Gravity Redux: Measuring International Trade Costs with Panel Data

Dennis Novy

No 861

WARWICK ECONOMIC RESEARCH PAPERS

DEPARTMENT OF ECONOMICS

THE UNIVERSITY OF WARWICK

Gravity Redux: Measuring International Trade Costs with Panel Data*

Dennis Novy[†]
University of Warwick

November 2008

Abstract

Barriers to international trade are known to be large. But have they become smaller over time? Building on the gravity framework by Anderson and van Wincoop (2003), I derive an analytical solution for time-varying multilateral resistance variables that can be related to observable trade data. This solution makes it possible to infer time-varying bilateral trade costs directly from the model's gravity equation without imposing arbitrary trade cost functions. As an illustration, I show that U.S. trade costs with major trading partners declined on average by about 40 percent between 1970 and 2000, with Mexico and Canada experiencing the biggest reductions.

JEL classification: F10, F15
Keywords: Trade Costs, Gravity, Multilateral Resistance, Panel Data

*I am grateful to participants at the 2007 NBER Summer Institute (International Trade and Investment), in particular James Harrigan, David Hummels, Nuno Limão and Peter Neary. I am also grateful to Iwan Barankay, Jeffrey Bergstrand, Natalie Chen, Alejandro Cuñat, Robert Feenstra, David Jacks, Chris Meissner, Niko Wolf, Adrian Wood, seminar participants at Oxford University, the University of Western Ontario and at the European Trade Study Group.

[†]Department of Economics, University of Warwick, Coventry CV4 7AL, United Kingdom. d.novy@warwick.ac.uk and http://www2.warwick.ac.uk/fac/soc/economics/staff/faculty/novy/

1 Introduction

Barriers to international trade are large and they consist of a variety of components. These include transportation costs and tariffs but also components that are rather difficult to observe such as language barriers, informational costs and bureaucratic red tape. These trade costs impede international trade flows and it is therefore important to measure them. It would be desirable to collect direct data on each component and then add up the individual components to obtain a summary measure of trade costs. But in practice this approach is hardly feasible because of data limitations. In this paper I propose an alternative way of measuring trade costs.

Instead of collecting direct data on trade costs I develop a methodology that infers trade costs indirectly from trade data. This methodology is easy to implement and yields a micro-founded measure of bilateral trade costs at the country pair level that varies over time. I obtain this trade cost measure based on the gravity equation framework developed by Anderson and van Wincoop (2003). Gravity equations are the workhorse model of international trade and have been used by economists for many decades to relate bilateral trade flows to bilateral trade cost proxies such as distance. They can be derived from a large number of theoretical models and have one of the strongest empirical track records in economics (see Evenett and Keller, 2002). But in their highly influential paper, Anderson and van Wincoop (2003) demonstrate that it is not only *bilateral* trade barriers but also *multilateral* trade barriers that determine the trade flows between two countries. This crucial insight about multilateral trade barriers is the motivation for deriving the trade cost measure from the Anderson and van Wincoop (2003) framework.

To illustrate the importance of multilateral trade barriers, consider the example of trade between the U.S. and Canada. U.S.-Canadian trade is not only influenced by their bilateral barrier but also by their trade barriers with other countries. To see this point, suppose that U.S. trade barriers go down with all countries in the world except for Canada (that is, the U.S. multilateral trade barrier goes down). In that case some U.S. trade will be diverted away from Canada towards other countries although the bilateral U.S.-Canadian trade barrier itself has not changed. My trade cost measure is able to separate the bilateral barrier from these multilateral effects.

The contribution of the paper is threefold. First, building on the gravity model by Anderson and van Wincoop (2003) I derive an analytical solution for time-varying multilateral trade barriers, or *multilateral resistance* variables. This solution is useful because it relates the unobservable multilateral trade barriers to observable trade data. In particular, I show that multilateral resistance is a function of how much a country trades with itself, that is, intranational trade flows. Intuitively, the more a country trades with itself, the higher must be the trade barriers it faces on international markets. Multilateral trade barriers have been acknowledged for some time, for example by Anderson (1979) and Bergstrand (1985). But so far it has been either impossible or very cumbersome to solve for them. I overcome this problem by relating them to observable data.

Second, with the solution for multilateral resistance variables at hand, I am able to analytically solve the model's gravity equation for the micro-founded bilateral trade cost measure. Since this trade cost measure is a function of observable trade data, it can be easily implemented with time series and panel data to track the changes of trade costs over time. This approach substantially facilitates the inference of time-varying trade costs from trade data. It generalizes the approach of Anderson and van Wincoop (2003) who only consider cross-sectional data.

As trade costs are a function of observable trade data, I do not need to assume any particular trade cost function. In contrast, every gravity regression implicitly assumes such a trade cost function by focusing on certain trade cost proxies such as geographical distance as explanatory variables. Moreover, the trade cost measure does not impose bilateral trade cost symmetry. It represents an average of bilateral trade barriers in both directions and it is therefore consistent with asymmetric trade costs.

The trade cost measure captures a wide range of trade cost components including those that are not typically considered in standard gravity regressions. For example, the measure can capture informational trade costs as identified by Portes and Rey (2005) as well as hidden transaction costs due to poor security highlighted by Anderson and Marcouiller (2002). It is therefore a comprehensive measure of trade costs that reflects a great variety of trade frictions. It can be interpreted as a 'gravity residual' that compares actual trade flows to those predicted in the absence of all trade frictions. In that sense its nature is related to the literature on missing trade that juxtaposes actual and predicted trade flows (see Trefler, 1995).

As an illustration I compute U.S. bilateral trade costs with a number of major trading partners. Over the period 1970-2000 U.S. trade costs declined by about 40 percent, consistent with improvements in transportation and communication technology and the formation of free trade agreements such at NAFTA. The level of trade costs in 2000, expressed as a tariff equivalent, is lowest with Canada at 25 percent, followed by Mexico at 33 percent. These levels are in the same overall range as those reported by Anderson and van Wincoop (2004) for the year 1993. The innovation of my approach is to produce such estimates not only for a cross section but also over time. This is possible because trade costs depend explicitly on observable time-varying trade data as opposed to time-invariant trade cost proxies.

The third contribution of the paper is to provide a simple analytical framework for explaining the growth of trade. I decompose the growth of bilateral trade into three distinct contributions – the growth of income, the decline of bilateral trade barriers and the decline of multilateral resistance. In an application to U.S. trade data over the period 1970-2000, I find that income growth explains the majority of U.S. trade growth. The decline of bilateral trade barriers is the second biggest contribution but this contribution varies considerably across trading partners. For example, the decline of bilateral trade barriers is about twice as important for explaining the growth of trade with Mexico as it is for explaining the growth of trade with Japan. My results are consistent with those of Baier and Bergstrand (2001) who argue that two-thirds of the growth in trade amongst OECD countries between 1958 and 1988 can be explained by the growth of income. But the innovation of my decomposition is to explicitly account for the role of multilateral resistance.

The Anderson and van Wincoop (2003) gravity framework has attracted a lot of attention in the literature. Baier and Bergstrand (2007) show that in gravity applications the nonlinear multilateral resistance terms can be approximated by a log-linear Taylor-series expansion. Instead of an approximation my approach yields an analytical solution for the multilateral resistance terms that is easy to implement. Balistreri and Hillberry (2007) argue that Anderson and van Wincoop's (2003) solution of the border puzzle critically hinges on the assumption of bilateral trade cost symmetry. In contrast, I do not constrain bilateral trade costs to be symmetric and focus on the average of bilateral trade barriers in both directions. This approach is consistent with underlying trade cost asymmetries.

The trade cost measure that I derive on the basis of the Anderson and van Wincoop (2003) framework is related to the 'freeness of trade' measure in the New Economic Geography literature. The freeness measure captures the inverse of trade costs so that a high value corresponds to low trade barriers (see Fujita, Krugman and Venables, 1999; Head and Ries, 2001; Baldwin, Forslid, Martin, Ottaviano and Robert-Nicoud, 2003; Head and Mayer, 2004). My paper points out that there is a direct link between this literature and the Anderson and van Wincoop (2003) gravity framework. In particular, I focus on the role of multilateral resistance and show how it can be related to observable data.

Finally, several authors present direct measures of trade costs (see Anderson and van Wincoop, 2004, for a survey). Limão and Venables (2001) employ data on the cost of shipping a standard 40-foot container from Baltimore, Maryland, to various destinations in the world, showing that transport costs are significantly increased by poor infrastructure and adverse geographic features such as being landlocked. Hummels (2007) examines the costs of ocean shipping and air transportation. Kee, Nicita and Olarreaga (2008) propose a trade restrictiveness index that is based on observable tariff and non-tariff barriers. They show that tariffs alone are a poor indicator of trade restrictiveness as non-tariff barriers also provide a considerable degree of trade protection. I view such direct measures of trade costs as complements to indirect trade cost measures that are inferred from trade flows. Direct measures have the advantage of being more precise on the particular trade cost components that they capture. But their use is often restricted by data limitations and by the fact that many trade cost components are unobservable.

The paper is organized as follows. Building on the model by Anderson and van Wincoop (2003) I show in Section 2 how to derive an analytical solution for multilateral resistance variables as a function of observable data. I also show how this solution can be used to solve the model's gravity equation for the micro-founded measure of bilateral trade costs. As an illustration I present U.S. bilateral trade costs for a number of major trading partners. In Section 3 I decompose the growth of bilateral trade into the growth of income and changes in trade costs. Section 4 demonstrates why estimates of changes in trade barriers over time are generally biased if multilateral resistance is misspecified as a constant. Section 5 provides a brief discussion of the results. Section 6 concludes.

2 International Trade with Trade Costs

2.1 The Anderson and van Wincoop Gravity Model

Anderson and van Wincoop (2003) develop a multi-country general equilibrium model of international trade. Each country is endowed with a single good that is differentiated from those produced by other countries. Optimizing individual consumers enjoy consuming a large variety of domestic and foreign goods. Their preferences are assumed to be identical across countries and are captured by constant elasticity of substitution utility.

As the key element in their model, Anderson and van Wincoop (2003) introduce exogenous bilateral trade costs. When a good is shipped from country i to j, bilateral variable transportation costs and other variable trade barriers drive up the cost of each unit shipped.[1] As a result of trade costs, goods prices differ across countries. Specifically, if p_i is the net supply price of the good originating in country i, then $p_{ij} = p_i t_{ij}$ is the price of this good faced by consumers in country j, where $t_{ij} \geq 1$ is the gross bilateral trade cost factor (one plus the tariff equivalent).

Based on this framework Anderson and van Wincoop (2003) derive a micro-founded gravity equation with trade costs:

$$x_{ij} = \frac{y_i y_j}{y^W} \left(\frac{t_{ij}}{\Pi_i P_j} \right)^{1-\sigma} \tag{1}$$

[1] Modeling trade costs in this way is well established in the literature. It is consistent with the iceberg formulation of trade costs that portrays trade costs as if an iceberg were shipped across the ocean and partly melted in transit (e.g., Samuelson, 1954, and Krugman, 1980).

x_{ij} denotes nominal exports from i to j, y_i is nominal income of country i and y^W is world income defined as $y^W \equiv \sum_j y_j$. $\sigma > 1$ is the elasticity of substitution across goods. Π_i and P_j are country i's and country j's price indices.

The gravity equation implies that all else being equal, bigger countries trade more with each other. Bilateral trade costs t_{ij} decrease bilateral trade but they have to be measured against the price indices Π_i and P_j.[2] Anderson and van Wincoop (2003) call these price indices *multilateral resistance* variables because they include trade costs with all other partners and can be interpreted as average trade costs. Their exact expressions are given by

$$\Pi_i^{1-\sigma} = \sum_j P_j^{\sigma-1} \theta_j t_{ij}^{1-\sigma} \quad \forall i \tag{2}$$

$$P_j^{1-\sigma} = \sum_i \Pi_i^{\sigma-1} \theta_i t_{ij}^{1-\sigma} \quad \forall j \tag{3}$$

where θ_j is the world income share of country j defined as $\theta_j \equiv y_j / y^W$. Π_i is the *outward* multilateral resistance variable as it includes bilateral trade costs t_{ij} summed over and weighted by all destination countries j, whereas P_j is the *inward* multilateral resistance variable as it includes bilateral trade costs t_{ij} summed over and weighted by all origin countries i. Thus, an important insight from gravity equation (1) is that bilateral trade flows do not only depend on the bilateral trade barrier but also on the multilateral trade barriers of the two countries involved. What matters is the relative trade barrier.

2.2 The Link between Multilateral Resistance and Intranational Trade

It has been a problem in the literature to find appropriate expressions for the multilateral resistance variables in equations (2) and (3). Anderson and van Wincoop (2003) point out that in general Π_i and P_j should not be interpreted as consumer price indices. For example, a home bias in preferences would yield the same gravity equation as (1) and the same expressions for Π_i and P_j as in equations (2) and (3). But then Π_i and P_j would include the nonpecuniary home bias and could therefore no longer be regarded as consumer price indices.

Instead, Anderson and van Wincoop (2003) assume that bilateral trade costs are a function of two particular trade cost proxies – a border barrier and geographical distance. In particular, they assume the trade cost function $t_{ij} = b_{ij} d_{ij}^{\rho}$ where b_{ij} is a border-related indicator variable, d_{ij} is bilateral distance and ρ is the distance elasticity. In addition, they

[2] To obtain this result Anderson and van Wincoop (2003) adopt a useful normalization.

simplify the model by assuming that bilateral trade costs are symmetric (i.e., $t_{ij} = t_{ji}$). Under the symmetry assumption it follows that outward and inward multilateral resistance are the same (i.e., $\Pi_i = P_i$). Thus, conditioning on these additional assumptions, Anderson and van Wincoop (2003) find an implicit solution for multilateral resistance based on (2) and (3).

But there are a number of drawbacks associated with the additional assumptions.[3] First, the chosen trade cost function might be misspecified. Its functional form might be incorrect and it might omit important trade cost determinants such as tariffs. Second, bilateral trade costs might be asymmetric, for example if one country imposes higher tariffs than the other. Third, in practice trade barriers are time-varying, for example when countries phase out tariffs. Time-invariant trade cost proxies such as distance are therefore hardly useful in capturing trade cost changes over time.

In what follows, I propose a method that helps to overcome these drawbacks by deriving an *analytical* solution for multilateral resistance variables. This method does not rely on any particular trade cost function and it does not impose trade cost symmetry. Instead, trade costs are inferred from time-varying trade data that are readily observable.

Intuitively, my method makes use of the insight that a change in bilateral trade barriers does not only affect *international* trade but also *intranational* trade. For example, suppose that country i's trade barriers with all other countries increase. In that case, some of the goods that i used to ship to foreign countries are now consumed domestically, i.e., intranationally. It is therefore not only the extent of international trade that depends on trade barriers with the rest of the world but also the extent of intranational trade.

This can be seen formally by using gravity equation (1) to find an expression for country i's intranational trade

$$x_{ii} = \frac{y_i y_i}{y^W} \left(\frac{t_{ii}}{\Pi_i P_i} \right)^{1-\sigma} \tag{4}$$

where t_{ii} represents intranational trade costs, for example domestic transportation costs. Equation (4) can be solved for the product of outward and inward multilateral resistance as

$$\Pi_i P_i = \left(\frac{x_{ii}/y_i}{y_i/y^W} \right)^{\frac{1}{(\sigma-1)}} t_{ii} \tag{5}$$

As an example suppose two countries i and j face the same domestic trade costs $t_{ii} = t_{jj}$ and are of the same size $y_i = y_j$ but country i is a more closed economy, that is, $x_{ii} > x_{jj}$. It follows directly from (5) that multilateral resistance is higher for country i ($\Pi_i P_i > \Pi_j P_j$). Equation (5) implies that for given t_{ii} it is easy to measure the change in multilateral resistance over time as it does not depend on time-invariant trade cost proxies such as

[3] Anderson and van Wincoop (2003, p. 180) provide a brief discussion on this point.

distance.

Multilateral resistance can also be thought of in terms of trade diversion and trade creation. For given output y_i and y^W and given domestic trade costs t_{ii}, trade diversion from one bilateral trading partner to another does not affect domestic trade x_{ii} and therefore neither multilateral resistance. However, trade creation implies a drop in domestic trade and therefore a drop in multilateral resistance.

2.3 A Micro-Founded Measure of Trade Costs

The explicit solution for the multilateral resistance variables can be exploited to solve the general equilibrium model for bilateral trade costs. Gravity equation (1) contains the product of outward multilateral resistance of one country and inward multilateral resistance of another country, $\Pi_i P_j$, whereas equation (5) provides a solution for $\Pi_i P_i$. It is therefore useful to multiply gravity equation (1) by the corresponding gravity equation for trade flows in the opposite direction, x_{ji}, to obtain a bidirectional gravity equation that contains both countries' outward and inward multilateral resistance variables:

$$x_{ij}x_{ji} = \left(\frac{y_i y_j}{y^W}\right)^2 \left(\frac{t_{ij}t_{ji}}{\Pi_i P_i \Pi_j P_j}\right)^{1-\sigma} \qquad (6)$$

Substituting the solution from equation (5) yields

$$x_{ij}x_{ji} = x_{ii}x_{jj} \left(\frac{t_{ii}t_{jj}}{t_{ij}t_{ji}}\right)^{\sigma-1} \qquad (7)$$

The size variable in gravity equation (7) is not total income $y_i y_j$ as in traditional gravity equations but intranational trade $x_{ii}x_{jj}$. Intranational trade does not only control for the countries' economic size, but according to equation (5) it is also directly linked to multilateral resistance. (7) can be rearranged as

$$\frac{t_{ij}t_{ji}}{t_{ii}t_{jj}} = \left(\frac{x_{ii}x_{jj}}{x_{ij}x_{ji}}\right)^{\frac{1}{\sigma-1}} \qquad (8)$$

As shipping costs between i and j can be asymmetric ($t_{ij} \neq t_{ji}$) and as domestic trade costs can differ across countries ($t_{ii} \neq t_{jj}$), it is useful to take the geometric mean of the barriers in both directions. It is also useful to deduct one to get an expression for the tariff equivalent. I denote the resulting micro-founded trade cost measure as τ_{ij}:

$$\tau_{ij} \equiv \left(\frac{t_{ij}t_{ji}}{t_{ii}t_{jj}}\right)^{\frac{1}{2}} - 1 = \left(\frac{x_{ii}x_{jj}}{x_{ij}x_{ji}}\right)^{\frac{1}{2(\sigma-1)}} - 1 \qquad (9)$$

τ_{ij} measures bilateral trade costs $t_{ij}t_{ji}$ relative to domestic trade costs $t_{ii}t_{jj}$. It therefore does not impose frictionless domestic trade and captures what makes international trade more costly over and above domestic trade.[4]

The intuition behind τ_{ij} is straightforward. If bilateral trade flows $x_{ij}x_{ji}$ increase relative to domestic trade flows $x_{ii}x_{jj}$, it must have become easier for the two countries to trade with each other. This is captured by a decrease in τ_{ij}, and vice versa. The measure thus captures trade costs in an indirect way by inferring them from observable trade flows. Since these trade flows vary over time, trade costs τ_{ij} can be computed not only for cross-sectional data but also for time series and panel data. This is an advantage over the procedure adopted by Anderson and van Wincoop (2003) who only use cross-sectional data.

It is important to stress that the trade cost measure τ_{ij} is consistent with trade cost asymmetries. τ_{ij} indicates the geometric average of the bilateral trade barriers in both directions. The underlying barriers might be asymmetric ($t_{ij} \neq t_{ji}$) and the bilateral trade flows might be unbalanced ($x_{ij} \neq x_{ji}$), but it is not possible to infer the extent of the asymmetry from τ_{ij}.

2.4 Illustration: U.S. Trade Costs

As an illustration of the trade cost measure τ_{ij} derived in equation (9), I compute U.S. bilateral trade costs for a number of major trading partners. I focus on how these bilateral trade costs have evolved over time using annual data for 1970-2000.

All bilateral trade data are taken from the IMF Direction of Trade Statistics (DOTS) and denominated in U.S. dollars. Data for intranational trade x_{ii} are not directly available but can be constructed following the approach by Shang-Jin Wei (1996). Due to market clearing intranational trade can be expressed as total income minus total exports, $x_{ii} = y_i - x_i$, where total exports x_i are defined as the sum of all exports from country i, $x_i \equiv \sum_{j \neq i} x_{ij}$.[5] However, GDP data are not suitable as income y_i because they are based on value added, whereas the trade data are reported as gross shipments. Moreover, GDP data include services that are not covered by the trade data.[6] To get the gross shipment counterpart of GDP excluding services I follow Wei (1996) in constructing y_i as total goods

[4] τ_{ij} can also be interpreted as a measure of the international component of trade costs net of distribution trade costs in the destination country. Formally, suppose total gross shipping costs t_{ij} can be decomposed into gross shipping costs up to the border of j, denoted by t^*_{ij}, times the gross shipping costs within j, denoted by t_{jj}, where t_{jj} is the same for all origins of shipment. It follows $t_{ij} = t^*_{ij}t_{jj}$ and $t_{ji} = t^*_{ji}t_{ii}$ so that $\tau_{ij} = \sqrt{t^*_{ij}t^*_{ji}} - 1$.

[5] See equation (8) in Anderson and van Wincoop (2003).

[6] Anderson (1979) acknowledges nontradable services and models the spending on tradables as ϕy_i, where ϕ is the fraction of total income spent on tradables. But ϕy_i would still be based on value added.

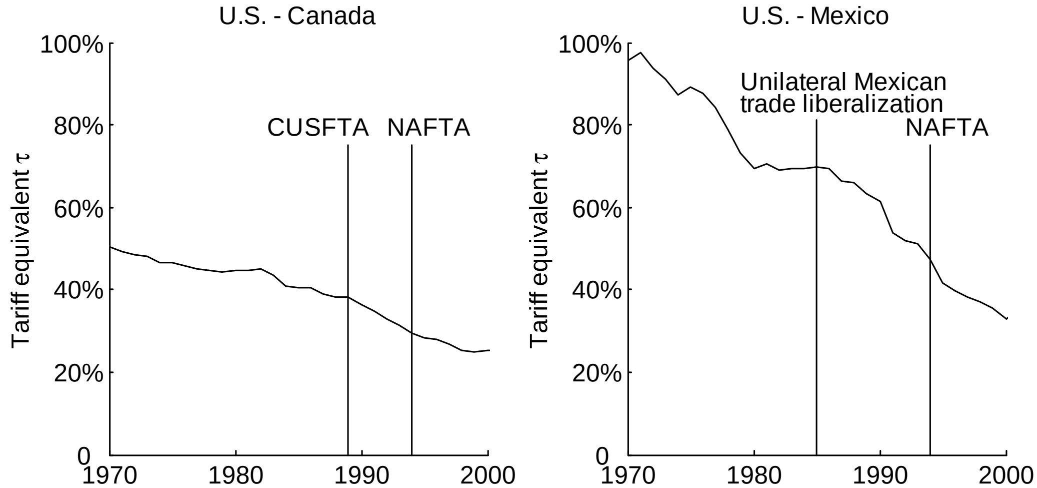

Figure 1: U.S. bilateral trade costs with Canada and Mexico.

production based on the OECD's Structural Analysis (STAN) database.[7] The production data are converted into U.S. dollars by the period average exchange rate taken from the IMF International Financial Statistics (IFS). In order to remain as close to existing trade cost measures as possible, I follow Anderson and van Wincoop (2004) in setting $\sigma = 8$ for the elasticity of substitution. I discuss in Section 5 that the inferred change of trade costs over time is very similar for alternative values of σ.

Figure 1 illustrates U.S. bilateral trade costs with its two biggest trading partners, Canada and Mexico. U.S. trade costs fell dramatically with Mexico (from 96 to 33 percent) and also with Canada (from 50 to 25 percent). The U.S. experienced a clear downward trend in trade costs with both its neighbors already prior to the North American Free Trade Agreement (NAFTA, effective from 1994), the Canada-U.S. Free Trade Agreement (CUSFTA, effective from 1989) and unilateral Mexican trade liberalization (from 1985).[8]

It is important to stress that these numbers represent bilateral relative to domestic trade costs. For example, take the result that U.S.-Canadian trade costs are 25 percent in the year 2000. Suppose that a particular good produced in either the U.S. or Canada costs \$10.00 at the factory gate. Also suppose that domestic wholesale and retail distribution costs are 55 percent (t_{ii}=1.55), which is the representative domestic distribution cost across OECD countries as reported by Anderson and van Wincoop (2004). A domestic

[7] Wei (1996) uses production data for agriculture, mining and total manufacturing. Also see Nitsch (2000).

[8] As pointed out earlier, τ_{ij} is related to the 'freeness of trade' measure in the New Economic Geography literature, see Fujita, Krugman and Venables (1999). For a plot of the inverse freeness measure in a two-country model, see Figure 2 in Head and Ries (2001).

Table 1: U.S. Bilateral Trade Costs

Partner country	*Tariff equivalent τ in %* **1970**	**2000**	*Percentage change*
CANADA	50	25	−50
GERMANY	95	70	−26
JAPAN	85	65	−24
KOREA	107	70	−35
MEXICO	96	33	−66
UK	95	63	−34
Plain average	88	54	−38
Trade-weighted average	74	42	−44

All numbers are in percent and rounded off to integers.
Countries listed are the six biggest U.S. export markets as of 2000.
Computations based on equation (9).

consumer could therefore buy the product for \$15.50, whereas a consumer abroad would have to pay \$19.40 (t_{ij}=1.94=1.55*1.25). This example illustrates that the absolute domestic trade costs (\$5.50=\$15.50-\$10.00) can be substantially bigger than the absolute cost of crossing the border (\$3.90=\$19.40-\$15.50). Of course, this particular example is based on an aggregate average and should be interpreted as such. In practice, trade costs can vary considerably across goods. For instance, perishable goods are more likely to be transported by air freight instead of less expensive truck or ocean shipping.

Table 1 reports the levels and the percentage decline in U.S. bilateral trade costs between 1970 and 2000 with its six biggest export markets as of 2000. In descending order these are Canada, Mexico, Japan, the UK, Germany and Korea.[9] The decline has been most dramatic with Mexico and Canada and has been sizeable with Korea, the UK, Germany and Japan. The trade-weighted average of U.S. trade costs declined by 44 percent between 1970 and 2000, corresponding to an annualized decline of 1.9 percent per year.[10] Its 2000 level stands at 42 percent.

It is important to take into consideration that the trade cost measure τ_{ij} does not only capture trade costs in the narrow sense of transportation costs and tariffs. τ_{ij} also comprises trade cost components such as language barriers and currency barriers. In their survey on trade costs, Anderson and van Wincoop (2004) show that such non-tariff barriers are substantial.

The magnitudes of the bilateral trade costs in Table 1 are entirely consistent with cross-sectional evidence from the previous literature. But the main advantage of τ_{ij} over previous

[9] These six countries are those for which the 2000 share of U.S. exports exceeded 3 percent. Between 1970 and 2000 their combined share of U.S. exports fluctuated between 43 and 58 percent.

[10] $x = -0.019$ is the solution to $42 = 74^*(1+x)^{30}$.

trade cost measures is that τ_{ij} can be easily tracked over time. For the year 1993 only, Anderson and van Wincoop (2004) report a 46 percent tariff equivalent of overall U.S.-Canadian trade costs, compared to 31 percent in Figure 1.[11] The reason why the number reported by Anderson and van Wincoop (2004) is somewhat higher is that they use GDP data as opposed to production data to compute trade costs. In fact, when using GDP data I obtain U.S.-Canadian trade costs of 47 percent for 1993, almost exactly the 46 percent value reported by Anderson and van Wincoop (2004).[12] But GDP data tend to overstate the extent of intranational trade and thus the level of trade costs because they include services.[13] I therefore prefer to follow Wei (1996) in using merchandise production data to match the trade data more accurately.

Eaton and Kortum (2002) report bilateral tariff equivalents based on data for 19 OECD countries in 1990. For countries that are 750-1500 miles apart, an elasticity of substitution of $\sigma = 8$ implies a trade cost range of 58-78 percent, consistent with the magnitudes in Table 1.

In summary, Figure 1 and Table 1 demonstrate that trade costs are large but generally experienced a substantial decline between 1970 and 2000. They exhibit considerable heterogeneity across country pairs that would be masked by a one-fits-all measure of trade costs.[14]

3 Decomposing the Growth of Trade

Bilateral trade has grown strongly for most country pairs in recent years. It is an important question whether this increase in trade is simply the result of secular economic growth or whether the increase can be related to reductions in trade frictions.

The micro-founded gravity equation (6) provides a simple analytical framework to describe the roles of economic growth and trade barrier reductions in determining the growth

[11] Anderson and van Wincoop (2004) calculate the tariff equivalent as the trade-weighted average barrier for trade between U.S. states and Canadian provinces relative to the trade-weighted average barrier for trade within the United States and Canada, using a trade cost function that includes a border-related dummy variable and distance.

[12] For $\sigma = 5$ and $\sigma = 10$ Anderson and van Wincoop (2004, Table 7) report 1993 U.S.-Canadian trade cost tariff equivalents of 91 and 35 percent, respectively. The corresponding numbers based on (9) are 97 and 35 percent when using GDP data and 61 and 24 percent when using production data. See Section 5 for a discussion of σ.

[13] Specifically, intranational trade is given by $x_{ii} = y_i - x_i$. As GDP data include services and as the service share of GDP has continually grown, the use of GDP data for y_i overstates x_{ii} compared to the use of production data despite the fact that imported intermediate goods are included in the trade data (see Helliwell, 2005). Novy (2008) develops a trade cost model with nontradable goods, showing that only the tradable part of output enters the model's micro-founded gravity equation.

[14] For a comparison of the period 1950-2000 to the period 1870-1913 see Jacks, Meissner and Novy (2008).

of bilateral trade. I take logarithms and first differences of equation (6) to arrive at

$$\Delta \ln (x_{ij}x_{ji}) = 2\Delta \ln \left(\frac{y_i y_j}{y^W}\right) + (1-\sigma)\Delta \ln (t_{ij}t_{ji}) - (1-\sigma)\Delta \ln (\Pi_i P_i \Pi_j P_j) \qquad (10)$$

Equation (10) relates the growth of bilateral trade, $\Delta \ln (x_{ij}x_{ji})$, to three driving forces: the growth of the two countries' economies relative to world output, changes in bilateral trade costs, $\Delta \ln (t_{ij}t_{ji})$, and changes in the two countries' multilateral trade barriers, $\Delta \ln (\Pi_i P_i \Pi_j P_j)$. The bilateral trade cost factors $t_{ij}t_{ji}$ are unknown. But we know from equation (9) that the trade cost measure τ_{ij} provides an expression of $t_{ij}t_{ji}$ relative to domestic trade costs $t_{ii}t_{jj}$ as a function of observable trade flows. I therefore substitute τ_{ij} into equation (10) to obtain

$$\Delta \ln (x_{ij}x_{ji}) = 2\Delta \ln \left(\frac{y_i y_j}{y^W}\right) + 2(1-\sigma)\Delta \ln (1+\tau_{ij}) - 2(1-\sigma)\Delta \ln (\Phi_i \Phi_j) \qquad (11)$$

where Φ_i is shorthand for country i's multilateral resistance relative to domestic trade costs

$$\Phi_i = \left(\frac{\Pi_i P_i}{t_{ii}}\right)^{\frac{1}{2}} \qquad (12)$$

The last term in equation (11) thus represents changes in multilateral resistance relative to domestic trade costs. Finally, I divide by the left-hand side to yield

$$100\% = \underbrace{\frac{2\Delta \ln \left(\frac{y_i y_j}{y^W}\right)}{\Delta \ln (x_{ij}x_{ji})}}_{\text{(a)}} + \underbrace{\frac{2(1-\sigma)\Delta \ln (1+\tau_{ij})}{\Delta \ln (x_{ij}x_{ji})}}_{\text{(b)}} - \underbrace{\frac{2(1-\sigma)\Delta \ln (\Phi_i \Phi_j)}{\Delta \ln (x_{ij}x_{ji})}}_{\text{(c)}} \qquad (13)$$

Equation (13) breaks down the growth of bilateral trade into three contributions: (a) the contribution of income growth, (b) the contribution of the decline in bilateral trade costs, and (c) the contribution of the decline in multilateral resistance.[15] If all trade barriers in the world are constant over time, then contributions (b) and (c) are zero and the growth of trade is driven entirely by the growth of income. If bilateral trade costs fall (i.e., $\Delta \ln (1+\tau_{ij}) < 0$), then contribution (b) becomes positive.[16] If multilateral trade

[15]Baier and Bergstrand (2001) further decompose the product of incomes, $y_i y_j$, into income shares and the sum of incomes. Define the bilateral income share as $s_i = y_i/(y_i + y_j)$. It follows $y_i y_j = s_i s_j (y_i + y_j)^2$ and thus $\Delta \ln (y_i y_j) = \Delta \ln (s_i s_j) + 2\Delta \ln (y_i + y_j)$. $\Delta \ln (s_i s_j)$ could then be interpreted as the contribution of income convergence. Also see Helpman (1987), Hummels and Levinsohn (1995) and Debaere (2005). However, after controlling for tariff cuts and transport cost reductions Baier and Bergstrand (2001) find virtually no effect of income convergence on trade growth. In any case this finer decomposition would not affect the contribution of bilateral trade costs and multilateral resistance in equation (13).

[16]Note that $\sigma > 1$. To be precise, a fall in bilateral trade costs also leads to a slight fall in $\Phi_i \Phi_j$ because

Table 2: Decomposing the Growth of U.S. Bilateral Trade

Partner country	*Growth in trade*	Contribution of the growth in income	Contribution of the decline in bilateral trade costs	Contribution of the decline in multilateral resistance	Total
CANADA	609	65.3	+ 42.3	− 7.6	= 100
GERMANY	526	67.1	+ 36.4	− 3.5	= 100
JAPAN	580	79.3	+ 28.3	− 7.6	= 100
KOREA	832	92.3	+ 33.5	− 25.8	= 100
MEXICO	944	54.8	+ 57.4	− 12.2	= 100
UK	578	55.9	+ 43.8	+ 0.3	= 100

Growth between 1970 and 2000. All numbers in percent.
Countries listed are the six biggest U.S. export markets as of 2000.
Computations based on equation (13).

barriers fall (i.e., $\Delta \ln(\Phi_i \Phi_j) < 0$), then contribution (c) becomes negative. This negative contribution is a trade diversion effect. If trade barriers with other countries fall, trade with those countries increases but bilateral trade between i and j decreases.

The decomposition does not depend on the value of the elasticity of substitution σ. Contribution (a) is given by the data. Contribution (b) is also given by the data through equation (9). Likewise, contribution (c) is given by the solution for multilateral resistance in equation (5).[17]

3.1 Illustration: Decomposing the Growth of U.S. Trade

I apply equation (13) to decompose the growth of U.S. bilateral trade. As in Table 1, I consider the six biggest U.S. export markets as of 2000. Table 2 reports the decomposition results.

Table 2 shows that for the period 1970 to 2000 the growth of income can explain more than half of the growth of U.S. bilateral trade. Income growth can explain almost all of the trade growth with Korea (92.3 percent) but only just over 50 percent with Mexico and the UK. The decline of bilateral trade costs on average provides the second most important contribution to the growth of bilateral trade. This contribution is biggest for Mexico (57.4 percent) and smallest for Japan (28.3 percent).

The decline of multilateral trade barriers diverts trade away from the U.S. Take the

multilateral resistance is a weighted average of all bilateral trade costs, see equations (2) and (3). Since the fall in $\Phi_i \Phi_j$ works against the effect of falling bilateral trade costs, contribution (b) slightly overstates their effect but is valid as an approximation.

[17] Equation (9) implies $2(1-\sigma)\Delta \ln(1+\tau_{ij}) = \Delta \ln(x_{ij}x_{ji}) - \Delta \ln(x_{ii}x_{jj})$. Equation (5) implies $2(1-\sigma)\Delta \ln(\Phi_i \Phi_j) = \Delta \ln\left(\frac{y_i/y^W}{x_{ii}/y_i}\right) + \Delta \ln\left(\frac{y_j/y^W}{x_{jj}/y_j}\right)$. It follows that the decomposition in equation (13) is not affected even if σ changes over time.

example of Korea. Korean trade barriers with other countries dropped considerably over time so that the diversion effect is strongly negative for Korea (−25.8 percent). While the decline in bilateral trade costs explains about a third in the growth of trade between Korea and the U.S., the trade-diverting effect of trade cost declines with other countries partially offsets the bilateral improvements so that the overall role of trade costs ($33.5 - 25.8 = 7.7$ percent) is modest compared to other countries in the sample.

The trade diversion effect is actually slightly positive for the UK (+0.3 percent). The positive multilateral resistance effect means that on average multilateral trade barriers for the UK increased over time, making trade with the U.S. relatively more attractive. This result is particular to the UK as a major former colonial power since the UK's traditionally strong trade relationships with former colonies such as Australia and New Zealand became weaker over time.[18]

In summary, Table 2 demonstrates that income growth is the biggest driving force behind the increase in bilateral U.S. trade. This result is consistent with the findings of Baier and Bergstrand (2001) who argue that two-thirds of the growth in trade amongst OECD countries between 1958 and 1988 can be explained by the growth of income.[19] But the innovation of decomposing the growth of trade by equation (13) is to explicitly take multilateral trade barriers into account. Multilateral trade barriers are important because in general equilibrium, the trade flows between any two countries are affected both by bilateral and multilateral trade barriers. As Table 2 shows, multilateral trade barriers play a decisive role in practice and neglecting them would convey a distorted view of the forces that drive the growth of international trade.[20]

4 What Happens When Multilateral Resistance is Misspecified as a Constant?

Many empirical applications are concerned with measuring how trade barriers change over time. For example, Glick and Rose (2002) examine whether joining a currency union improves countries' trade flows over time. Fontagné, Mayer and Zignago (2005) study how

[18] Novy (2008) shows that the trade-enhancing effect of a former colonial relationship was strong in 1970 but gradually tapered off thereafter, becoming insignificant by the year 2000.

[19] Whalley and Xin (2007) calibrate a general equilibrium model of world trade. For a sample of both OECD and non-OECD countries they find that income growth explains 76 percent of the growth of international trade between 1975 and 2004. This finding suggests that trade barrier reductions might have been less important for explaining the trade growth of non-OECD countries.

[20] Another difference is that Baier and Bergstrand (2001) only consider tariffs and transportation costs, whereas trade costs in the context of the Anderson and van Wincoop (2003) model are more broadly defined to include informational, institutional and nontariff barriers to trade.

border-related barriers evolve over time for the U.S., the EU and Japan. Such applications are inherently of interest to policymakers who aim at reducing barriers that impede international trade.

The challenge in such panel data applications is to adequately control for multilateral resistance terms. In gravity equations they are often proxied by time-invariant fixed effects. But clearly, if trade barriers change over time, there is reason to believe that multilateral resistance also changes over time. I now demonstrate why estimates of trade cost changes over time are generally biased if they ignore that multilateral resistance changes over time.

To see the consequences of misspecifying multilateral resistance as a constant I take the trade cost measure from (9)

$$\tau_{ij} = \left(\frac{x_{ii} x_{jj}}{x_{ij} x_{ji}} \right)^{\frac{1}{2(\sigma-1)}} - 1$$

and substitute equation (4) for x_{ii} and x_{jj} to arrive at

$$\tau_{ij} = \left(\frac{\left(y_i y_j / y^W \right)^2}{x_{ij} x_{ji}} \right)^{\frac{1}{2(\sigma-1)}} \left(\frac{\Pi_i P_i \Pi_j P_j}{t_{ii} t_{jj}} \right)^{\frac{1}{2}} - 1 \tag{14}$$

The variables in the second pair of parentheses of (14) are frequently ignored or misspecified in standard gravity equations, that is, multilateral resistance and domestic trade costs are not properly taken into account. But an analytical solution for these terms follows from equation (5) as

$$\left(\frac{\Pi_i P_i}{t_{ii}} \right)^{\frac{1}{2}} = \left(\frac{x_{ii} / y_i}{y_i / y^W} \right)^{\frac{1}{2(\sigma-1)}} = \Phi_i \tag{15}$$

I can therefore compute Φ_i directly from the data without imposing a trade cost function that includes distance or other trade cost proxies.

In order to see the misspecification bias more clearly I rewrite equation (14) as

$$\tau_{ij} = \left(\frac{\left(y_i y_j / y^W \right)^2}{x_{ij} x_{ji}} \right)^{\frac{1}{2(\sigma-1)}} \Phi_i \Phi_j - 1 \tag{16}$$

Likewise, the misspecified counterpart of equation (16) can be written as

$$\widehat{\tau}_{ij} = \left(\frac{\left(y_i y_j / y^W \right)^2}{x_{ij} x_{ji}} \right)^{\frac{1}{2(\sigma-1)}} \widehat{\Phi}_i \widehat{\Phi}_j - 1 \tag{17}$$

where $\widehat{\tau}_{ij}$ denotes the biased trade cost measure and $\widehat{\Phi}_i$ and $\widehat{\Phi}_j$ denote the misspecified multilateral resistance terms. By rearranging equations (16) and (17), taking logarithms and first differences I obtain a simple expression that compares the change in biased trade costs to the change in true trade costs:

$$\Delta \ln (1+\widehat{\tau}_{ij}) - \Delta \ln (1+\tau_{ij}) = \Delta \ln \left(\widehat{\Phi}_i \widehat{\Phi}_j\right) - \Delta \ln (\Phi_i \Phi_j) \tag{18}$$

Equation (18) shows that the difference between the change in biased trade costs and the change in true trade costs, $\Delta \ln (1+\widehat{\tau}_{ij}) - \Delta \ln (1+\tau_{ij})$, equals the difference between the change in the misspecified multilateral resistance terms and the change in the correct multilateral resistance terms, $\Delta \ln \left(\widehat{\Phi}_i \widehat{\Phi}_j\right) - \Delta \ln (\Phi_i \Phi_j)$.

I use equation (18) to examine the effect of misspecifying the multilateral resistance terms as constants. This misspecification is equivalent to assuming $\Delta \ln \left(\widehat{\Phi}_i \widehat{\Phi}_j\right) = 0$.[21] The implication of this misspecification is that if the actual multilateral resistance terms follow a secular trend, then the resulting estimated trend of bilateral trade costs will be biased. Figure 2 illustrates this point. The left-hand side panels plot the correct Φ_i for the U.S., Canada and Korea for the period 1970-2000 as computed on the basis of equation (15).[22] The right-hand side panels plot the true trade costs based on the correct time-varying multilateral resistance variables (solid lines) as well as the biased trade costs based on the misspecified, time-invariant multilateral resistance terms (dashed lines).[23]

As the top part of Figure 2 shows, both the U.S. and the Canadian Φ's prove to be fairly stable over time.[24] This means that for those two countries multilateral resistance $\Pi_i P_i$ and domestic trade costs t_{ii} changed at roughly equal pace. As a result, there is hardly a difference between the correct and incorrect trade costs series in the right-hand side panel.

In contrast, as the bottom part of Figure 2 shows, Korean multilateral resistance declined markedly over time relative to domestic trade costs. The biased U.S.-Korean trade cost series thus fails to reflect the full actual decline.[25] In fact, the biased series only reports a small decline in trade costs from 107 to 98 percent between 1970 and 2000 (dashed line), whereas actual trade costs declined from 107 to 70 percent (solid line, also see

[21] A special case of this misspecification is to ignore the multilateral resistance terms altogether, that is, $\widehat{\Phi}_i = \widehat{\Phi}_j = 1$.

[22] Annual world income y^W is constructed as the combined production data of Belgium, Canada, Denmark, Finland, France, Germany, Italy, Japan, Korea, Mexico, the Netherlands, Norway, Sweden, the UK and the U.S.

[23] In this example the multilateral resistance terms are held constant at their 1970 levels. But this is merely a normalization and does not affect the argument.

[24] Φ_i represents multilateral resistance relative to domestic trade costs (i.e. $t_{ii} \geq 1$), whereas Anderson and van Wincoop (2004, Table 8) normalize trade costs within Maryland to zero (i.e. $t_{ii} = 1$) and report multilateral resistance relative to this trade barrier within Maryland. They therefore obtain multilateral resistance terms for U.S. states and Canadian provinces that are higher than those reported for the U.S. and Canada in Figure 2.

[25] As $\Delta \ln (\Phi_i \Phi_j) < 0$, it follows from equation (18) that $\Delta \ln (1+\widehat{\tau}_{ij}) > \Delta \ln (1+\tau_{ij})$. That is, the decline in $\widehat{\tau}_{ij}$ is not as strong as the decline in τ_{ij}.

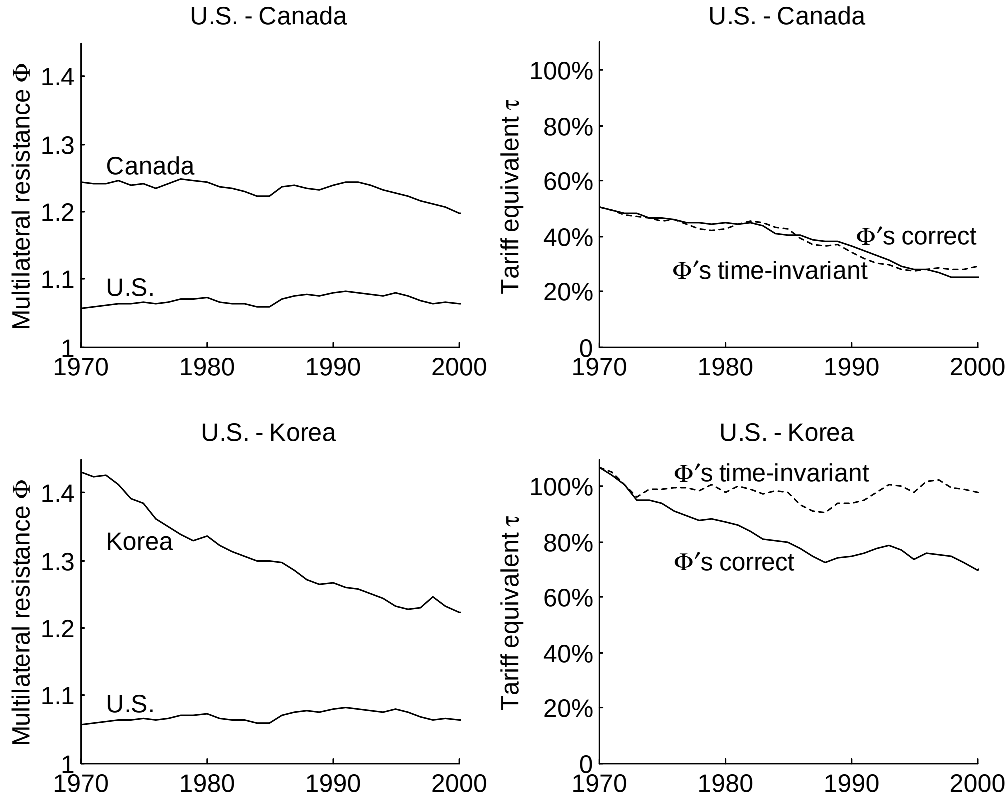

Figure 2: Multilateral resistance variables and U.S. bilateral trade costs based on correct time-varying and incorrect time-invariant multilateral resistance variables.

Table 1). Ignoring the fact that Korean multilateral resistance dropped over time relative to domestic trade costs therefore leads to a miscalculation of the time trend by almost 30 percentage points.

Korea serves as a clear example of a country that has experienced a striking drop in general trade costs and hence a striking drop in its multilateral resistance. The failure to capture the downward trend in multilateral resistance by misspecifying it as a constant results in the failure to capture the downward trend in bilateral trade costs. The intuition rests on the crucial insight of the Anderson and van Wincoop (2003) gravity framework that bilateral trade flows are determined by bilateral relative to multilateral trade barriers. If one underestimates the trend of a country's multilateral barriers, one will also underestimate the trend of its bilateral barriers.

Which is the most likely direction of the bias in practice? Of course, the decrease in multilateral resistance might not be quite as strong for other countries as it is for Korea.

But as long as there is a secular decrease in multilateral resistance, the bias will go in the direction of underestimating the decline in bilateral trade costs.

As Figure 2 illustrates, the extent of the bias is not uniform across country pairs. In gravity applications with panel data the bias can therefore generally not be avoided by using time dummies. Instead, it is important to use time-varying fixed effects at the country or country pair level. In a similar vein, Baldwin and Taglioni (2006) argue for the use of time-varying country fixed effects to control for the fact that multilateral resistance changes over time.[26]

5 Discussion

The elasticity of substitution σ is a crucial parameter in the gravity literature. Anderson and van Wincoop (2004) show that estimates of trade cost *levels* are quite sensitive to the value of σ. The same is of course true for the trade cost levels reported in Table 1. However, it turns out that the *changes* of trade costs over time are hardly affected by the elasticity of substitution. In fact, the decomposition of the growth of trade in Table 2 is not affected by the value of σ at all.

The trade cost levels reported in Table 1 and Figures 1 and 2 are based on $\sigma = 8$, which is in the middle of the common empirical range of 5 to 10 for the elasticity of substitution, as surveyed by Anderson and van Wincoop (2004). For $\sigma = 8$ the trade-weighted average of U.S. bilateral trade costs in Table 1 falls from 74 to 42 percent, a decline of 44 percent. Equation (9) implies that a higher value of σ would lead to lower trade cost levels. Intuitively, a higher elasticity of substitution means that goods are less differentiated and consumers more price-sensitive. The more price-sensitive consumers are, the fewer foreign goods they would buy for a given difference between bilateral and domestic trade costs. In order to match the given empirical trade flows, a higher elasticity of substitution implies that the difference between bilateral and domestic trade costs must be relatively small, that is, τ_{ij} must be relatively low. But although the elasticity of substitution affects the level of τ_{ij}, it hardly affects the change of τ_{ij} over time. For example, in the case of $\sigma = 10$ the trade-weighted average falls from 54 to 31 percent, a similar decline of 42 percent. In the case of $\sigma = 5$ the trade-weighted average falls from 167 to 87 percent, a decline of 48 percent.

It might be the case that the elasticity of substitution has systematically changed over time. Following the approach of Feenstra (1994), Broda and Weinstein (2006) estimate elasticities of substitution based on demand and supply relationships for disaggregated U.S.

[26] Also see Anderson and van Wincoop (2004, p. 732).

imports. When comparing the period 1972-1988 with 1990-2001, they find that the median elasticity fell marginally. But the difference is not significant for all levels of disaggregation and it is unclear whether there has been a significant change in the elasticity at the aggregate level. If it were the case that the aggregate elasticity fell over time, this would suggest that trade costs would have declined less quickly than indicated in Table 1. But quantitatively, this effect would seem unlikely to be large.[27]

The trade cost measure in equation (9) is a comprehensive measure that captures a wide range of trade cost components such as transportation costs and tariffs, but also components that are not directly observable such as the costs associated with language barriers and red tape. It should therefore be regarded as an upper bound that captures all trade cost elements that make international trade more costly over and above domestic trade. Instead, direct measures of specific trade cost components can be seen as a lower bound of trade costs, for example international transportation costs reported by Hummels (2007).

The trade costs are computed on the basis of the model's general equilibrium solution for trade costs. The advantage of this method is that it directly relates trade costs to observable trade data. This obviates the need to impose specific trade cost functions that are implicit in standard gravity applications. Imposed trade cost functions can be problematic in that they heavily rely on time-invariant trade cost proxies such as distance and might omit important trade cost components. The advantage of avoiding arbitrary trade cost functions comes at the cost of a lack of stochastic elements. But a stochastic estimation framework could be easily implemented in a second stage by relating the computed trade costs to common trade cost proxies such as bilateral distance, tariffs, exchange rate volatility etc. This is the approach taken by Jacks, Meissner and Novy (2008). We show that such trade cost proxies are sensibly related to the trade cost measure derived in equation (9).

Lastly, the Anderson and van Wincoop (2003) model, which forms the basis of the trade cost measure, is in many respects a very simple model. It rests on the Armington assumption that each country is endowed with a single differentiated aggregate good. Trade is driven by consumers' love of variety, leading to the core gravity equation. While the gravity model by Anderson and van Wincoop (2003) is arguably one of the most parsimonious trade models of recent years, it is by no means the only one that leads to a gravity equation with trade costs. In fact, my approach of solving the gravity model for the implied trade costs is valid more generally, as isomorphic trade cost measures can be derived from other leading trade models. Chen and Novy (2008) show that a measure akin to τ_{ij} in equation (9) can be derived from the Ricardian trade model by Eaton and Kortum (2002), from

[27] According to Broda and Weinstein (2006, Table IV) the median elasticity fell from 3.7 to 3.1 at the 7-digit level, from 2.8 to 2.7 at the 5-digit level and from 2.5 to 2.2 at the 3-digit level.

Chaney's (2008) extension of the Melitz (2003) heterogeneous firms model to asymmetric countries as well as from the heterogeneous firms model by Melitz and Ottaviano (2008) with a non-CES linear demand system and endogenous markups. As Chen and Novy (2008) discuss, the reason why an isomorphic measure can be derived from such a broad range of theories is related to the fact that they all lead to gravity equations that have a similar structure as equation (6).[28]

6 Conclusion

This paper develops a measure of international trade costs that varies across country pairs and over time. The measure is micro-founded and based on the gravity framework by Anderson and van Wincoop (2003). In particular, I derive an analytical solution for multilateral resistance variables that depends on intranational trade flows. This solution is useful because it relates the unobservable multilateral trade barriers to observable trade data. Given this expression for time-varying multilateral resistance variables, I analytically solve the model's gravity equation for the micro-founded bilateral trade cost measure. This trade cost measure is a function of observable trade data and can therefore be implemented easily with time series and panel data to track the changes of trade costs over time. This approach obviates the need to impose specific trade cost functions that rely on trade cost proxies such as distance.

As an illustration I compute U.S. bilateral trade costs for a number of major trading partners. I find that the trade-weighted average of these trade costs declined by about 40 percent between 1970 and 2000. The decline of U.S. trade costs has been particularly strong with its neighbors Mexico and Canada. I also decompose the growth of U.S. bilateral trade and find that income growth is the single most important driving factor, followed by declines in bilateral trade costs. On the contrary, declines in multilateral resistance slow down the growth of bilateral trade by diverting trade to other countries.

[28] As many authors have pointed out, gravity equations are consistent with various competing trade models (Deardorff, 1998; Feenstra, Markusen and Rose, 2001; Evenett and Keller, 2002; Feenstra, 2004).

References

Anderson, J., 1979. A Theoretical Foundation for the Gravity Equation. *American Economic Review* 69, pp. 106-116.

Anderson, J., Marcouiller, D., 2002. Insecurity and the Pattern of Trade: An Empirical Investigation. *Review of Economics and Statistics* 84, pp. 342-352.

Anderson, J., van Wincoop, E., 2003. Gravity with Gravitas: A Solution to the Border Puzzle. *American Economic Review* 93, pp. 170-192.

Anderson, J., van Wincoop, E., 2004. Trade Costs. *Journal of Economic Literature* 42, pp. 691-751.

Baier, S., Bergstrand, J., 2001. The Growth of World Trade: Tariffs, Transport Costs, and Income Similarity. *Journal of International Economics* 53, pp. 1-27.

Baier, S., Bergstrand, J., 2007. Bonus Vetus OLS: A Simple Method for Approximating International Trade-Cost Effects Using the Gravity Equation. Mimeo, University of Notre Dame.

Baldwin, R., Forslid, R., Martin, P., Ottaviano, G., Robert-Nicoud, F., 2003. The Core-Periphery Model: Key Features and Effects. In: The Monopolistic Competition Revolution in Retrospect, edited by S. Brakman and B. Heijdra, Cambridge University Press.

Baldwin, R., Taglioni, D., 2006. Gravity for Dummies and Dummies for Gravity Equations. NBER Working Paper #12516.

Balistreri, E., Hillberry, R., 2007. Structural Estimation and the Border Puzzle. *Journal of International Economics* 72, pp. 451-463.

Bergstrand, J., 1985. The Gravity Equation in International Trade. Some Microeconomic Foundations and Empirical Evidence. *Review of Economics and Statistics* 67, pp. 474-481.

Broda, C., Weinstein, D., 2006. Globalization and the Gains from Variety. *Quarterly Journal of Economics* 121, pp. 541-585.

Chaney, T., 2008. Distorted Gravity: The Intensive and Extensive Margins of International Trade. *American Economic Review* 98, pp. 1707-1721.

Chen, N., Novy, D., 2008. International Trade Integration: A Disaggregated Approach. Mimeo, University of Warwick.

Deardorff, A., 1998. Determinants of Bilateral Trade: Does Gravity Work in a Neoclassical World? In: The Regionalization of the World Economy, edited by J. Frankel, University of Chicago Press.

Debaere, P., 2005. Monopolistic Competition and Trade, Revisited: Testing the Model without Testing for Gravity. *Journal of International Economics* 66, pp. 249-266.

Eaton, J., Kortum, S., 2002. Technology, Geography and Trade. *Econometrica* 70, pp. 1741-1779.

Evenett, S., Keller, W., 2002. On Theories Explaining the Success of the Gravity Equation. *Journal of Political Economy* 110, pp. 281-316.

Feenstra, R., 1994. New Product Varieties and the Measurement of International Prices. *American Economic Review* 84, pp. 157-177.

Feenstra, R., 2004. Advanced International Trade – Theory and Evidence. Princeton University Press.

Feenstra, R., Markusen, J., Rose, A., 2001. Using the Gravity Equation to Differentiate among Alternative Theories of Trade. *Canadian Journal of Economics* 34, pp. 430-447.

Fontagné, L., Mayer, T., Zignago, S., 2005. Trade in the Triad: How Easy is the Access to Large Markets? *Canadian Journal of Economics* 38, pp. 1401-1430.

Fujita, M., Krugman, P., Venables, A., 1999. The Spatial Economy – Cities, Regions, and International Trade. MIT Press.

Glick, R., Rose, A., 2002. Does a Currency Union Affect Trade? The Time-Series Evidence. *European Economic Review* 46, pp. 1125-1151.

Head, K., Mayer, T., 2004. The Empirics of Agglomeration and Trade. In: Handbook of Regional and Urban Economics: Cities and Geography, Volume 4, North-Holland.

Head, K., Ries, J., 2001. Increasing Returns versus National Product Differentiation as an Explanation for the Pattern of U.S.-Canada Trade. *American Economic Review* 91, pp. 858-876.

Helliwell, J., 2005. Borders, Common Currencies, Trade, and Welfare: What Can We Learn from the Evidence? *Bank of Canada Review*, Spring, pp. 19-33.

Helpman, E., 1987. Imperfect Competition and International Trade: Evidence from Fourteen Industrial Countries. *Journal of the Japanese and International Economies* 1, pp. 62-81.

Hummels, D., 2007. Transportation Costs and International Trade in the Second Era of Globalization. *Journal of Economic Perspectives* 21, pp. 131-154.

Hummels, D., Levinsohn, J., 1995. Monopolistic Competition and International Trade: Reconsidering the Evidence. *Quarterly Journal of Economics* 110, pp. 799-836.

Jacks, D., Meissner, C., Novy, D., 2008. Trade Costs, 1870-2000. *American Economic Review* 98, Papers & Proceedings, pp. 529-534.

Kee, H., Nicita, A., Olarreaga, M., 2008. Estimating Trade Restrictiveness Indices. *Economic Journal*, forthcoming.

Krugman, P., 1980. Scale Economies, Product Differentiation and the Pattern of Trade. *American Economic Review* 70, pp. 950-959.

Limão, N., Venables, A., 2001. Infrastructure, Geographical Disadvantage, Transport Costs and Trade. *World Bank Economic Review* 15, pp. 451-479.

Melitz, M., 2003. The Impact of Trade on Intra-Industry Reallocations and Aggregate Industry Productivity. *Econometrica* 71, pp. 1695-1725.

Melitz, M., Ottaviano, G., 2008. Market Size, Trade, and Productivity. *Review of Economic Studies* 75, pp. 295-316.

Nitsch, V., 2000. National Borders and International Trade: Evidence from the European Union. *Canadian Journal of Economics* 33, pp. 1091-1105.

Novy, D., 2008. Is the Iceberg Melting Less Quickly? International Trade Costs after World War II. Mimeo, University of Warwick.

Portes, R., Rey, H., 2005. The Determinants of Cross-Border Equity Flows. *Journal of International Economics* 65, pp. 269-296.

Samuelson, P., 1954. The Transfer Problem and Transport Costs: Analysis of Effects of Trade Impediments. *Economic Journal* 64, pp. 264-289.

Trefler, D., 1995. The Case of the Missing Trade and Other Mysteries. *American Economic Review* 85, pp. 1029-1046.

Wei, S., 1996. Intra-National versus International Trade: How Stubborn are Nations in Global Integration? NBER Working Paper #5531.

Whalley, J., Xin, X., 2007. Regionalization, Changes in Home Bias, and the Growth of World Trade. NBER Working Paper #13023.

Yi, K., 2003. Can Vertical Specialization Explain the Growth of World Trade? *Journal of Political Economy* 111, pp. 52-102.