

# Gravity Redux: Measuring International Trade Costs with Panel Data\*

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## Abstract

Barriers to international trade are known to be large. But have they become smaller over time? Building on the model by Anderson and van Wincoop (2003), I derive an analytical solution for time-varying and observable multilateral resistance variables. This solution gives rise to a new micro-founded gravity equation from which bilateral trade costs can be readily computed without imposing a trade cost function that makes use of distance or other trade cost proxies. 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.

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# 1 Introduction

Barriers to international trade are large and of considerable interest to policymakers. The tool that economists use most frequently to calculate the magnitude of trade barriers is the gravity equation. The typical gravity equation relates two countries' bilateral trade flows to their economic size and to various bilateral trade barriers such as distance, linguistic differences, tariffs and exchange rate volatility. However, in an important and highly influential paper James Anderson and Eric 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. For example, trade between the U.S. and Canada is not only influenced by their bilateral trade barrier but also by their trade barriers with other countries. If U.S. trade barriers go up with all countries in the world except for Canada, then some U.S. trade will be diverted to Canada although the bilateral U.S.-Canadian barrier itself has not changed. What matters therefore is the bilateral *relative* to the multilateral trade barrier.

The aim of this paper is to derive a micro-founded trade cost measure that accurately accounts for both bilateral and multilateral trade barriers. The contribution of the paper is twofold. 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, that only depends on observable trade and output data. These multilateral trade barriers have been acknowledged for some time, for example by Anderson (1979), Bergstrand (1985) and Anderson and van Wincoop (2003), but so far it has been either impossible or very cumbersome to solve for them. Second, with the solution for multilateral resistance variables at hand, I am able to derive a theoretically consistent gravity equation that implies a micro-founded trade cost measure. This trade cost measure controls for multilateral resistance and can be directly computed from trade and output data without imposing a trade cost function that has to rely on distance or other trade cost proxies. Generalizing the approach by Anderson and van Wincoop (2003), who only consider cross-sectional data, the trade cost measure accurately captures how trade costs change over time and can therefore be used with time series and panel data.

Another advantage of the trade cost measure is that it 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 as identified by Anderson and Marcouiller (2002).

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 as NAFTA. In addition, I show that if multilateral-

eral resistance variables are misspecified as constants, trade cost estimates are likely to be biased because they will fail to account for secular trends in multilateral resistance.

The paper is organized as follows. Building on the model by Anderson and van Wincoop (2003) I show in Section 2 how multilateral resistance variables can be expressed as a function of observable trade and output data. I also show how this expression can in turn be used to derive the micro-founded measure of bilateral trade costs. As an illustration Section 3 presents U.S. bilateral trade costs for a number of major trading partners. In Section 4 I provide a brief discussion of the results before concluding in Section 5.

## 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 that incorporates trade costs. Their model is based on constant elasticity of substitution preferences and goods that are differentiated by country of origin.<sup>1</sup> It is assumed that each country is specialized in the production of one good whose supply is fixed. Goods prices differ across countries because of trade costs. Specifically, if  $p_i$  is the net supply price of the good produced 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). Assuming that bilateral trade costs are symmetric ( $t_{ij} = t_{ji}$ ) Anderson and van Wincoop (2003) derive a micro-founded gravity equation that includes both bilateral and multilateral trade barriers

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

where  $x_{ij}$  denotes exports from  $i$  to  $j$ ,  $y_i$  is 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.  $P_i$  and  $P_j$  are price indices that Anderson and van Wincoop (2003) call “multilateral resistance” variables because they comprise all bilateral trade costs

$$P_i^{1-\sigma} = \sum_j P_j^{\sigma-1} \theta_j t_{ji}^{1-\sigma} \quad \forall i \quad (2)$$

where  $\theta_j$  is the world income share of country  $j$  defined as  $\theta_j \equiv y_j/y^W$ .

Gravity equation (1) relates bilateral trade flows  $x_{ij}$  to the incomes of countries  $i$  and  $j$ , to bilateral trade costs  $t_{ij}$  and to the multilateral trade barriers  $P_i$  and  $P_j$ . When bilateral trade costs  $t_{ij}$  go up, this will obviously lead to a decrease in bilateral trade

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<sup>1</sup>Anderson and van Wincoop (2003) refer to regions instead of countries but this makes no difference to the subsequent analysis.

$x_{ij}$ . But if bilateral trade costs  $t_{ki} = t_{ik}$  between country  $i$  and country  $k \neq j$  go up, then multilateral resistance  $P_i$  for country  $i$  rises due to (2), leading to an increase in bilateral trade  $x_{ij}$ .<sup>2</sup> Intuitively, when trade barriers go up between  $i$  and other countries except for  $j$ , then some of  $i$ 's trade is diverted to  $j$ . An important insight from Anderson and van Wincoop's model therefore 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

A problem in empirical work has so far been to find an appropriate expression for multilateral resistance variables. Anderson and van Wincoop (2003) point out that in general  $P_i$  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 solution to  $P_i$  as (2), but in that case  $P_i$  would include the nonpecuniary home bias and could therefore no longer be regarded as a consumer price index. Instead, Anderson and van Wincoop (2003) suppose that bilateral trade costs  $t_{ij}$  are a function of two observable trade cost proxies, distance and a border effect, so that they can obtain an implicit solution for  $P_i$ .<sup>3</sup> But the drawback of this method is that if the assumed functional form or the number of included proxies are misspecified, then the resulting solution for  $P_i$  might be inaccurate. In what follows, I overcome this problem and show how to obtain an analytical solution for multilateral resistance variables without imposing any trade cost function.

In fact, there is a simple and intuitive way of expressing multilateral resistance as a function of observable trade and output data. The crucial intuition is that a change in bilateral trade barriers does not only affect *international* trade but also *intranational* trade. For example, if country  $i$ 's trade barrier with country  $j$  increases all else being equal, then some of the trade with  $j$  is diverted to other foreign countries and some is diverted back to  $i$ 's domestic economy. 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.

It turns out that there is a direct relationship between a country's multilateral resistance and its intranational trade flows. This can be seen formally by using gravity equation (1) to find an expression for country  $i$ 's intranational trade

$$x_{ii} = \frac{y_i^2}{y^W} \left( \frac{t_{ii}}{P_i^2} \right)^{1-\sigma} \quad (3)$$

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<sup>2</sup>An increase in  $t_{ij} = t_{ji}$  will also increase  $P_i$  and  $x_{ij}$ , but this indirect effect on  $x_{ij}$  is smaller than the direct effect of  $t_{ij}$  on  $x_{ij}$ .

<sup>3</sup>In particular, they assume  $t_{ij} = b_{ij}d_{ij}^\rho$  where  $b_{ij}$  is a border-related indicator variable and  $d_{ij}$  is bilateral distance.

where  $t_{ii}$  represents intranational trade costs, for example intranational transportation costs. Equation (3) can be solved for the multilateral resistance variable  $P_i$  as

$$P_i = \left( \frac{x_{ii}/y_i}{y_i/y^W} \right)^{\frac{1}{2(\sigma-1)}} (t_{ii})^{\frac{1}{2}} \quad (4)$$

As an example, suppose there are two countries  $i$  and  $j$  that face the same intranational trade costs  $t_{ii} = t_{jj}$  and that have 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 (4) that multilateral resistance is higher for country  $i$  ( $P_i > P_j$ ). Expression (4) also implies that for given  $t_{ii}$  it is easy to measure the change in multilateral resistance over time as  $P_i$  does not depend on time-invariant trade cost proxies such as distance.

### 2.3 A Micro-Founded Measure of Trade Costs

The explicit solution for multilateral resistance variables can be exploited to derive a micro-founded measure of bilateral trade costs. Plug the solutions for  $P_i$  and  $P_j$  given by (4) into gravity equation (1) to obtain

$$x_{ij} = (x_{ii}x_{jj})^{\frac{1}{2}} (t_{ij})^{1-\sigma} (t_{ii}t_{jj})^{\frac{\sigma-1}{2}} \quad (5)$$

As interest ultimately centers on bilateral trade costs and as bilateral trade costs affect trade flows in both directions, it is useful to combine  $x_{ij}$  in (5) with its counterpart for  $x_{ji}$ . The standard way of combining unidirectional trade flows is by multiplication, yielding<sup>4</sup>

$$x_{ij}x_{ji} = x_{ii}x_{jj} \left( \frac{t_{ii}t_{jj}}{t_{ij}t_{ji}} \right)^{\sigma-1} \quad (6)$$

The size variable in this joint gravity equation is not total income  $y_i y_j$  as in traditional gravity equations, but intranational trade  $x_{ii}x_{jj}$  which is a size variable that controls for multilateral resistance. (6) can be solved for trade costs as

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

Since gross shipping costs (one plus the tariff equivalent) between  $i$  and  $j$  are symmetric ( $t_{ij} = t_{ji}$ ), it is useful to take the square root of (7) and to deduct one to get an expression for the tariff equivalent. Denote the resulting variable as  $\tau_{ij}$

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

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<sup>4</sup>See Baldwin and Taglioni (2006) for a discussion, in particular why it is problematic to take the sum of unidirectional trade flows as opposed to their product.

Bilateral trade costs  $\tau_{ij}$  follow from (7) as

$$\tau_{ij} = \left( \frac{x_{ii}x_{jj}}{x_{ij}x_{ji}} \right)^{\frac{1}{2(\sigma-1)}} - 1 \quad (8)$$

Suppose that the total gross shipping costs can be decomposed into the gross shipping costs up to the border of the destination country times the gross shipping costs within the destination country. Then  $\tau_{ij}$  can be interpreted as a measure of the international component of trade costs that abstracts from trade costs incurred within the destination country.<sup>5</sup>

The intuition for bilateral trade costs  $\tau_{ij}$  is as follows. Suppose that bilateral trade flows  $x_{ij}x_{ji}$  between  $i$  and  $j$  increase but intranational trade flows  $x_{ii}x_{jj}$  remain constant. This means that it must have become easier for these two countries to trade with each other. In other words, bilateral trade costs  $\tau_{ij}$  must have come down. In contrast, now suppose that bilateral trade flows remain constant but that intranational trade flows increase. We know from (4) that the increase in intranational trade flows implies an increase in multilateral resistance. If bilateral trade costs had been constant, this increase in multilateral resistance should have stimulated bilateral trade flows. But since bilateral trade flows remain constant, bilateral trade costs  $\tau_{ij}$  must have gone up.

To summarize, bilateral trade flows depend on both bilateral and multilateral trade barriers. As shown by (4), multilateral resistance variables are directly related to intranational trade flows and can therefore be conveniently incorporated into micro-founded gravity equation (6). As a result, the implied bilateral trade costs  $\tau_{ij}$  can be directly computed from observable variables. Since the multilateral resistance variables are free to vary over time, trade costs  $\tau_{ij}$  can be computed not only for cross-sectional data but also for time series and panel data.

### 3 Illustration

#### 3.1 U.S. Trade Costs

As an illustration of trade costs  $\tau_{ij}$  given in (8), I compute U.S. bilateral trade costs for a number of major trading partners. Due to market clearing intranational trade  $x_{ii}$  can be rewritten as total income minus total exports,  $x_{ii} = y_i - x_i$ .<sup>6</sup> Total exports  $x_i$  are defined as the sum of all exports from country  $i$ ,  $x_i \equiv \sum_{j \neq i} x_{ij}$ . All trade data are taken from the IMF Direction of Trade Statistics (DOTS) and denominated in U.S. dollars. GDP data are not suitable as  $y_i$  because they are based on value added, whereas the trade data are

<sup>5</sup>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  $t_{ij} = t_{ij}^*t_{jj} = t_{ji} = t_{ji}^*t_{ii}$  and  $\tau_{ij} = \sqrt{t_{ij}^*t_{ji}^*} - 1$ .

<sup>6</sup>See equation (8) in Anderson and van Wincoop (2003).

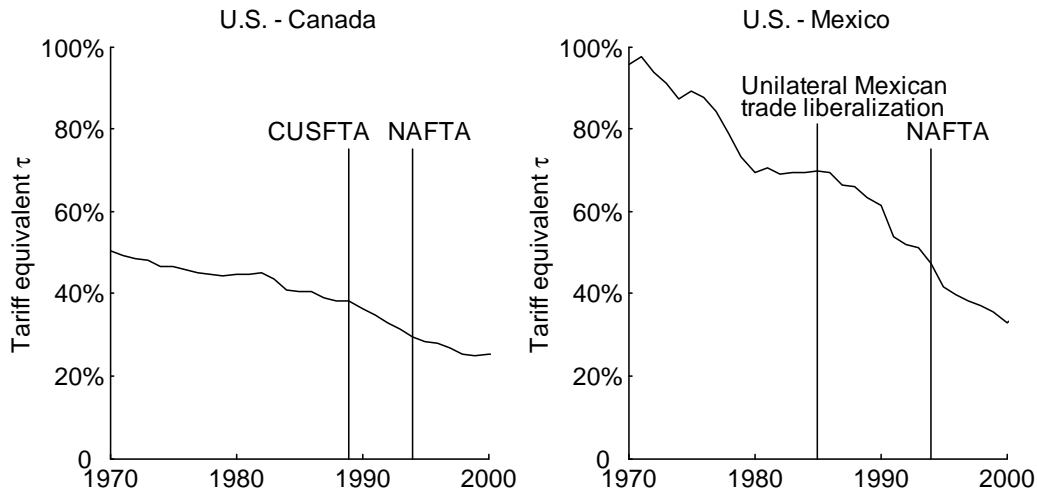


Figure 1: U.S. bilateral trade costs with Canada and Mexico.

reported as gross shipments. In addition, GDP data include services that are not covered by the trade data. To get the shipment counterpart of GDP excluding services I follow Shang-Jin Wei (1996) in constructing  $y_i$  as total goods production based on the OECD's Structural Analysis (STAN) database.<sup>7</sup> The production data are converted into U.S. dollars by the period average exchange rate taken from the IMF International Financial Statistics (IFS). I consider annual data for 1970-2000. 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.<sup>8</sup>

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 95.8 to 33.0 percent) and also with Canada (from 50.4 to 25.1 percent). The U.S. experienced clear downward trends 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).

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.<sup>9</sup> The decline has been most dramatic with Mexico and Canada, but still sizeable with Korea, the UK, Germany and Japan. The trade-weighted average of U.S. trade costs declined by 43.5

<sup>7</sup>Wei (1996) uses production data for agriculture, mining and total manufacturing.

<sup>8</sup>See Section 4 for a discussion of  $\sigma$ .

<sup>9</sup>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.

**Table 1: U.S. Bilateral Trade Costs**

<i>Partner country</i>	<i>Tariff equivalent <math>\tau</math></i>		
	1970	2000	Percentage change
Canada	50.4	25.1	-50.2
Germany	94.8	70.0	-26.2
Japan	85.2	64.7	-24.1
Korea	107.0	69.6	-35.0
Mexico	95.8	33.0	-65.6
UK	95.4	63.1	-33.9
<i>Plain average</i>	88.1	54.3	-38.4
<i>Trade-weighted average</i>	74.3	42.0	-43.5

All numbers in percent.  
Countries listed are the six biggest U.S. export markets as of 2000.  
Computations based on (8).

percent between 1970 and 2000, corresponding to an annualized decline of 1.8 percent per year.<sup>10</sup> Its 2000 level stands at 42 percent. It is important to stress that the trade cost measure  $\tau_{ij}$  does not only capture trade costs in the narrow sense of transportation costs and tariffs.  $\tau_{ij}$  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 previous cross-sectional evidence. Anderson and van Wincoop (2004) report a 46 percent tariff equivalent of overall U.S.-Canadian trade costs in 1993, compared to 31.2 percent in Figure 1. The reason why the numbers reported by Anderson and van Wincoop (2004) are somewhat higher is that they use GDP data as opposed to production data to compute trade costs and that GDP data tend to overstate the extent of intranational trade and thus the level of trade costs.<sup>11</sup> In fact, when using GDP data I obtain U.S.-Canadian trade costs of 47.4 percent for 1993, almost exactly the number reported by Anderson and van Wincoop (2004).<sup>12</sup> But as noted earlier, GDP data include services and are based on value added, whereas the trade data do not include services and represent shipment values. I therefore follow Wei (1996) in using production data to match the trade data more accurately.

<sup>10</sup>  $x = -0.018$  is the solution to  $42.0 = 74.3*(1+x)^{31}$ .

<sup>11</sup> 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 (2007) develops a trade cost model with nontradable goods, showing that only the tradable part of GDP enters the model's micro-founded gravity equation.

<sup>12</sup> 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 (8) are 97 and 35 percent when using GDP data and 61 and 24 percent when using production data. See Section 4 for a discussion of  $\sigma$ .



Furthermore, Eaton and Kortum (2002) report tariff equivalents based on data for 19 OECD countries in 1990. An elasticity of substitution of  $\sigma = 8$  implies a range of 58-78 percent for countries that are 750-1500 miles apart, consistent with the magnitudes in Table 1. But the main advantage of  $\tau_{ij}$  over previous trade cost measures is that  $\tau_{ij}$  can be easily computed for specific country pairs and that  $\tau_{ij}$  can be easily tracked over time.

### 3.2 What Happens when Multilateral Resistance is Misspecified?

I now demonstrate why estimated changes in trade costs over time are likely to be incorrect if they ignore the fact that multilateral trade barriers change over time. To see why take trade costs from (8)

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

and substitute expression (3) for  $x_{ii}$  and  $x_{jj}$  to arrive at

$$\tau_{ij} = \left( \frac{y_i y_j}{y^W (x_{ij} x_{ji})^{1/2}} \right)^{\frac{1}{\sigma-1}} \left( \frac{P_i P_j}{(t_{ii} t_{jj})^{1/2}} \right) - 1 \quad (9)$$

The variables in the second pair of parentheses of (9) are frequently ignored or misspecified in standard gravity equations, that is, the multilateral resistance variables  $P_i$  and  $P_j$  and intranational trade costs  $t_{ii}$  and  $t_{jj}$  are not properly taken into account. But an analytical solution for these terms follows directly from equation (4) as

$$\frac{P_i}{(t_{ii})^{1/2}} = \left( \frac{x_{ii}/y_i}{y_i/y^W} \right)^{\frac{1}{2(\sigma-1)}} \equiv \Phi_i \quad (10)$$

where  $\Phi_i$  is country  $i$ 's multilateral trade barrier adjusted for intranational trade costs. Equation (9) can then be rewritten as

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

Equation (11) is now used to examine the consequences of two mistakes. The first mistake is to completely ignore the multilateral resistance variables. The second mistake is to incorrectly specify the multilateral resistance variables as constants, for example in the form of time-invariant country fixed effects.

What happens if the multilateral resistance variables and intranational trade costs are completely ignored, that is, if one implicitly assumes  $\Phi_i = \Phi_j = 1$ ?<sup>13</sup> As  $\Phi_i$  is greater

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<sup>13</sup>  $P_i = P_j = t_{ii} = t_{jj} = 1$  holds in a frictionless equilibrium. See Anderson and van Wincoop (2003, p. 176).

than unity for all countries in my sample, the assumption of  $\Phi_i = \Phi_j = 1$  leads to an underestimation of bilateral trade costs  $\tau_{ij}$ . Intuitively, what determines bilateral trade flows is the bilateral barrier relative to the multilateral barrier. If one underestimates the level of a country's multilateral barrier, one will also underestimate the level of its bilateral barriers.

Turning to the second mistake, what happens if the multilateral resistance variables are misspecified as constants, that is, if one assumes  $\Phi_i = \bar{\Phi}_i$  and  $\Phi_j = \bar{\Phi}_j$ ? As one can see from (11), in that case changes in the multilateral resistance variables will not be picked up by bilateral trade costs. This implies that if the multilateral resistance variables follow a secular trend, then the resulting estimated time trend of trade costs will be biased. Figure 2 illustrates the second mistake. The left-hand side panels plot the multilateral resistance variables  $\Phi_i$  for the U.S., Canada and Korea. They are computed on the basis of (10).<sup>14</sup> The right-hand side panels plot the correct trade costs based on time-varying multilateral resistance variables as well as the incorrect trade costs based on constant multilateral resistance variables. In this example the multilateral resistance variables are held constant at their 1970 levels but this particular normalization is irrelevant for the argument.

Both the U.S. and the Canadian multilateral resistance variables happen to be fairly stable over time. As a result, there is hardly a difference between the correct and incorrect trade costs in the right-hand side panels. But the Korean multilateral resistance variable declined markedly over time such that the incorrect U.S.-Korean trade costs fail to reflect the decline in actual trade costs according to (11). In fact, the incorrect measure reports a decline in trade costs from 107 to only 97.7 percent between 1970 and 2000, whereas actual trade costs declined from 107 to 69.6 percent (see Table 1). Ignoring the fact that Korean multilateral resistance dropped over time thus leads to a miscalculation of the time trend by almost 30 percentage points. Again, the intuition of this result is that if one fails to capture the decline in a country's multilateral trade barrier, one will also fail to capture the decline in its bilateral barriers. Korea serves as a clear example of a country that has experienced a striking drop in general trade costs and thus a striking drop in its multilateral resistance. Although the decrease in multilateral resistance might not be as strong for other countries, in general the bias is likely to go in the direction of underestimating the decline in trade costs.

In summary, as Figure 1 and Table 1 demonstrate, 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. In addition, Figure 2 demonstrates that if multilateral resistance variables are as-

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<sup>14</sup>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.

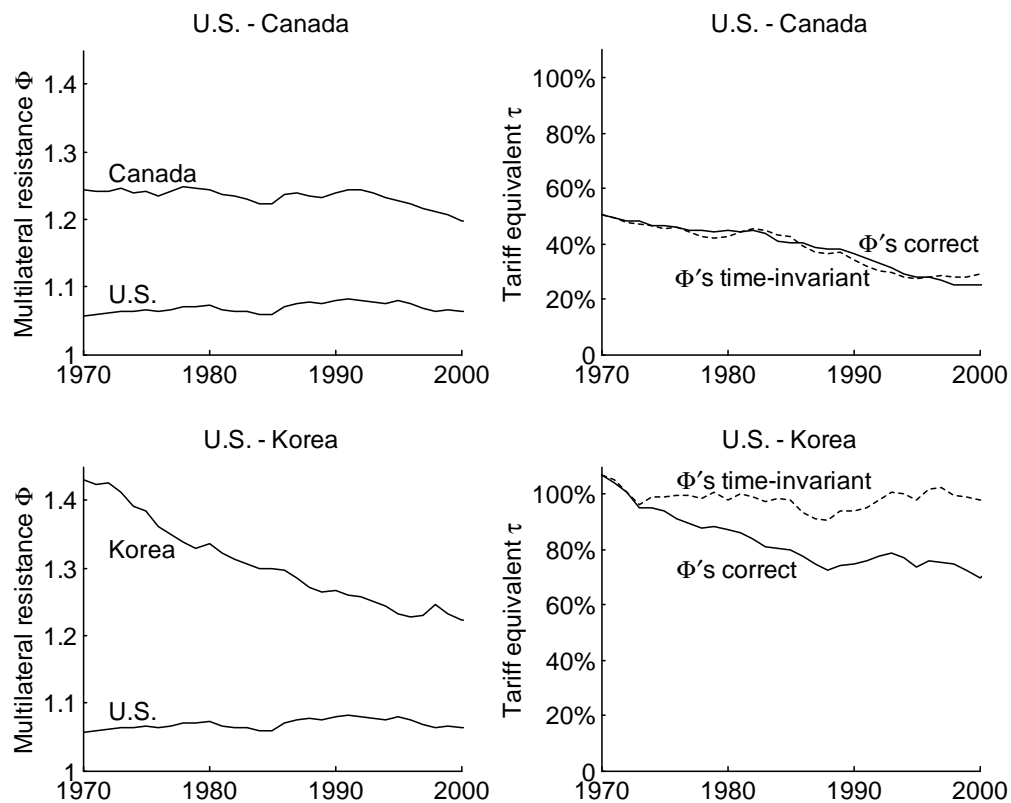


Figure 2: Multilateral resistance variables and U.S. bilateral trade costs based on correct time-varying and incorrect time-invariant multilateral resistance variables.

sumed to be constants, bilateral trade costs will fail to capture the decline in multilateral resistance over time such that the decline in bilateral trade costs is likely to be understated.

## 4 Discussion

The trade cost measure in (8) 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, whereas direct measures of trade cost components, for example international transportation costs provided by Hummels (2007), can be seen as a lower bound of trade costs.

The precise magnitude of trade costs depends of course on the elasticity of substitution  $\sigma$ . Table 1 and the graphs in Figures 1 and 2 are based on  $\sigma = 8$ , which is in the middle of the common empirical range of 5 to 10, 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 74.3 to 42 percent, a decline of 43.5 percent. It is well-known that higher elasticities lead to lower trade cost magnitudes.<sup>15</sup> For example, in the case of  $\sigma = 10$  the trade-weighted average falls from 53.9 to 31.2 percent, a similar decline of 42.1 percent. In the case of  $\sigma = 5$  the trade-weighted average falls from 167.1 to 86.7 percent, a decline of 48.1 percent. In comparison, although the magnitude of trade costs is sensitive to the elasticity of substitution, their change over time is hardly affected.

Following the approach of Feenstra (1994), Broda and Weinstein (2006) estimate elasticities of substitution based on demand and supply relationships for disaggregated U.S. 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. Nevertheless, this result might suggest that trade costs could have declined slightly less than indicated in Table 1 but quantitatively, this effect is unlikely to be large.

Novy (2007) develops a general equilibrium model of trade that incorporates trade costs as well as the fact that some goods are nontradable. However, he finds that estimated trade costs are barely affected when the share of nontradable goods is allowed to vary over time.

## 5 Conclusion

This paper develops a measure of international trade costs without imposing any trade cost function that uses distance, borders barriers or other trade cost proxies. Building on

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<sup>15</sup>Higher elasticities of substitution imply that goods are not as differentiated so that consumers are more price-sensitive and thus less likely to switch to more expensive foreign goods. Given actual trade flows, trade costs must therefore be lower.

the gravity model by Anderson and van Wincoop (2003), I show how intranational trade flows can be used to express multilateral resistance terms as a function of observable trade and output data. Given this expression for time-varying multilateral resistance terms, I am able to derive a micro-founded gravity equation from which international trade costs can be directly computed for specific country pairs. This trade cost measure is valid for both cross-sectional and time series data.

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 show that if multilateral resistance variables are misspecified as constants, bilateral trade cost estimates will fail to capture the decline in multilateral resistance and thus understate the true fall in trade costs over time.

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