Comparing estimation methods of trade costs

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Gravity models are used to understand intra- and international trade flows. Trade costs play a central role in these models, but are not clearly observable. In order to infer these costs, different estimation methods exist. The aim of this paper is to investigate these methods on systematic patterns in their predicted trade costs. By applying the methods to one dataset, the resulting trade cost estimates become comparable. For a given trade elasticity, the inverse gravity framework from Novy (2013a) is found to predict lower values than ratio gravity, used for example by Simonovska and Vaugh (2014). However, when moderating the impact of outliers, inverse gravity produces lower estimates.

JEL codes: gravity models, trade costs, trade policy
Key words: F10, F14, F16

1 Introduction

Free trade negotiations have experienced both headwinds and tailwinds in recent years. Nowadays, however, the forces opposing free trade tend be on the stronger side. On the one hand, stiff opposition from the United States is curtailing new large-scale free trade agreements. For instance, the Trump administration cancelled the Trans-Pacific Partnership (TPP) upon entering the office, arguing that the agreement would be to the detriment of the American worker (*New York Times*, 2017). On the other hand, negotiations for global agreements under the lead of the World Trade Organization (WTO) are failing to achieve their goals due to diverging interests of the member countries and small sectors like agriculture having disproportionate importance (*New York Times*, 2016). Nevertheless, understanding the sources of trade costs and (potentially) eliminating them is especially relevant for countries like Switzerland which rely on a strong exporting sector. While trade costs with partners like Germany are relatively low, they are much higher for countries with which a free trade agreement (FTA) is yet to be agreed (Indonesia recently agreed to sign an FTA while others, like the United States or the members of Mercosur, are still open).

Economists usually emphasize the large potential gains from scrapping impediments to trade, which should ultimately benefit everyone. Many channels exist through which gains can be achieved. One of these is consumers having a larger set of choices available. Another is greater efficiency, as more efficient suppliers reach further markets. However, to estimate the impact of scrapping barriers, an understanding of the economic cost of the current situation is needed.

Therefore, the size of trade barriers must be calculated (Moïsé and Le Bris, 2013). However, there is no agreement on the size and importance of these barriers, since they are hard to pin down both qualitatively and quantitatively – qualitatively because of many subcomponents, both tariff and non-tariff as well as observed and unobserved (i.e. transportation costs or taxes on imported goods, filling documents for customs and administrative procedures, bribery, delay and storage time at the border); and quantitatively because of methodological identification problems. Essentially, as described in Anderson and van Wincoop (2004), two paths can be followed to find an estimate: either trade costs are summed up in a direct, bottom-up approach for which numbers on the individual components which constitute total trade costs are needed; or, in a indirect, top-down approach, trade cost are inferred from trade flows. This usually relies on a gravity equation which essentially says that trade flows increase in (economic) size and decrease in (economic) distance. Higher trade costs then can be interpreted as increasing the distance, thereby lowering trade flows. Usually, observed trade flows are compared to theoretical predictions assuming a frictionless world (Moïsé and Le Bris, 2013). A big issue arises when identifying trade costs, however, since the resulting discrepancy can be either attributed to high trade costs or to a high elasticity of trade flows with respect to trade costs (Simonovska and Waugh, 2014).

Many theoretical approaches which yield a gravity equation and different estimation methods are presented in the literature. However, to the best of our knowledge, no empirical comparison of the main gravity estimation methods exists. Thus, the aim of this paper is to evaluate trade cost estimation methods based on gravity approaches. By applying different methods to the same set of data, the approaches can be investigated on systematic patterns in their predictions.

In this paper, we use two methods to estimate trade costs. The inverse gravity framework from Novy (2013a) yields lower trade costs than using ratio gravity, used for example by Simonovska and Waugh (2014). The opposite holds true when using trade-volume weighted averages. Generally, economically advanced countries are found to have relatively low trade costs.

The rest of this paper is organized as follows. Section 2 provides an overview on the different sources of trade costs. Section 3 outlines the main approaches to estimating trade costs indirectly and discusses issues arising in modelling and estimation. A short review of the data is presented in Section 4, and all results are displayed and explained in Section 5. Finally, a discussion of the analysis and an outline of its main limitations are presented in Section 6.

2 Overview of trade costs

2.1 What constitutes trade costs?

Before outlining the literature on trade costs and conducting the subsequent analysis, it is worth reviewing what is actually meant by the term "trade costs". As ANDERSON and VAN WINCOOP (2004) discuss in their paper, trade costs include all cost components other than the actual production cost of the good itself. Trade costs are not limited to those incurred when trading internationally, but also include any expenditures related to domestic trading. According to MOÏSÉ and LE BRIS (2013), trade costs can be interpreted as the wedge between trade flows in a hypothetical world without frictions and empirically observed flows.

Following SAMUELSON (1954), trade costs are commonly modelled as "iceberg" trade cost t_{ij} when shipping a good from country i to country j. Thus, $t_{ij} - 1$ is the ad valorem tax equivalent of a trade friction (ANDERSON and VAN WINCOOP, 2004), where an ad valorem tax is based on the value of a good.[1] Therefore, a $t_{ij} > 1$ indicates positive trade costs. Put differently, $t_{ij} - 1$ units of the product are 'used' (i.e., melt away) to ship a good from i to j. This is why they are called "iceberg costs". A common assumption, seen for instance in EATON and KORTUM (2002), is that intra-national trade is frictionless, such that $t_{ii} = 1$.

2.2 Direct evidence of trade costs

Having discussed the meaning of trade costs and shown the common modelling approach, here we present an overview of trade cost calculation. ANDERSON and VAN WINCOOP (2004) differentiate between direct and indirect approaches to calculating trade costs. As a start, they conducted an exercise aimed at collecting direct evidence of trade costs to build a bottom-up measure of such costs. They summarized their findings into three categories:

1. policy/border costs (e.g., tariffs and non-tariff barriers);

2. transportation costs (e.g., freight charges, insurances, transit fees and inventory costs); and

3. wholesale and retail distribution costs (e.g. local distribution costs).

1 Source: Investopedia (see http://www.investopedia.com/terms/a/advaloremtax.asp).

For industrialized countries, ANDERSON and VAN WINCOOP (2004) arrive at an estimate of about 170% ad valorem trade costs. This measure contains 21% transportation costs, 44% costs attributable to border barriers and 55% stemming from retail and distribution costs,[2] while the overall number is split into 74% international and 55% domestic trade costs. Although direct estimation of trade costs would be very useful as policy-makers could then quickly identify the largest impediments to trade, this approach suffers heavily from incomplete or inexistent data and aggregation issues (MOÏSÉ and LE BRIS, 2013).

3 Indirect trade cost estimation methods

3.1 Motivation for indirect estimation

Indirect estimation of trade costs is popular as no distinction between the different subcomponents of trade costs is needed, thereby avoiding the data issues described for direct estimation. Instead, trade costs are inferred from trade flows using a gravity framework of trade (ANDERSON and VAN WINCOOP, 2004). In this framework, the gap between expectations of trade flows in a theoretically frictionless world and actual observed trade flows is attributed to trade costs (MOÏSÉ and LE BRIS, 2013). One difficulty lies in making the distinction between trade costs themselves and the elasticity of trade flows with respect to trade costs (SIMONOVSKA and WAUGH, 2014). Another difficulty is the assumption of specific trade cost functions needed to infer trade costs from gravity equations in a wide range of estimation methods (NOVY, 2013a). Nevertheless, using gravity equations to infer trade costs have become very popular and various estimation methods exist. Our analysis in this paper focuses on estimation methods based on gravity frameworks.

3.2 Gravity equation based on the demand side with multilateral resistance

ANDERSON and VAN WINCOOP (2003) assume differentiated goods by country of production, as in ARMINGTON (1969), and that every country specializes in one good which is inelastically supplied. Furthermore, building on ANDERSON (1979), they assume constant elasticity of substitution (CES) preferences which are identical across countries. As described in NOVY (2013a), this is a demand-side model because production is taken as exogenous. To their model, ANDERSON and VAN WINCOOP (2003) then introduce exogenous trade costs such that prices

2 ANDERSON and VAN WINCOOP (2003) arrive at the overall number by multiplying the gross rates and subtracting one to get the ad valorem tax equivalent: $1.7 = 1.21 \times 1.44 \times 1.55 - 1$ and for the international estimate similarly by $0.74 = 1.21 \times 1.44 - 1$.

will generally differ across countries. Therefore, given trade cost $t_{ij} > 1$ for $i \neq j$ and the exporter's net supply price p_i, then the price for this good in country j produced in i is going to be $p_{ij} = p_i t_{ij}$. Note that t_{ij} is the gross trade cost, i.e. one plus the ad valorem equivalent of the trade cost. Anderson and van Wincoop (2003) derive the following gravity equation:

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

where,

$$\Pi_i = \left[\sum_j \left(\frac{t_{ij}}{P_j}\right)^{1-\sigma} \frac{y_j}{y^W}\right]^{\frac{1}{1-\sigma}} \tag{2}$$

and,

$$P_j = \left[\sum_i \left(\frac{t_{ij}}{\Pi_i}\right)^{1-\sigma} \frac{y_i}{y^W}\right]^{\frac{1}{1-\sigma}} \tag{3}$$

Note that $\sigma > 1$ represents the elasticity of substitution across goods, y_i the total output value of country i, y^W world output, and the terms Π_i in equation (2) and P_j in equation (3) outward and inward multilateral resistance, respectively. Anderson and van Wincoop (2003) assume trade cost symmetry between bilateral country pairs i and j, $t_{ij} = t_{ji}$. Therefore, the two multilateral terms are equal $\Pi_i = p_i$. Given this additional assumption, they present the following simplified gravity equation:

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

Using the gravity equation (4), Anderson and van Wincoop (2003) emphasize what they mean by multilateral resistance: if, for a given country i, outward multilateral resistance p_i rises but the barrier t_{ij} stays constant, then exports to country j will rise. Put differently, if it becomes harder for two countries to trade with the rest of the world, they will trade more with each other. Therefore, trade between two countries does not only depend on the barrier between the two countries, but rather on the size of the barrier relative to the average trade barrier these two countries face with all other trade partners. The next step Anderson and van Wincoop (2003) take is to assume a specific trade cost function:

$$t_{ij} = b_{ij} d_{ij}^{\rho} \tag{5}$$

where b_{ij} is a border indicator being one if region i and j share a border or zero otherwise, d_{ij} measures bilateral distance, and ρ denotes distance elasticity. As Anderson and van Wincoop (2003) state, the multilateral terms are not observed in the data. For their estimation, they find an implicit solution for both inward and outward multilateral resistance and retrieve a log-linearized gravity equation which they use for estimation. Then, they apply an iterative procedure using non-linear least squares (NLS) to consistently estimate the model parameters. Yet, Feenstra (2004) argues that using fixed effects estimated with ordinary least squares (OLS) is preferable to the custom programing approach with NLS due to its easy implementation. Furthermore, Anderson (2011) points out that there may be other country-specific unobserved variables aside from the multilateral resistance terms that would be picked up by fixed effects but not by the approach of Anderson and van Wincoop (2003).

Aside from the NLS approach of Anderson and van Wincoop (2003), several methods for coping with multilateral resistance exist in order to consistently estimate gravity coefficients such as bilateral trade costs. However, before looking at these in Section 3.4, we next present an alternative derivation of structural gravity from Eaton and Kortum (2002).

3.3 Gravity equation based on the supply side

Having considered a demand-side model as in Anderson and van Wincoop (2003), the next variant of trade model which yields a structural gravity equation, by Eaton and Kortum (2002), comes from the supply side (Novy, 2013a; Head and Mayer, 2013). The resulting estimator, called a ratio gravity estimator (Head and Mayer, 2013), successfully deals with multilateral resistance.

The set-up in Eaton and Kortum (2002) is as follows. Assuming a continuum of tradable goods $n \in [0, 1]$ as in Dornbusch, Fischer and Samuelson (1977) and perfect competition, consumers with CES preferences can choose a certain good n from potentially N different source countries, and opt for the one which is offered at the lowest price. All countries can potentially produce any good. As before, there are iceberg-style trade costs[3] t_{ij} with $t_{ii} = 1$, which are added to the

3 Note that in Eaton and Kortum (2002), the notation is different. They use j as index for the good and n as index for the destination country. However, for comparability, the notation is chosen such that all models presented in this paper have the same indices – specifically, they are based on Novy (2013a).

marginal cost of producing a good, such that the price in country *j* of buying a good from country *i* is:

$$p_{ij}(n) = \left(\frac{c_i}{z_i(n)}\right)t_{ij} \tag{6}$$

where $z_i(n)$ denotes country *i*'s efficiency in producing good n and ci the input cost in country i. According to equation (6), country *i* is more likely to be chosen as provider if it has lower input cost c_i, higher efficiency $z_i(n)$, or lower trade cost t_{ij} relative to the other countries, since consumers opt for the provider offering the lowest price.

EATON and KORTUM (2002) model productivity as a the realization of a random variable which is country-specific and drawn for every good. Specifically, they assume a country-specific Frechet probability distribution:

$$F_i(z) = exp(-T_i z^{-\theta}) \tag{7}$$

where $T_i > 0$ measures aggregate efficiency in country, and $\theta > i$ the distribution of efficiency across goods. Note that while T_i is country-specific (i.e., countries with a higher T_i are more likely to draw a high efficiency for any good *n*), θ is common across all countries. A lower θ stands for more variability. Therefore, T_i can be interpreted as a country's absolute advantage and θ as its comparative advantage. EATON and KORTUM (2002) explain that stronger comparative advantage (i.e., a lower θ) generates relatively more variation in efficiencies such that trade barriers become relatively less important.

Given this set-up, they present the following gravity-like equation for trade flows in their paper:

$$\frac{x_{ij}}{x_j} = \frac{T_i(c_i t_{ij})^{-\theta}}{\sum_N^{k=1} T_k(c_k t_{kj})^{-\theta}} \tag{8}$$

Or, as reformulated by NOVY (2013a):

$$x_{ij} = \frac{T_i(c_i t_{ij})^{-\theta}}{\sum_N^{k=1} T_k(c_k t_{kj})^{-\theta}} x_j \tag{9}$$

where x_j denotes the total expenditure of country *j*. EATON and KORTUM (2002) raise an important difference between their model and models based on ARMINGTON

(1969), namely, that in the latter, products are imperfect substitutes. The more similar the products from the consumer's point of view, the more important the trade costs. Therefore, the lower the degree of product differentiation, the higher the elasticity of trade with respect to trade costs. This contrasts with equation (9), where the CES parameter does not show up. Instead, elasticity of trade with respect to trade costs is given by θ. Hence, more heterogeneity of goods in production decreases the relative importance of trade costs (EATON and KORTUM, 2002).

Moreover, EATON and KORTUM (2002) note that, on the one hand, in models built on ARMINGTON (1969), trade shares react at the intensive margin – consumers spend less on each product when trade costs rise, but still consume the same set of products. On the other hand, in supply-side models like their own, the extensive margin is key – given an increase in trade costs, the origin country exports a smaller set of products as it is no longer the least-cost provider of more and more goods.

3.4 Estimating gravity equations

3.4.1 Ratio gravity

One approach, used by EATON and KORTUM (2002) and SIMONOVSKA and WAUGH (2014), builds on equation (8) and is called the ratio gravity estimator or the odds specification (HEAD and MAYER, 2013). SIMONOVSKA and WAUGH (2014) arrive at the following equation (see KNUCHEL (2018) for a summary of the derivation):

$$log\left(\frac{x_{ij}/x_j}{x_{jj}/x_j}\right) = S_i - S_j - \theta log(t_{ij}) \tag{10}$$

where,

$$S_i = log(T_i c_i^{-\theta}) \tag{11}$$

A functional form for trade cost has to be assumed. For instance, SIMONOVSKA and WAUGH (2014) use:

$$log(t_{ij}) = d_k + b_{ij} + ex_i \tag{12}$$

where d_k is a distance indicator variable with six intervals,[4] b_{ij} a shared border dummy variable and e_{xi} an exporter specific fixed effect.

3.4.2 Inverse gravity approach

NOVY (2013a) criticizes the need to assume a specific trade cost function in conventional estimation procedures like fixed effect or ratio gravity estimators. Therefore, his trade measure relies neither on assuming a specific trade cost function nor on costless domestic trade and trade cost symmetry. Hence, the inverse gravity framework is a calibration rather than estimation approach (LARCH, MONTEIRO, PIERMARTINI AND YOTOV, 2017)

Using an analytical solution for the multilateral resistance terms, NOVY (2013a) exploits bidirectional gravity to construct his trade measure. Finally, he arrives at the following equation (KNUCHEL (2018) provides a summary of the derivation):

$$\tau_{ij} \equiv \left(\frac{t_{ij}t_{ji}}{t_{ii}t_{jj}}\right)^{\frac{1}{2}} - 1 \tag{13}$$

$$= \left(\frac{x_{ii}x_{jj}}{x_{ij}x_{ji}}\right)^{\frac{1}{2(\sigma-1)}} - 1 \tag{14}$$

where τ_{ij} is his trade cost measure. Therefore, unlike in the estimation methods shown above, this trade measure represents an average trade cost between a bilateral pair and it does not impose frictionless domestic trade. Hence, a lower τ_{ij} could be due to either higher domestic trade cost or lower bilateral trade cost (or both together). This is measured by analyzing bilateral relative domestic trade flows. If bilateral trade flows increase relative to domestic ones, then this will be interpreted as lower bilateral barriers in this method (NOVY, 2013a). Additionally, similar expressions can be derived for the other three models. In fact, the only difference is the exponent, which is simply $1/2\theta$ in the EATON and KORTUM (2002) model or $1/2\gamma$ in the models of CHANEY (2008) and MELITZ and OTTAVIANO (2008). As NOVY (2013a) explains, the differences in interpretation can arise as the measure based on the model of CHANEY (2008) will contain a fixed cost of trade. Another important difference to the estimation approaches described in Section 3.4.1 is that with the inverse gravity approach, trade costs are not estimated but instead are directly calculated from a gravity equation (JACKS, MEISSNER and NOVY, 2008).

4 SIMONOVSKA and WAUGH (2014) use the following intervals (in miles): [0,375), [375, 750), [750, 1500), [1500, 3000), [3000, 6000), [6000, maximum].

3.5 Comparing both estimation methods

With respect to assumptions, the following differences between inverse gravity and ratio gravity should be noted. First of all, in Novy (2013a), trade costs are not estimated by conducting a regression, but instead are inferred mathematically from the combinations of ratios. Thus, no specific trade cost function needs to be assumed.

Furthermore, the resulting trade cost is, by construction, not a distinct value for a country but an average for a bilateral pair. This is important because the patterns of trade costs will differ between the two approaches. The ratio gravity approach will estimate an exporter-specific component of trade cost. Thus, countries that can be expected to have lower relative trade costs, such as Switzerland, will have a lower t_{ij} against most trading partners. On the other hand, the inverse gravity approach averages trade costs over trading partners. Hence, unequal bilateral pairs in terms of actual trade costs will get some intermediate τ. In addition to this, note the difference in notation between ratio gravity and inverse gravity – while the former denotes trade cost as tij for exports from country i to country j, the latter does not identify t_{ij} but instead uses a trade measure τ_{ij}.

Finally, both approaches have in common that they exogenously assume a trade elasticity. In summary, the ratio gravity tends to make more assumptions as this approach relies on regressing flows on gravity variables, whereas the inverse gravity approach eliminates multilateral resistance and backs out trade costs from the gravity equation.

3.6 Trade elasticity and trade costs

Observing relatively low trade flows can be explained by either high trade costs and a low trade elasticity or vice versa (Simonovska and Waugh, 2014). Put differently, higher variation of productivity implies a lower trade elasticity such that more products overcome a given trade barrier. However, if only low trade flows are observed despite low elasticity, then this can only be because of high trade costs (Novy, 2013a).

Depending on the theoretical model underlying a given gravity equation, the source of the elasticity is different. Eaton and Kortum (2002) explain that while in supply-side model like theirs, elasticity is technology driven (higher heterogeneity in efficiency implies a lower elasticity), in demand-side models built on Armington (1969) such as that in Anderson and van Wincoop (2003), elasticity is preference-driven (higher heterogeneity of goods implies a lower elasticity).

However, as trade elasticity and trade costs are both unobserved, they cannot be disentangled from a gravity equation only – either a model for one variable independent of the other variable is found such that the first can be estimated and the second inferred from the gravity equation, or one variable is simply assumed. For instance, papers like Novy (2013a) assume a value for σ of eight[5] for trade elasticity based on existing estimates from other papers such as Anderson and van Wincoop (2004), who find a range for σ of 5-10. In contrast, Simonovska and Waugh (2014) refine the approach of Eaton and Kortum (2002) using price data and arrive at an estimate for θ of roughly four.

4 Data

Having discussed the motivation for using gravity equations and the two trade cost estimation methods in Section 3, this section provides a short overview of the data sources.

This paper uses data from Fensore, Legge and Schmid (2017). Their dataset contains bilateral trade flows from UN COMTRADE based on ISIC Rev 3 between countries at the 4-digit industry level in the year 2000. In total, 111 countries and 119 commodities are covered. Thus, there are 111 × 110 × 119 = 1,452,990 observations of trade flows. In addition, for every commodity for each country, manufacturing output data are taken from UNIDO dataset IDSB Rev 3. Detailed data descriptions and sources can be found in Section 4 and the appendix of Knuchel (2018).

5 Results

Section 3 reviewed the gravity literature with a special focus on trade cost inference and discussed how two important methods – ratio gravity estimation and an inverse gravity framework – are used for this analysis. Following the data summary in Section 4, this section is dedicated to presenting and discussing the results.

5 Novy (2013a) assumes that $\sigma = 8$, therefore $\theta = \gamma = 7$, where σ denotes the elasticity of substitution in a demand-side model, θ the Frechet parameter in a supply-side model and γ the Pareto parameter from the heterogeneous firm models.

5.1 Overview

Before we begin the discussion, special emphasis should be given to the fact that all trade costs here are stated in ad valorem tax equivalents. Furthermore, trade elasticity refers to θ for both methods in order to simplify comparability.[6]

Table 1: Ratio gravity model comparison

	Long model		Base model	
	Coefficient	**Tax equivalent**	**Coefficient**	**Tax equivalent**
[0, 375)	–10.8*** (0.4)	3.66 ǀ 13.80	–10.8*** (0.4)	3.66 ǀ 13.75
[375, 750)	–11.5*** (0.3)	4.16 ǀ 16.69	–11.5*** (0.3)	4.17 ǀ 16.76
[750, 1500)	–12.4*** (0.3)	4.87 ǀ 21.16	–12.5*** (0.3)	4.95 ǀ 21.68
[1500, 3000)	–13.5*** (0.3)	5.88 ǀ 28.22	–13.6*** (0.3)	5.98 ǀ 28.98
[3000, 6000)	–14.5*** (0.3)	6.90 ǀ 36.22	–14.6*** (0.3)	7.10 ǀ 37.86
[6000, max]	–15.2*** (0.3)	7.71 ǀ 43.18	–15.4*** (0.3)	7.98 ǀ 45.55
contiguity	1.1*** (0.1)	–0.14 ǀ –0.24	1.4*** (0.1)	–0.18 ǀ –0.30
same language	0.8*** (0.1)	–0.11 ǀ –0.18		
same country	0.6** (0.2)	–0.13 ǀ –0.21		
colony	1.0*** (0.1)	–0.08 ǀ –0.13		
Observations	8,517	8,517		
Adjusted R2	0.97	0.97		

Notes: *p:0.1; **p:0.05; ***p:0.01; dummy variables: [0, 375)...[6000, *max*]: distance in miles; *contiguity*: the countries share the same border; *same language*: the countries speak the same language; *same country*: the countries were united once; *colony*: one country was the colony of the other.

6 While NOVY (2013a) presents his results assuming $\sigma = 8$, he emphasizes isomorphism of his trade cost measure, since θ equals σ minus one.

Table 1 shows the results of conducting a regression on equation (10). In particular, two specifications for the regression of the ratio gravity approach are presented: on the left side is the long specification including all variables of the dataset, and on the right side the specification as in SIMONOVSKA and WAUGH (2014). Due to multicollinearity with the country fixed effects, no country-specific variable such as GDP or the island dummy appears. Finally, for both models, coefficients are transformed into ad valorem tax equivalents by dividing by $-\theta$, taking exponents and subtracting one. For exposition, two common values are assumed for trade elasticity: $\sigma = 8$, which implies $\theta = 7$, as used by Novy (2013a) and ANDERSON and VAN WINCOOP (2003), and $\theta = 4$ as estimated by SIMONOVSKA and WAUGH (2014). As is apparent from Table 1, all coefficients show the expected sign: greater distance seems to increase trade costs, while similarity in terms of sharing a border, having the same language, once belonging to the same country or past colonial ties tends to moderate costs. Both specifications yield highly similar estimates. In addition, the fit in terms of the R^2 is very large.

In order to make the ad valorem tax values in Table 1 more tangible, we now discuss the example of trade costs when exporting from Switzerland to Germany. Assuming $\theta = 7$ and using the long specification, the calculation works as follows:

$$\tau_{i,j} = (1 + d_k)(1 + b_{ij})(1 + l_{ij})(1 + sc_{ij})(1 + c_{ij})(1 + ex_i) \tag{15}$$

where d_k is the border bracket, b_{ij} the border indicator and l_{ij} the same language indicator. sc_{ij} shows whether both countries once belonged to the same country and cij if they had a colonial relationship. Finally, exi is the exporter-specific fixed effect. For exports from Switzerland to Germany, Switzerland is i, Germany is j and k is 1 as they belong to the first distance bracket, being less than 375 miles apart. Plugging in the corresponding exporter-specific fixed effect from Switzerland, which is –0.66, the numbers from Table 1 yield:[7]

$$\tau_{CHE,GER} = (1 + 3.66)(1 - 0.14)(1 - 0.11)(1 - 0.66) - 1 \tag{16}$$

$$= 0.22 \tag{17}$$

Thus, according to the ratio gravity estimation approach estimated using all the variables from the long specification, there is a trade cost in tax equivalents of 22% involved when exporting from Switzerland to Germany. Bilateral trade costs for all country pairs can be calculated in a similar manner if data exist. For most of the country pairs in the sample, trade costs are far higher than in this example. Now, doing the same exercise again but for $\theta = 4$, the numbers look different:

7 The coefficients in this exposition are rounded while the results are taken from the code which uses exact numbers. Thus, there may be a small discrepancy.

$$\tau_{CHE,GER} = (1 + 13.8)(1 - 0.24)(1 - 0.18)(1 - 0.85) - 1 \tag{18}$$

$$= 0.42 \tag{19}$$

Thus, estimated trade costs almost double in size. As discussed in Section 3, there is an inverse relationship between trade elasticity and trade costs – higher values of trade elasticity yield lower ad valorem tax equivalents of trade costs.

Turning to the inverse gravity framework, plugging in numbers for Germany and Switzerland into equation (14) yields trade costs of 64%. Given estimated trade costs of exporting from Germany to Switzerland of 4.8% and remembering the ratio gravity assumption that domestic trade is costless, it follows from equations (13) and (14) that the geometric mean of bilateral trade costs between Switzerland and Germany based on trade cost estimates from ratio gravity is 13.25%. Thus, for the case of Switzerland and Germany, the inverse gravity method yields higher ad valorem trade costs than the ratio gravity approach.

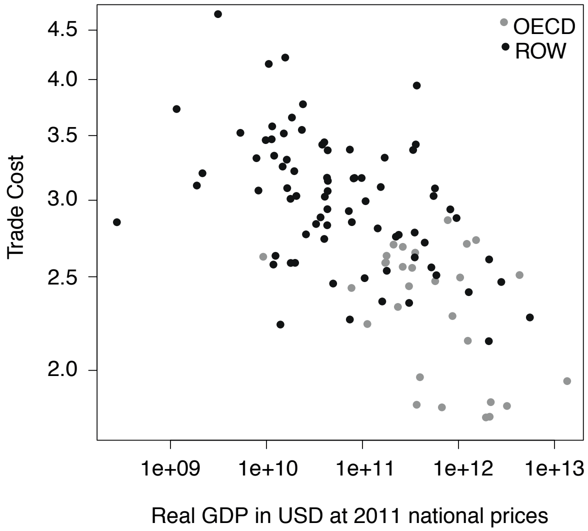
While trading costs are relatively low for Switzerland in the case of a close partner like Germany, they are much higher for other countries. For instance, according to the results from the inverse gravity analysis (with $\theta = 7$), a 190% trade cost applies when trading with Indonesia. For Mercosur countries like Brazil (145%) or Argentina (176%) the value is of a similar magnitude.

Turning back to the global analysis, according to Figure 1, ratio gravity seems to return higher values of trade costs compared to inverse gravity. Moreover, there seems to be a negative relationship between a country's trade costs and its GDP – i.e., higher GDP correlates with lower trade costs. Qualitatively, the basic findings of this analysis are comparable to those of Arvis, Duval, Shepherd, Utoktham and Raj (2016), who also find significantly higher trade costs for less-developed countries using inverse gravity. Similarly, Waugh (2010) finds higher trade cost for non-OECD countries based on the ratio gravity approach akin to the one in Eaton and Kortum (2002), but with exporter-specific instead of importer-specific fixed effects.[8]

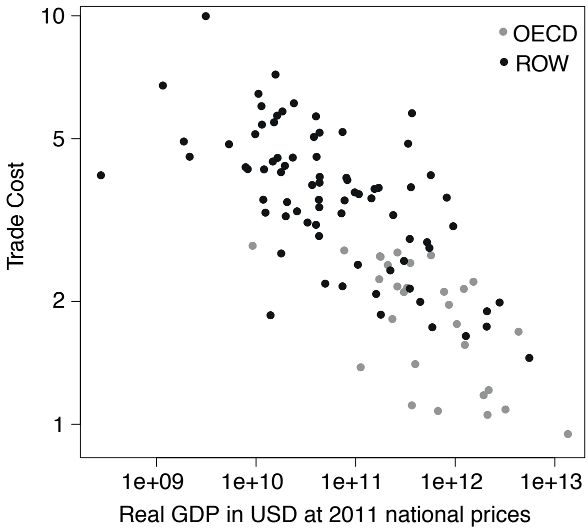
8 Eaton and Kortum (2002) interpreted the difference between the country dummies as importer-specific fixed effects. Thus, the cost for exporting to a given country is the same for two countries if they have the same geographical values. This is criticized by Waugh (2010), who showed that interpreting the difference as exporter-specific fixed effects produces preferable results. In any case, on a global level, average trade costs will be the same.

Figure 1: Trade cost vs GDP for θ = 7

a) Inverse gravity



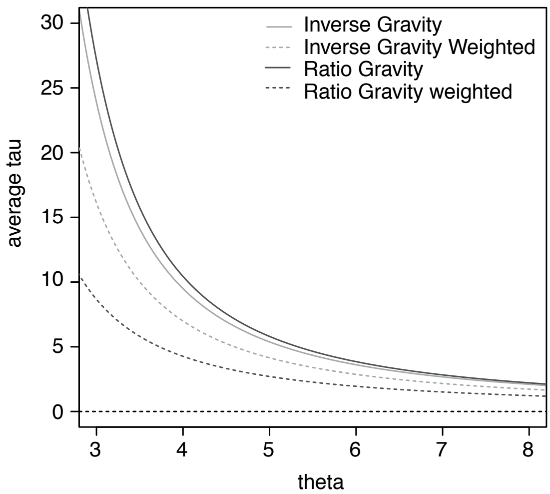
b) Ratio gravity



Having seen the specific example of trade costs in the case of Swiss-German bilateral trade and the general pattern of trade costs relative to GDP, our analysis now shifts to the global comparison of both estimation procedures. In general, the results show trade costs inferred using the inverse gravity framework and ratio gravity regression over a grid of θ. Specifically, trade cost are calculated for 1,000 evenly distributed θ between two and ten.

Figure 2: Overview of results

(a) Aggregated τ against θ



(b) Aggregated τ against τ

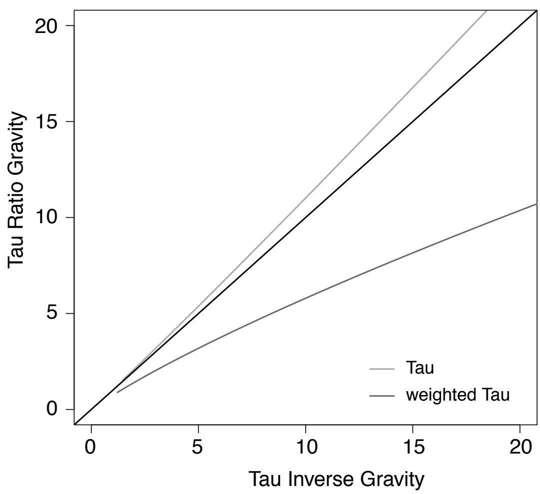


Figure 2 presents an overview of average estimated trade cost according to both methods, with panel a plotting τ against θ and panel *b* plotting trade cost estimates against each other. The solid lines in Figure 2a correspond to simple arithmetic means taken across all estimated trade cost while the doted lines show trade volume weighted means.[9] Overall, the figure confirms that estimated trade costs are highly sensitive to choosing parameter θ – all curves are downward sloping, implying that a higher trade elasticity corresponds to lower estimated trade costs. Furthermore, Figure 2a shows that using trade-weighted averages yields lower values for both methods. In addition, using weighted averages seems to increase the wedge between trade costs estimated from both methods, as apparent from Figure 2b.

Nevertheless, there are differences. Figure 2 shows that the inverse gravity framework produces higher simple average trade costs than ratio gravity estimation. However, when taking into account the importance of countries in terms of their share in global exports, the relationship turns upside down. This pattern can also be seen in Figure 2b, where inferred τ from both methods are plotted against each other. If both methods predicted the same τ, they would lie on the solid black 45-degree line. However, the light grey for non-weighted and the dark grey for weighted τ clearly lie beside the 45-degree line. This stands in contrast with what can be observed in Figure 3, where geometric means are taken for each bilateral pairs. Thus, as in the example of Swiss-German bilateral trade, every country pair has the same measured trade costs. For these pairwise geometric averages, the global means – both weighted and non-weighted – are calculated. As in Figure 2, all curves are downward sloping and the light grey curves representing inferred trade costs from inverse gravity are the same in both figures. However, average trade costs estimated with the ratio gravity approach are now lower than those inferred by inverse gravity. This seems to be in line with Novy (2013a), who stated that his measure should yield relatively higher estimates than ratio gravity approaches.

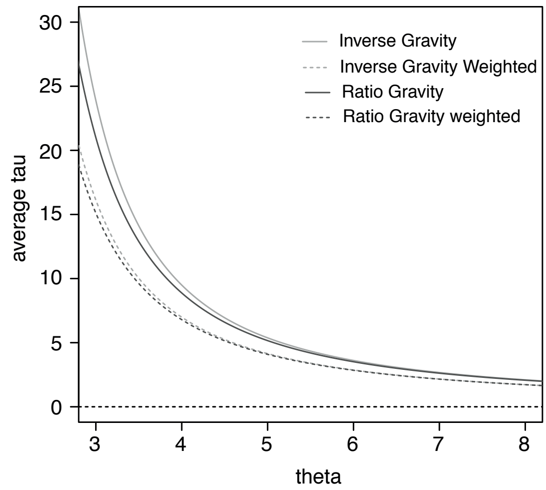
Nevertheless, there is actually a loss of information when taking geometric averages across bilateral trade costs in order to compare ratio gravity with inverse gravity. On the one hand, both countries have the same measure of trade costs even though ratio gravity allows us to estimate country-specific trade costs. On the other hand, inverse gravity needs bilateral flows in both directions in order to estimate trade costs, whereas ratio gravity only requires unidirectional trade

9 First, country-level trade costs are calculated as simple, non-weighted means. Then, the global average trade cost is calculated using trade weights, where the weights are calculated as the share of total exports from country i in global total exports. Thus, countries which are responsible for a large part of global exports receive a higher weight when calculating the global average trade cost.

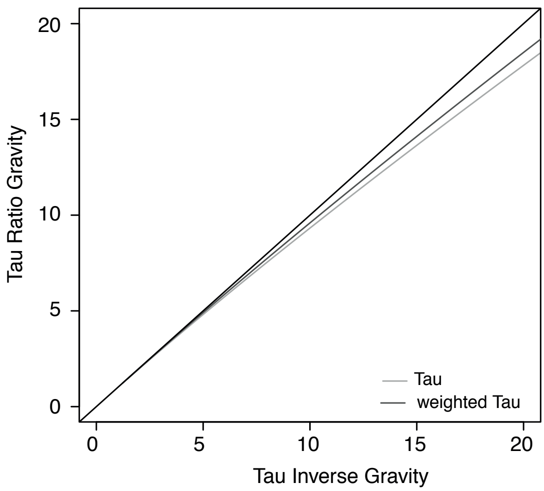
flows. Thus, there are more 'observations' of trade costs which are discarded when taking geometric averages.

Figure 3: Geometric averages

(a) Aggregated τ against θ



(b) Aggregated τ against τ



5.2 Analysis

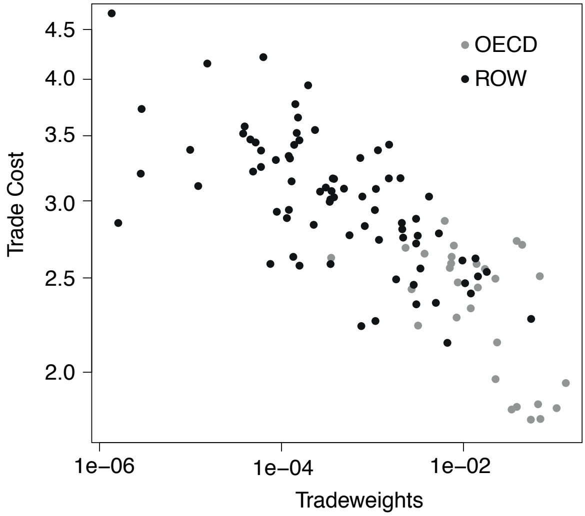
Having seen the differences in both approaches on an aggregate level, this section investigates sources of differences when applying the inverse gravity framework or the ratio gravity estimation. Following Waugh (2010), countries are split into OECD and non-OECD, rest of the world (ROW) countries in order to investigate differences in the resulting trade costs when using either the inverse gravity framework or ratio gravity estimation.

First of all, looking at Figure 4, which shows the relationship between τ and the trade weights assuming a θ of seven, the reason for the big jump between non-weighted and weighted averages becomes apparent. Countries with a large share of worldwide exports have relatively low trade costs. Thus, when using weights, the global mean will also be lower. Moreover, estimated trade costs from ratio gravity seem to be more dispersed relative to those from the inverse gravity approach. Therefore, when calculating simple averages, the global mean seems to be influenced by those outliers in the ratio gravity case. This finding is robust to assuming other trade cost elasticities (i.e., $\theta = 4$).

Turning to Figures 5 and 6, the strong influence of using weighted averages instead of simple averages can be seen again. The solid black line representing the global average seems to be strongly influenced by the high number of estimates for countries with large estimated trade costs in the ROW group, as opposed to a small group which has low estimated trade costs, such as the OECD. As seen in Figure 2a, the effect of weighting is especially strong for the global average using estimates from the ratio gravity approach due to more dispersed estimated trade costs. Turning back to Figure 5, what differentiates the trade costs inferred from the two methods becomes especially clear. Trade costs for the OECD countries when trading among themselves are lowest on average according to both methods (light grey dashed curves in Figures 5a and 5c). However, when investigating trade with all other countries (ROW, light grey solid curves) or generally with all countries (all, dark grey dashed curves), a clear discrepancy becomes apparent – estimated trade costs are much higher under the inverse gravity approach than with in the ratio gravity estimation, since the latter calculates trade costs as a geometric average for bilateral pairs.

Figure 4: Relationship between τ and trade weights

a) Inverse gravity



b) Ratio gravity

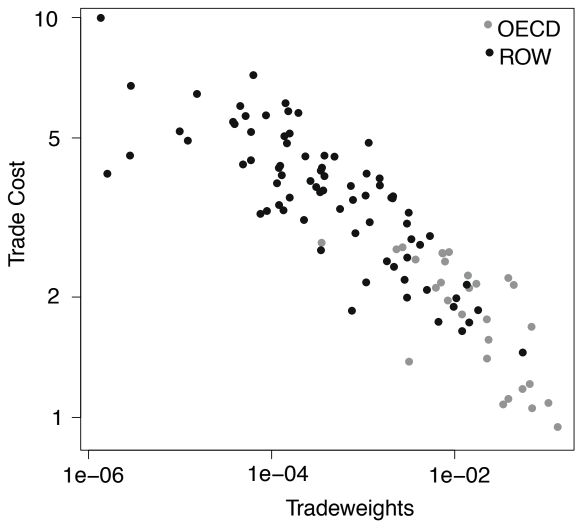
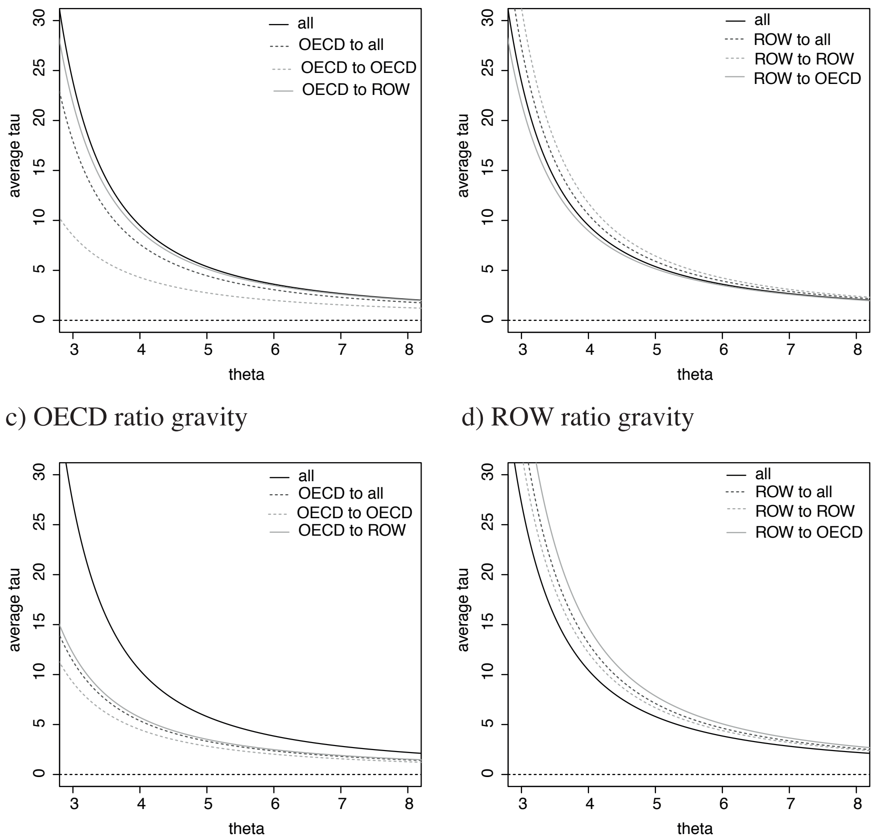


Figure 5: Simple average τ against θ

a) OECD inverse gravity b) ROW inverse gravity

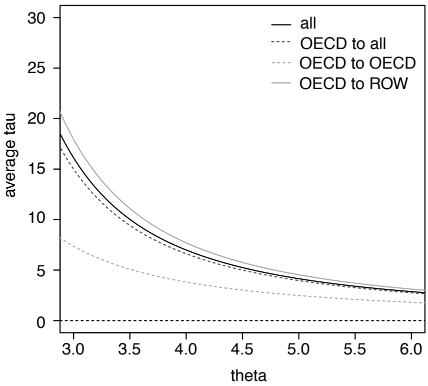


The observed patterns are very similar in Figure 6 – the global means rotate downwards, reflecting lower trade costs for any given trade elasticity as countries with higher trade costs get a lower weighting in the average. Additionally, ratio gravity now produces lower global average trade costs.

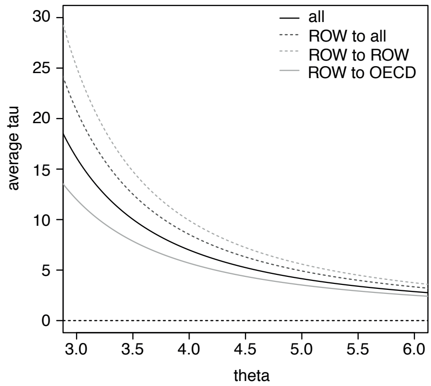
This could be due to the fact that, given the lower dispersion of trade costs estimated with inverse gravity, attaching higher weights to very low trade cost observations does not reduce global average trade costs as much as under ratio gravity.

Figure 6: Weighted average τ against θ

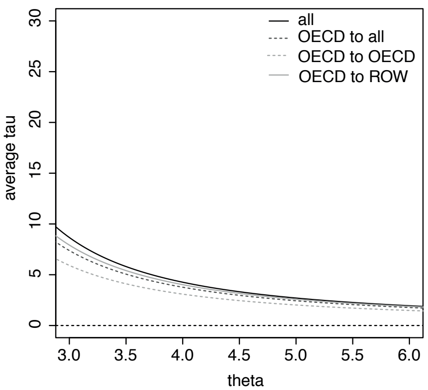
a) OECD inverse gravity



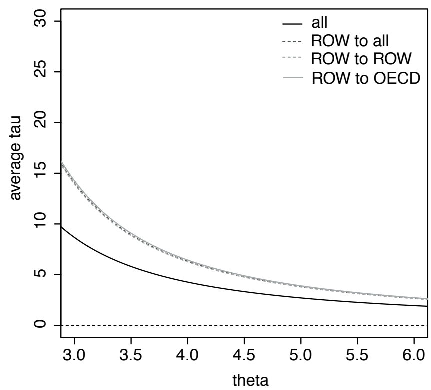
b) ROW inverse gravity



c) OECD ratio gravity



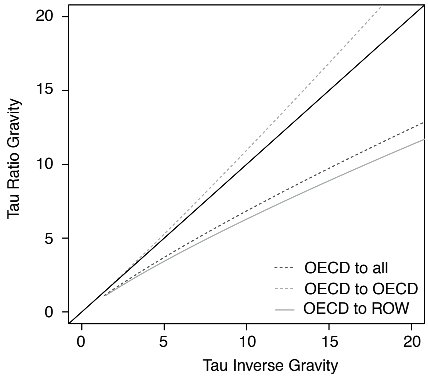
d) ROW ratio gravity



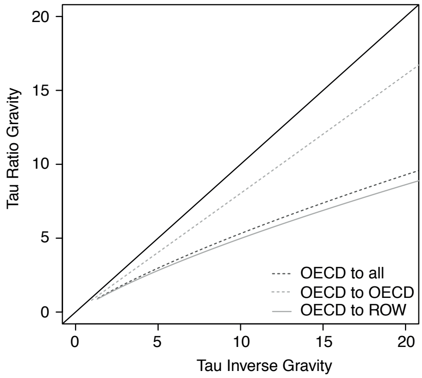
In addition, using weighted averages seems to result in more clustered trade cost estimates for ROW countries when using ratio gravity (Figures 5d to 6d), while the respective estimates for ratio gravity are more dispersed (Figures 5b to 6b). Figure 7, where trade costs are plotted against each other, confirms the tendency described before. While all inferred trade costs are lower, the reaction to weighting is relatively stronger for the ratio gravity trade cost estimates. Thus, all curves rotate downward since inverse gravity produces larger estimates of trade cost now. The tendency of inverse gravity to return relatively high estimates of trade costs when unequal pairs are compared can be seen once more in Figure 7a. The cost of trade among OECD countries seems to be higher when calculated with ratio gravity. However, when comparing trade among very unequal pairs, such as exports from OECD to non-OECD countries, then inverse gravity yields higher estimates.

Figure 7: Comparison of predicted τ

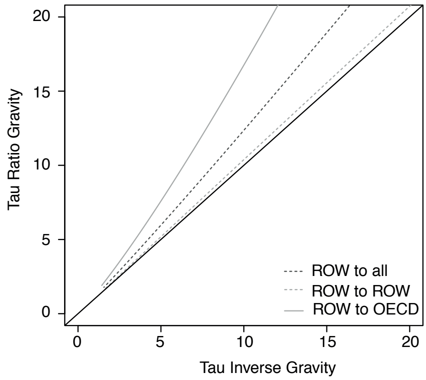
a) From OECD, non-weighted τ



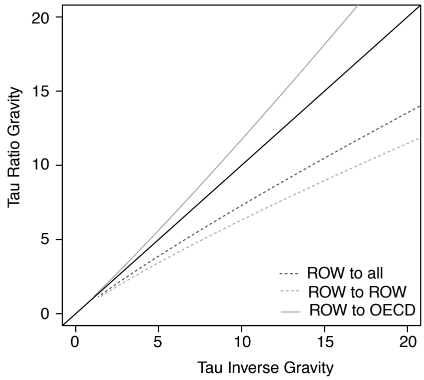
b) From OECD, weighted τ



c) From Rest, non-weighted τ



d) From Rest, weighted τ



6 Conclusion

This paper compares different approaches estimating trade costs. On the one hand, Novy (2013a) proposes an inverse gravity framework which makes relatively few assumptions about the specific form of trade costs. Under this approach, trade costs are inferred from trade flows only. Ratio gravity estimation (as used by Eaton and Kortum (2002); Waugh (2010); Simonovska and Waugh (2014)), on the other hand, provides more insight into the sources of trade costs but makes stronger assumptions. Thus, while the trade costs from inverse gravity fit trade flows perfectly (Larch, Monteiro, Piermartini and Yoto, 2017), differences in trade costs are not immediately clear as the measure always represents an average across two countries. Regressing relative trade shares on country dummies and trade cost proxies yields asymmetric trade costs. In comparison, taking simple means of trade costs results in higher values for ratio gravity relative to inverse gravity. This relationship reverses when using trade-weighted means instead or when trade cost estimates based on ratio gravity are geometrically averaged for each bilateral pair. Generally, even for countries like Switzerland, trade costs are relatively high and thus present an opportunity for improvement, for example by entering into FTAs.

With respect to limitations, it should be noted that the data used for this paper are cross-sectional only. As suggested by PIERMARTINI and YOTOV (2016), panel data are preferable if available, as trade costs vary over time. For ratio gravity, this could be easily incorporated by using time-varying exporter and importer fixed effects (PIERMARTINI and YOTOV, 2016). In contrast, the inverse gravity approach would be time-varying in any case as it is only based on yearly trade flows (Novy, 2013a). Second, zero trade flows are dropped by OLS. To overcome this, PIERMARTINI and YOTOV (2016) propose the use of a Poisson pseudo maximum likelihood (PPML) estimator based on the approach of SANTOS SILVA and TENREYRO (2011). Additionally, disaggregated data could be used instead of country-level data as done in this analysis. This would further aggravate the problem of zeros, as more flows would be missing unless PPML is used. Furthermore, using disaggregated data would allow different elasticities to be used for different sectors, as proposed by NOVY (2013b). A further limitation arises when considering the sources of changes in trade costs. While the ratio gravity approach could provide answers as it is based on a regression framework (so that additional regressors controlling for certain policies could be included), this is more difficult for inverse gravity because it is a calibration approach rather than an estimation approach (LARCH, MONTEIRO, PIERMARTINI and YOTO, 2017). In order to cope with this, NOVY (2013a) proposes regressing inferred trade costs on trade cost variables such as distance or policy indicators. Finally, the data used in this paper contain manufacturing values only, so the comparison conducted here does not necessarily apply to agricultural or service data.

Future research could additionally exploit the time dimension to investigate systematic differences or differentiate between different industries and use separate trade elasticities for each industry to investigate in more detail how estimated trade costs react.

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