).

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Appendix 1. A Baier and Bergstrand (2009) type approximation with zero trade flows

Let us start with aggregate nominal bilateral exports being determined as in (13), but expressed as

$$X_{ijt} = Y_t \tau_{ijt}^{1-\sigma} \theta_{it} \Pi_{it}^{\sigma-1} \theta_{jt} P_{jt}^{\sigma-1} V_{ijt}.$$

where $\Pi_{it}^{1-\sigma}$ and $P_{jt}^{1-\sigma}$ are determined as in (12). Akin to Baier and Bergstrand (2009), the nonlinear system in $\Pi_{it}^{1-\sigma}$ and $P_{jt}^{1-\sigma}$ in equation (12) can be reformulated and linearly approximated around $\tau_{iht} = 1$, $\Pi_{it} = 1$ and $P_{jt} = 1$ as

$$T_{1,i}(\mathbf{\Pi}_t, \mathbf{P}_t) = \Pi_{it}^{1-\sigma} - \sum_{h=1}^{J} \left(\frac{\tau_{iht}}{P_{ht}} \right)^{1-\sigma} \theta_{ht} V_{iht}$$

$$\approx 1 - \sum_{h=1}^{J} V_{iht}\theta_{ht} - (1-\sigma)\sum_{h=1}^{J} V_{iht}\theta_{ht} \ln \tau_{iht} + (1-\sigma)\ln \Pi_{it} + (1-\sigma)\sum_{h=1}^{J} V_{iht}\theta_{ht} \ln P_{ht}$$

$$T_{2,j}(\mathbf{\Pi}_t, \mathbf{P}_t) = P_{jt}^{1-\sigma} - \sum_{h=1}^{J} \left(\frac{\tau_{hjt}}{\Pi_{ht}} \right)^{1-\sigma}_h \theta_{ht} V_{hjt}$$

$$\approx 1 - \sum_{h=1}^{J} V_{hjt}\theta_{ht} - (1-\sigma)\sum_{h=1}^{J} \theta_h V_{hjt} \ln \tau_{hjt} + (1-\sigma)\sum_{h=1}^{J} \theta_h V_{hjt} \ln \Pi_{ht} - (1-\sigma)\ln P_{jt}.$$

To write this system in matrix form for period t, it is useful to define the two $J \times 1$ vectors $\mathbf{d}_{\mathbf{\Pi},t}$, $\mathbf{d}_{\mathbf{P},t}$, $\mathbf{T}_{\mathbf{\Pi},t}$, and $\mathbf{T}_{\mathbf{P},t}$ as

$$
\mathbf{d}_{0\mathbf{\Pi},t} = \begin{bmatrix} 1 - \sum_{h=1}^{J} V_{1ht}\theta_{ht} \\ 1 - \sum_{h=1}^{J} V_{2ht}\theta_{ht} \\ \vdots \\ 1 - \sum_{h=1}^{J} V_{Jht}\theta_{ht} \end{bmatrix}, \quad \mathbf{T}_{\mathbf{\Pi},t} \begin{bmatrix} \sum_{h=1}^{J} V_{1ht}\theta_{ht} \ln \tau_{1ht} \\ \sum_{h=1}^{J} V_{2ht}\theta_{ht} \ln \tau_{2ht} \\ \vdots \\ \sum_{h=1}^{J} V_{Jht}\theta_{ht} \ln \tau_{Jht} \end{bmatrix},
$$

$$
\mathbf{d}_{0\mathbf{P},t} = \begin{bmatrix} 1 - \sum_{h=1}^{J} V_{h1t}\theta_{ht} \\ 1 - \sum_{h=1}^{J} V_{h2t}\theta_{ht} \\ \vdots \\ 1 - \sum_{h=1}^{J} V_{hJt}\theta_{ht} \end{bmatrix}, \quad \mathbf{T}_{\mathbf{P},t} \begin{bmatrix} \sum_{h=1}^{J} \theta_h V_{h1t} \ln \tau_{h1t} \\ \sum_{h=1}^{J} \theta_h V_{h2t} \ln \tau_{h2t} \\ \vdots \\ \sum_{h=1}^{J} \theta_h V_{hJt} \ln \tau_{hJt} \end{bmatrix}.
$$

Furthermore, define the two $J \times 1$ vectors $\mathbf{d}_{\mathbf{\Pi},t} = \mathbf{d}_{0\mathbf{\Pi},t} + (\sigma - 1)\mathbf{T}_{\mathbf{\Pi},t}$ and $\mathbf{d}_{\mathbf{P},t} = \mathbf{d}_{0\mathbf{P},t} + (\sigma - 1)\mathbf{T}_{\mathbf{P},t}$, the two $J \times 1$ vectors $\mathbf{\Pi}_t = (\ln \Pi_{1t}, ..., \ln \Pi_{Jt})'$ and $\mathbf{P}_t = (\ln P_{1t}, ..., \ln P_{Jt})'$, and the two $J \times J$ matrices

$$
\mathbf{V}_{\mathbf{P},t} = \begin{bmatrix} V_{11t}\theta_{1t} & \ldots & V_{1Jt}\theta_{Jt} \\ V_{21t}\theta_{1t} & \ldots & V_{2Jt}\theta_{Jt} \\ \vdots & \vdots & \vdots \\ V_{J1}\theta_{1t} & \ldots & V_{JJt}\theta_{Jt} \end{bmatrix}, \quad \mathbf{V}_{\mathbf{\Pi},t} = \begin{bmatrix} V_{11t}\theta_{1t} & \ldots & V_{J1t}\theta_{Jt} \\ V_{12t}\theta_{1t} & \ldots & V_{J2t}\theta_{Jt} \\ \vdots & \vdots & \vdots \\ V_{1Jt}\theta_{1t} & \ldots & V_{JJt}\theta_{Jt} \end{bmatrix}.
$$

Then, we may write the $2J \times 1$ equations of the system for period t with typical elements $T_{1,i}(\mathbf{\Pi}_t, \mathbf{P}_t)$ and $T_{2,i}(\mathbf{\Pi}_t, \mathbf{P}_t)$, respectively, in matrix form as

$$
\begin{bmatrix} \mathbf{T}_1(\mathbf{\Pi}_t, \mathbf{P}_t) \\ \mathbf{T}_2(\mathbf{\Pi}_t, \mathbf{P}_t) \end{bmatrix} = \begin{bmatrix} \mathbf{d}_{\mathbf{\Pi},t} \\ \mathbf{d}_{\mathbf{P},t} \end{bmatrix} + (1 - \sigma) \begin{bmatrix} \mathbf{I} & \mathbf{V}_{\mathbf{P},t} \\ \mathbf{V}_{\mathbf{\Pi},t} & \mathbf{I} \end{bmatrix} \begin{bmatrix} \mathbf{\Pi}_t \\ \mathbf{P}_t \end{bmatrix} = \begin{bmatrix} \mathbf{0} \\ \mathbf{0} \end{bmatrix},
$$

where $\mathbf{I}$ is a $J \times J$ identity matrix. Denoting approximated price terms by an asterisk, defining the two $J \times 1$ vectors $\mathbf{\Pi}_t^* = (\ln \Pi_{1t}^*, ..., \ln \Pi_{Jt}^*)'$ and

$\mathbf{P}_t = (\ln P_{1t}^*, ..., \ln P_{Jt}^*)'$, and using the formula for the partitioned inverse (assuming that it exists), the approximate solution for the one-step Newton iteration at the point $(\mathbf{\Pi}_t + \mathbf{P}_t) = \mathbf{0}$ is given by

$$(\sigma - 1) \begin{bmatrix} \mathbf{\Pi}_t^* \\ \mathbf{P}_t^* \end{bmatrix} = \begin{bmatrix} \mathbf{I} + \mathbf{V_P}(\mathbf{I} - \mathbf{V_\Pi V_P})^{-1}\mathbf{V_\Pi} & -\mathbf{V_P}(\mathbf{I} - \mathbf{V_\Pi V_P})^{-1} \\ -(\mathbf{I} - \mathbf{V_\Pi V_P})^{-1}\mathbf{V_\Pi} & (\mathbf{I} - \mathbf{V_\Pi V_P})^{-1} \end{bmatrix} \begin{bmatrix} \mathbf{d_\Pi} \\ \mathbf{d_P} \end{bmatrix}$$

$$= \begin{bmatrix} \mathbf{V_{P}}_{,t}(\mathbf{I} - \mathbf{V_{\Pi}}_{,t}\mathbf{V_{P}}_{,t})^{-1}\mathbf{V_{\Pi}}_{,t}\mathbf{d_{\Pi}}_{,t} - \mathbf{V_{P}}_{,t}(\mathbf{I} - \mathbf{V_{\Pi}}_{,t}\mathbf{V_{P}}_{,t})^{-1}\mathbf{d_{\Pi}}_{,t} \\ -(\mathbf{I} - \mathbf{V_{\Pi}}_{,t}\mathbf{V_{P}}_{,t})^{-1}\mathbf{V_{\Pi}}_{,t}\mathbf{d_{\Pi}}_{,t} + (\mathbf{I} - \mathbf{V_{\Pi}}_{,t}\mathbf{V_{P}}_{,t})^{-1}\mathbf{d_{P}}_{,t} \end{bmatrix}.$$

Then,

$$(\sigma - 1)\left(\mathbf{\Pi}_t^* + \mathbf{P}_t^*\right) =$$

$$= \mathbf{d_{\Pi}}_{,t} + (\mathbf{I} - \mathbf{V_{P}}_{,t})(\mathbf{I} - \mathbf{V_{\Pi}}_{,t}\mathbf{V_{P}}_{,t})^{-1}\mathbf{d_{P}}_{,t} - (\mathbf{I} - \mathbf{V_{P}}_{,t})\left(\mathbf{I} - \mathbf{V_{P}}_{,t}\mathbf{V_{\Pi}}_{,t}\right)^{-1}\mathbf{V_{\Pi}}_{,t}\mathbf{d_{\Pi}}_{,t}$$

$$= \mathbf{d_{0\Pi}}_{,t} + (\mathbf{I} - \mathbf{V_{P}}_{,t})(\mathbf{I} - \mathbf{V_{\Pi}}_{,t}\mathbf{V_{P}}_{,t})^{-1}\mathbf{d_{0P}}_{,t} - (\mathbf{I} - \mathbf{V_{P}}_{,t})\left(\mathbf{I} - \mathbf{V_{P}}_{,t}\mathbf{V_{\Pi}}_{,t}\right)^{-1}\mathbf{V_{\Pi}}\mathbf{d_{0\Pi}}_{,t}$$

$$+(\sigma - 1)\left[\mathbf{T_{\Pi}}_{,t} + (\mathbf{I} - \mathbf{V_{P}}_{,t})(\mathbf{I} - \mathbf{V_{\Pi}}_{,t}\mathbf{V_{P}}_{,t})^{-1}\mathbf{T_{P}}_{,t} - (\mathbf{I} - \mathbf{V_{P}}_{,t})\left(\mathbf{I} - \mathbf{V_{P}}_{,t}\mathbf{V_{\Pi}}_{,t}\right)^{-1}\mathbf{V_{\Pi}}_{,t}\mathbf{T_{\Pi}}_{,t}\right].$$

Note that the vector

$$\mathbf{d_{0\Pi}}_{,t} + (\mathbf{I} - \mathbf{V_{P}}_{,t})(\mathbf{I} - \mathbf{V_{\Pi}}_{,t}\mathbf{V_{P}}_{,t})^{-1}\mathbf{d_{0P}}_{,t} - (\mathbf{I} - \mathbf{V_{P}}_{,t})\left(\mathbf{I} - \mathbf{V_{P}}\mathbf{V_{\Pi}}_{,t}\right)^{-1}\mathbf{V_{\Pi}}_{,t}\mathbf{d_{0\Pi}}_{,t}$$

has typical element $d_{X,ijt}$ as used in the text, while

$$-(\mathbf{I} - \mathbf{V_{\Pi}}_{,t}\mathbf{V_{P}}_{,t})^{-1}\mathbf{V_{\Pi}}_{,t}\mathbf{d_{0\Pi}}_{,t} + (\mathbf{I} - \mathbf{V_{\Pi}}_{,t}\mathbf{V_{P}}_{,t})^{-1}\mathbf{d_{0P}}_{,t}$$

has typical element $d_{V,ijt}$. This procedure obtains the first step of the iterative Newton iteration that solves the system of trade resistance equations for the empirically relevant case with zero trade flows. By Walras' law, we can choose an arbitrary country's P_{jt}^* as numéraire in each period t.

Without zero trade flows, i.e., if $V_{ijt} = 1$ for all ijt, $\mathbf{d}_{0\mathbf{\Pi},t} = \mathbf{0}$, $\mathbf{d}_{0\mathbf{P},t} = \mathbf{0}$, and $\mathbf{V}_{\mathbf{\Pi},t}\mathbf{V}_{\mathbf{P},t} = \mathbf{V}_{\mathbf{P},t}\mathbf{V}_{\mathbf{\Pi},t} = \mathbf{V}_t$. Then, $(\mathbf{I} - \mathbf{V}_{\mathbf{P},t})(\mathbf{I} - \mathbf{V}_{\mathbf{\Pi},t}\mathbf{V}_{\mathbf{P},t})^{-1}$ in $(\sigma - 1)(\mathbf{\Pi}_t^* + \mathbf{P}_t^*)$ has to be replaced by $(\mathbf{I} - \mathbf{V}_t)(\mathbf{I} - \mathbf{V}_t)^+ = \mathbf{I}$, where superscript $+$ refers to the Moore-Penrose inverse, since $\mathbf{V}_t$ is idempotent, so that $(\mathbf{I} - \mathbf{V}_t)^2 = (\mathbf{I} - \mathbf{V}_t)$ and $(\mathbf{I} - \mathbf{V}_{\mathbf{P},t})(\mathbf{I} - \mathbf{V}_{\mathbf{\Pi},t}\mathbf{V}_{\mathbf{P},t})^+ = (\mathbf{I} - \mathbf{V}_t)(\mathbf{I} - \mathbf{V}_t)^+$ with

$$
\begin{aligned}
\mathbf{V}_t &= \mathbf{V}_{\mathbf{\Pi},t}\mathbf{V}_{\mathbf{P},t} = \\
&= \begin{bmatrix}
\theta_{1t}\sum_{h=1}^{J}V_{h1t}\theta_h V_{1ht} & \theta_{2t}\sum_{h=1}^{J}V_{h1t}\theta_{ht}V_{2ht} & \dots & \theta_J\sum_{h=1}^{J}V_{h1t}\theta_{ht}V_{Jht} \\
\theta_{1t}\sum_{h=1}^{J}V_{h2t}\theta_{ht}V_{1ht} & \theta_{2t}\sum_{h=1}^{J}V_{h2t}\theta_{ht}V_{2ht} & \dots & \theta_J\sum_{h=1}^{J}V_{h2t}\theta_{ht}V_{Jht} \\
\vdots & \vdots & \vdots & \vdots \\
\theta_{1t}\sum_{h=1}^{J}V_{hJt}\theta_{ht}V_{1ht} & \theta_{2t}\sum_{h=1}^{J}V_{hJt}\theta_{ht}V_{2ht} & \dots & \theta_J\sum_{h=1}^{J}V_{hJt}\theta_{ht}V_{Jht}
\end{bmatrix} \\
&\neq \mathbf{V}_{\mathbf{\Pi},t}
\end{aligned}
$$

In that case, which corresponds exactly to the one in Baier and Bergstrand (2009, p. 85), $(\sigma - 1)(\mathbf{\Pi}_t^* + \mathbf{P}_t^*) = \mathbf{T}_{\mathbf{\Pi},t} + \mathbf{T}_{\mathbf{P},t} - \mathbf{T}_{\mathbf{\Pi},t}\mathbf{d}_{\mathbf{\Pi},t}$.

Appendix 2. Solving the fully nonlinear model in counterfactual equilibrium

Based on known (or estimated) parameters including σ, known counterfactual GDP shares θ_i^c, and counterfactual trade barriers $(\tau_{it}^{1-\sigma})^c$ and f_{it}^c for each period, we may solve for counterfactual trade resistance terms from the system (14) by using

$$
V_{ijt}^c = 1\left[\ln\left(\frac{\tau_{ijt}^{1-\sigma}}{\tau_{iit}^{1-\sigma}}\right)^c + \ln\frac{m_{jt}^c}{m_{it}^c} + \ln\frac{f_{iit}^c}{f_{ijt}^c} + \delta V_{ij,t-1}^c\right], \tag{30}
$$

where $\tau_{ijt}^{1-\sigma}$ and f_{ijt}^c depend on the same variables capturing trade barriers by assumption. Of course, $\theta_{it}^c = Y_{it}^c/(\sum_{i=1}^{J} Y_{it}^c)$ is not observed, but Y_{it}^c it can

be solved for using

$$
\begin{aligned}
Y_{it}^c &= \frac{p_{it}^c}{p_{it}} \frac{\Upsilon_{it}^c}{\Upsilon_{it}} Y_{it} = \left(\frac{\mu_{it}^c/n_{it}^c}{\mu_{it}/n_{it}}\right)^{\frac{1}{1-\sigma}} \frac{\Upsilon_{it}^c}{\Upsilon_{it}} Y_i = \\
&= \left(\frac{\mu_{it}^c}{\mu_{it}}\right)^{\frac{1}{1-\sigma}} \left(\frac{L_{it}^c}{L_{it}}\right)^{\frac{\sigma}{\sigma-1}} \left(\frac{\sum_{j=1}^{J} V_{ijt}^c e^{-\delta V_{ij,t-1}^c} f_{ijt}^c}{\sum_{j=1}^{J} V_{ijt} e^{-\delta V_{ij,t-1}} f_{ijt}}\right)^{\frac{1}{1-\sigma}} \frac{a_{it}}{a_{it}^c} Y_{it}, \quad (31)
\end{aligned}
$$

where we used $\Upsilon_{it} \equiv n_{it}\overline{y}_{it}$ and $\overline{y}_{it} \equiv \sum_j^J x_{ijt}$ for the baseline scenario and an analogous definition for Υ_{it}^c. Moreover, we used $p_{it} = (\mu_{it}/n_{it})^{\frac{1}{1-\sigma}}$ from (11) and assume throughout that $f_{iit}^c = f_{iit}$. For estimation, replace estimates of V_{ijt} by ones of V_{ijt}^c from (30) and Y_{it} by Y_{it}^c from (31) in (14). In particular, use $\widehat{V}_{ijt}^c = 1[P(\ln \widehat{\widetilde{V}}_{ijt}^c > 0) > \frac{1}{TN(N-1)} \sum_{t=1}^{T} \sum_{j=1}^{J} \sum_{i\neq j} P(\ln \widehat{\widetilde{V}}_{ijt}^c > 0)]$ as an estimate for V_{ijt}^c in (30) by.

Notice that (14) and (30)-(31) have to be solved simultaneously (or iteratively until convergence), since, in counterfactual equilibrium, (14) depend on (30) and (31) both of which are a function of the multilateral resistance terms in (14).

Appendix 3. Solving the model based on linearized multilateral resistance terms in counterfactual equilibrium

With the linearized system of multilateral trade resistance equations à la Baier and Bergstrand (2009), one has to solve for counterfactual terms $\left(\Pi_{it}^{\sigma-1}\right)^{*c}$ and $\left(P_{jt}^{\sigma-1}\right)^{*c}$ (or logs thereof) instead of μ_{it} and m_{jt} as functions of all Y_{it}^c. Solutions can proceed along the lines of Appendix 2, after replacing $\frac{\mu_{it}^c}{\mu_{it}}$ by $\frac{\theta_{it}^c \left(\Pi_{it}^{\sigma-1}\right)^{*c}}{\theta_{it} \left(\Pi_{it}^{\sigma-1}\right)^{*}}$.

We implement three versions of the generalized Baier and Bergstrand (2009) linearization for zero trade flows. First, in a model without zero

trade flows Feenstra (2002) and Baier and Bergstrand (2009) assumed that (variable) trade costs affect linearized multilateral resistance terms but do not have repercussions on GDP. We implement one version of the linearized model, where we assume that neither θ_{it} nor V_{ijt} changes with trade costs. Of course, this assumption is violated on theoretical grounds, but the error may be smaller or larger, depending on the data. In a second version, we allow V_{ijt} to change in response to changes of the linearized multilateral resistance terms. Already in this case, one has to solve (jointly or iteratively) numerically the system of $2JT$ multilateral resistance terms and the $J(J-1)T$ equations determining V_{ijt} at $i \neq j$. Then, there is no advantage from linearizing the system of multilateral trade resistance terms anymore. In a third version, we allow both V_{ijt} and θ_{it} to respond to changes in linearized multilateral resistance terms. Like the fully nonlinear model, this solves numerically for $2JT$ linearized multilateral resistance terms as in Appendix 1, for JT terms θ_{it}, and for $J(J-1)T$ terms V_{ijt} at $i \neq j$. In either version, we can also replace P_{it}^c and P_{it} in (5.1) with the linearized terms P_{it}^{*c} and P_{it}^* as derived in Appendix 1 to estimate comparative static welfare effects.

Overall, linearization of the system of multilateral trade resistance terms only avoids using a nonlinear solver for parameter estimation – which in some panel data applications can readily be achieved by fixed exporter-by-year and fixed importer-by-year effects estimation –, but it can not avoid usage of a nonlinear solver for comparative static analysis which the models of Eaton and Kortum (2002), Anderson and van Wincoop (2003), and Helpman, Melitz, and Rubinstein (2008) ultimately were designed for.

Appendix 4. Details on the maximum likelihood estimation procedure

Following Raymond, Mohnen, Palm, and Schim van der Loeff (2007a,b), the likelihood of country-pair ij at period t, starting in $t = 1$ and conditional on the regressors in $\mathbf{w}_{V,ijt}$ (including the initial conditions) and $\mathbf{w}_{X,ijt}$ is given by terms in (28)-(29). We integrate out the country-pair-specific random effects $\eta_{V,ij}$ and $\eta_{X,ij}$ using a two-step Gauss-Hermite quadrature, which is based on

$$\int_{-\infty}^{\infty} e^{-z^2} f(z) dz \approx \sum_{m=1}^{M} w_m f(a_m),$$

where, e^{-z^2} plays the role of the normal density and $f(z)$ is any continuous function of z. w_m and a_m are the weights and abscissas, respectively, as defined by the Hermite polynomial (see, e.g., Abramovitz and Stegun, 1964), where m indexes to the integration points of which there are M. Use the transformation of the random variables $z_{V,ij} = \frac{\eta_{V,ij}}{\sigma_{V,\eta}\sqrt{2(1-\rho_\eta^2)}}$ and $z_{X,ij} = \frac{\eta_{X,ij}}{\sigma_{X,\eta}\sqrt{2(1-\rho_\eta^2)}}$ with the likelihood weights w_p and w_m and corresponding abscissas a_p and a_m. Then, we can approximate the likelihood function as

$$
\begin{aligned}
L_{ijt} \approx{}& \frac{\sqrt{(1-\rho_\eta^2)}}{\pi} \sum_{p=1}^{M} w_p \Pi_{t=1}^{T} \left(\frac{1}{\sigma_{X,\varepsilon}} \Phi \left(\frac{\ln X_{ijt} - B_{ijt} - a_p \sigma_{X,\eta}\sqrt{2(1-\rho_\eta^2)}}{\sigma_{X,\varepsilon}} \right) \right)^{V_{ijt}} \\
&\times \sum_{m=1}^{M} w_m \left(e^{2\rho_\eta a_p a_m} \Pi_{t=1}^{T} \left(\Phi \left(-A_{ijt} + a_m \sigma_{V,\eta}\sqrt{2(1-\rho_\eta^2)} \right) \right)^{1-V_{ijt}} \right) \\
&\times \Phi \left(\frac{-A_{ijt} + a_m \sigma_{V,\eta}\sqrt{2(1-\rho_\eta^2)} + \frac{\rho_\varepsilon}{\sigma_{V,\varepsilon}}\left(\ln X_{ijt} - B_{ijt} - a_p \sigma_{X,\eta}\sqrt{2(1-\rho_\eta^2)} \right)}{\sqrt{(1-\rho_\eta^2)}} \right).
\end{aligned}
$$

Note that the double integral in (28) is then approximated by a weighted double summation over all abscissa points a_p and a_m.

Appendix 5. List of included countries by continent

Africa (47 countries): Algeria, Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Cape Verde, Central African Republic, Chad, Comoros, Congo (Democratic Republic of), Congo (Republic of), Côte d'Ivoire, Djibouti, Egypt, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Madagascar, Malawi, Mali, Mauritania, Mauritius, Morocco, Mozambique, Namibia, Niger, Nigeria, Rwanda, Senegal, Seychelles, Sierra, Leone, South Africa, Sudan, Swaziland, Tanzania, Togo (United Rep. of), Tunisia, Uganda, Zambia, Zimbabwe.

Americas (33 countries): Antigua and Barbuda, Argentina, Barbados, Belize, Bolivia, Brazil, Canada, Chile, Colombia, Costa Rica, Dominica, Dominican Republic, Ecuador, El Salvador, Grenada, Guatemala, Guyana, Haiti, Honduras, Jamaica, Mexico, Nicaragua, Panama, Paraguay, Peru, Saint Kitts and Nevis, Saint Lucia, Saint Vincent and the Grenadines, Suriname, Trinidad and Tobago, United States, Uruguay, Venezuela.

Asia (40 countries): Armenia, Azerbaijan, Bahrain, Bangladesh, Bhutan, Brunei Darussalam, Cambodia, China, Georgia, Hong Kong, India, Indonesia, Iran, Israel, Japan, Jordan, Kazakhstan, Korea, Kuwait, Kyrgyzstan, Lebanon, Malaysia, Maldives, Mongolia, Nepal, Oman, Pakistan, Philippines, Qatar, Russian Federation, Saudi Arabia, Singapore, Sri Lanka, Syrian Arab Republic, Tajikistan, Thailand, Turkmenistan, United Arab Emirates, Viet Nam, Yemen.

Europe (36 countries): Albania, Austria, Belarus, Belgium and Luxembourg, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Macedonia (former Yugoslav Rep. of), Malta, Moldova

(Rep. of), Netherlands, Norway, Poland, Portugal, Romania, Slovak Republic, Slovenia, Spain, Sweden, Switzerland, Turkey, Ukraine, United Kingdom.
Pacific (9 countries): Australia, Fiji, Kiribati, New Zealand, Papua New Guinea, Samoa, Solomon Islands, Tonga, Vanuatu.

Appendix 6. Details on the construction of the tariff quintile indicator variables

TO BE COMPLETED

Table 1 - Persistence of the extensive margin of bilateral exports in 171 countries
(Included years are 1992, 1995, 1998, 2001, 2004)

Country-pairs with	Percent	Country-pairs with	Percent
Exports both in a year and three years earlier	0.44	Exports in 2004 and 1989	0.21
Exports neither in a year nor in three years earlier	0.41	Exports neither in 2004 nor in 1989	0.36
Exports in a year but not three years earlier	0.12	Exports in 2004 but not in 1989	0.43
Exports three years before but not in a given year	0.04	Exports in 1989 but not in 2004	0.01

Table 2 - Descriptive statistics on log exports on elements of $(1-\sigma) \ln \tau_{ijt}$ and $\ln f_{ijt}$
(171 countries; included years are 1992, 1995, 1998, 2001, and 2004)

Variables	Levels		Three-year changes	
	Mean	Std.dev.	Mean	Std.dev.
Log bilateral exports ($\ln X_{ijt}$)	0.648	3.786	0.290	1.301
Extensive margin of bilateral exports (V_{ijt})	0.559	0.497	0.083	0.382
Lagged extensive margin of bilateral exports ($V_{ij,t-1}$)	0.475	0.499	-	-
Initial condition for extensive margin of bilateral exports ($V_{ij,0}$)	0.221	0.415	-	-
GDP share (θ_{it})	0.006	0.026	0.000	0.003
Variables in $(1-\sigma) \ln \tau_{ijt}$ and $\ln f_{ijt}$				
PTA non-membership (binary)	0.875	0.331	-0.018	0.143
Lowest quintile of bilateral tariffs (binary)	0.222	0.416	0.032	0.271
Second quintile of bilateral tariffs (binary)	0.203	0.402	0.008	0.363
Third quintile of bilateral tariffs (binary)	0.187	0.390	-0.012	0.395
Fourth quintile of bilateral tariffs (binary)	0.190	0.392	-0.011	0.396
Highest quintile of bilateral tariffs (binary)	0.198	0.399	-0.017	0.322
Log bilateral distance	3.907	1.487	-	-
Non-contiguity (binary)	0.976	0.152	-	-
No common language (binary)	0.836	0.371	-	-
No colonial relationship (binary)	0.878	0.327	-	-
No common colonizer (binary)	0.982	0.133	-	-

Table 3 - Regression results for variants of Specification 1

			Model 1A Nonlin. multilat. resistance	Model 1B Linearized multilat. Resistance	Model 1C Nonlin. multilat. resistance	Model 1D Linearized multilat. Resistance
				Extensive margin		
Variables in ln f_{ijt}	Acronym	Parameter	(Dependent is Bernoully response variable V_{ijt})		(V_{ijt} is treated exogenously)	
PTA non-membership (binary)	ln χ_1 + ln ζ_1	$\beta_1 + \alpha_1$	-0.366 ***	-0.521 ***	-	-
			0.047	0.040	-	-
Log bilateral distance	ln χ_2 + ln ζ_2	$\beta_2 + \alpha_2$	-0.695 ***	-0.545 ***	-	-
			0.012	0.015	-	-
Non-contiguity (binary)	ln χ_3 + ln ζ_3	$\beta_3 + \alpha_3$	1.126 ***	1.902 ***	-	-
			0.114	0.121	-	-
No common language (binary)	ln χ_4 + ln ζ_4	$\beta_4 + \alpha_4$	-0.243 ***	-0.651 ***	-	-
			0.044	0.046	-	-
No colonial relationship (binary)	ln χ_5 + ln ζ_5	$\beta_5 + \alpha_5$	-0.181	3.379 ***	-	-
			0.138	0.135	-	-
No common colonizer (binary)	ln χ_6 + ln ζ_6	$\beta_6 + \alpha_6$	0.137 ***	-0.217 ***	-	-
			0.049	0.051	-	-
Lagged dependent variable	$V_{ij,t-1}$	δ	1.421 ***	1.248 ***	-	-
			0.013	0.013	-	-
Initial condition	$V_{ij,0}$	λ_{V0}	5.133 ***	4.096 ***	-	-
			0.050	0.055	-	-
Constant		β_0	1.164 ***	0.159	-	-
			0.165	0.166	-	-
Variables in $(1-\sigma)$ ln τ_{ijt}	Acronym	Parameter	Intensive margin (Dependent variable is ln X_{ijt})			
PTA membership (binary)	ln ζ_1	α_1	-0.548 ***	-0.760 ***	-0.451 ***	-0.356 ***
			0.026	0.029	0.027	0.030
Log bilateral distance	ln ζ_2	α_2	-0.448 ***	-0.791 ***	-0.478 ***	-0.724 ***
			0.009	0.017	0.013	0.018
Non-contiguity (binary)	ln ζ_3	α_3	-2.413 ***	-0.189 *	-2.719 ***	-0.711 ***
			0.094	0.100	0.122	0.106
No common language (binary)	ln ζ_4	α_4	-0.303 ***	-1.081 ***	-0.313 ***	-1.343 ***
			0.039	0.040	0.052	0.052
No colonial relationship (binary)	ln ζ_5	α_5	-2.199 ***	2.192 ***	-1.920 ***	1.631 ***
			0.095	0.073	0.140	0.099
No common colonizer (binary)	ln ζ_6	α_6	-0.489 ***	0.178 ***	-0.573 ***	-0.659 ***
			0.043	0.051	0.060	0.060
Constant		α_0	9.699 ***	4.015 ***	9.733 ***	4.418 ***
			0.117	0.017	0.176	0.018
$(\sigma_{V,\eta})^2$		$(\sigma_{V,\eta})^2$	2.221 ***	2.366 ***	-	-
$(\sigma_{X,\eta})^2$		$(\sigma_{X,\eta})^2$	1.954 ***	1.969 ***	2.356 ***	2.101 ***
ρ_η		ρ_η	0.334 ***	0.572 ***	-	-
$(\sigma_{X,\varepsilon})^2$		$(\sigma_{X,\varepsilon})^2$	1.262	1.184	1.131	1.120
ρ_ε		ρ_ε	-0.368 ***	-0.114 ***	-	-

Notes: The total number of observations is 135,300 out of which exhibits 75,609 strictly positive trade flows. ***, **, and * indicate significance levels of 1%, 5%, and 10%, respectively, using two-tailed test statistics. Figures below coeffcients are standard errors. Significance levels of variances, ρ_η, and ρ_ε are based on transformed statistics.

Table 4 - Regression results for variants of Specification 2

Determinants of bilateral exports			Model 2A Nonlin. multilat. resistance	Model 2B Linearized multilat. Resistance	Model 2C Nonlin. multilat. resistance	Model 2D Linearized multilat. Resistance
Variables in ln f_{ijt}	Acronym	Parameter	Extensive margin (Dependent is Bernoully response variable V_{ijt})		(V_{ijt} is treated exogenously)	
Lowest quintile of bilateral tariffs (binary)	ln χ_1 + ln ζ_1	$\beta_1 + \alpha_1$	Basis	Basis	-	-
			Basis	Basis	-	-
Second quintile of bilateral tariffs (binary)	ln χ_2 + ln ζ_2	$\beta_2 + \alpha_2$	-0.300 ***	-0.362 ***	-	-
			0.026	0.029	-	-
Third quintile of bilateral tariffs (binary)	ln χ_3 + ln ζ_3	$\beta_3 + \alpha_3$	-0.670 ***	-0.581 ***	-	-
			0.028	0.030	-	-
Fourth quintile of bilateral tariffs (binary)	ln χ_4 + ln ζ_4	$\beta_4 + \alpha_4$	-0.869 ***	-0.789 ***	-	-
			0.028	0.031	-	-
Highest quintile of bilateral tariffs (binary)	ln χ_5 + ln ζ_5	$\beta_5 + \alpha_5$	-0.672 ***	-0.654 ***	-	-
			0.029	0.032	-	-
Log bilateral distance	ln χ_6 + ln ζ_6	$\beta_6 + \alpha_6$	-0.655 ***	-0.601 ***	-	-
			0.011	0.015	-	-
Non-contiguity (binary)	ln χ_7 + ln ζ_7	$\beta_7 + \alpha_7$	1.011 ***	1.900 ***	-	-
			0.142	0.145	-	-
No common language (binary)	ln χ_8 + ln ζ_8	$\beta_8 + \alpha_8$	-0.245 ***	-0.646 ***	-	-
			0.042	0.049	-	-
No colonial relationship (binary)	ln χ_9 + ln ζ_9	$\beta_9 + \alpha_9$	-0.064	3.281	-	-
			0.152	0.156	-	-
No common colonizer (binary)	ln χ_{10} + ln ζ_{10}	$\beta_{10} + \alpha_{10}$	0.156 ***	-0.252 ***	-	-
			0.053	0.055	-	-
Lagged dependent variable	$V_{ij,t-1}$	δ	1.394 ***	1.225 ***	-	-
			0.013	0.013	-	-
Initial condition	$V_{ij,0}$	λ_{V0}	4.768 ***	4.102 ***	-	-
			0.051	0.062	-	-
Constant		β_0	1.242 ***	0.526 ***	-	-
			0.188	0.169	-	-
Variables in (1-σ) ln τ_{ijt}	Acronym	Parameter	Intensive margin (Dependent variable is ln X_{ijt})			
Lowest quintile of bilateral tariffs (binary)	ln ζ_1	α_1	Basis	Basis	Basis	Basis
			Basis	Basis	Basis	Basis
Second quintile of bilateral tariffs (binary)	ln ζ_2	α_2	-0.160 ***	-0.180 ***	-0.141 ***	-0.102 ***
			0.020	0.022	0.020	0.021
Third quintile of bilateral tariffs (binary)	ln ζ_3	α_3	-0.247 ***	-0.226 ***	-0.255 ***	-0.136 ***
			0.023	0.024	0.022	0.024
Fourth quintile of bilateral tariffs (binary)	ln ζ_4	α_4	-0.397 ***	-0.236 ***	-0.419 ***	-0.189 ***
			0.024	0.026	0.023	0.026
Highest quintile of bilateral tariffs (binary)	ln ζ_5	α_5	-0.414 ***	-0.155 ***	-0.436 ***	-0.140 ***
			0.025	0.027	0.024	0.027
Log bilateral distance	ln ζ_6	α_6	-0.472 ***	-0.862 ***	-0.492 ***	-0.750 ***
			0.010	0.018	0.013	0.018
Non-contiguity (binary)	ln ζ_7	α_7	-2.645 ***	-0.539 ***	-2.793 ***	-0.781 ***
			0.129	0.099	0.121	0.106
No common language (binary)	ln ζ_8	α_8	-0.321 ***	-1.166 ***	-0.326 ***	-1.363 ***
			0.044	0.043	0.051	0.052
No colonial relationship (binary)	ln ζ_9	α_9	-2.088 ***	2.336 ***	-1.883 ***	1.627 ***
			0.119	0.072	0.140	0.099
No common colonizer (binary)	ln ζ_{10}	α_{10}	-0.450 ***	0.144 ***	-0.588 ***	-0.682 ***
			0.047	0.050	0.060	0.060
Constant		α_0	9.455 ***	4.035 ***	9.638 ***	4.419 ***
			0.129	0.018	0.176	0.018
$(\sigma_{V,\eta})^2$		$(\sigma_{V,\eta})^2$	2.105 ***	2.369 ***		
$(\sigma_{X,\eta})^2$		$(\sigma_{X,\eta})^2$	1.950 ***	1.966 ***	2.347 ***	2.106 ***
ρ_{η}		ρ_{η}	0.264 ***	0.554 ***		
$(\sigma_{X,\varepsilon})^2$		$(\sigma_{X,\varepsilon})^2$	1.277	1.183	1.152	1.121
ρ_{ε}		ρ_{ε}	-0.409 ***	-0.111 ***		

Notes: The total number of observations is 135,300 out of which exhibits 75,609 strictly positive trade flows. ***, **, and * indicate significance levels of 1%, 5%, and 10%, respectively, using two-tailed test statistics. Figures below coeffcients are standard errors. Significance levels of variances, ρ_{η}, and ρ_{ε} are based on transformed statistics.

Table 5 - Average three-year change in indicator variables for bilateral trade-weighted tariff quintiles and other variables (171 countries; 1992, 1995, 1998, 2001, 2004)

Quintiles	All pairs (as in Table 2)	Within Africa	Within Americas	Within Asia	Within Europe	Within Pacific
Quintile 1 (lowest)	3.179	1.431	3.985	4.063	10.139	0.000
Quintile 2	0.753	-0.616	-0.294	0.875	2.469	0.000
Quintile 3	-1.157	-1.829	-0.643	-1.075	-5.941	0.000
Quintile 4	-1.059	-1.249	-0.331	-1.725	-4.645	0.000
Quintile 5 (highest)	-1.716	0.272	-2.718	-2.138	-2.022	0.000
Induced average three-year change of						
$\tau_{ijt}^{1-\sigma}$ using Model 2A	1.692	1.280	1.267	1.595	2.343	2.343
$\tau_{ijt}^{1-\sigma}$ using Model 2B	1.710	1.288	1.663	1.412	2.681	1.516
f_{ijt} using Model 2A	-10.897	-18.168	-5.146	-9.601	-6.116	-18.894
f_{ijt} using Model 2B	-10.924	-18.172	-5.269	-9.605	-6.132	-18.848
Observed/computed average three-year change of						
L_{it}	4.884	7.542	4.489	5.757	0.742	5.136
a_{it}	-5.859	-2.841	-5.621	-8.122	-7.964	-4.014