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Petr Polák, Nikol Poláková, and Anna Tlustá *

Abstract

We use more than 1,600 estimates from 71 studies to investigate the relation between international trade flows and tariffs. Our results suggest that the empirical literature suffers from the presence of publication bias, which has exaggerated the effect (the true elasticity is closer to zero). After accounting for publication bias, we estimate the trade elasticity with respect to tariffs to be between -0.9 and -2.0. The results of Bayesian model averaging, which takes into account model uncertainty, show that the differences among estimates are systematically driven by the type of data (panel and level of aggregation), the data source (WITS vs. other databases), control variables (distance and trade agreements dummy), and estimation techniques (use of country-level fixed effects). The effect is also diminishing over time.

Abstrakt

S využitím více než 1 600 odhadů ze 71 studií zkoumáme vztah mezi mezinárodními obchodními toky a cly. Naše výsledky naznačují, že empirická literatura je zatížena publikační selektivitou, což příslušný efekt nadhodnocuje (skutečná elasticita je blíže nule). Po očištění o publikační selektivitu odhadujeme elasticitu obchodu ve vztahu ke clům mezi -0,9 a -2,0. Výsledky bayesovského průměrování modelů, které zohledňuje modelovou nejistotu, ukazují, že rozdíly mezi jednotlivými odhady jsou systematicky způsobovány typem dat (panel a úroveň agregace), jejich zdrojem (WITS vs. ostatní databáze), kontrolními proměnnými (vzdálenost a dummy proměnná pro obchodní dohody) a technikami odhadu (použití fixních efektů na úrovni zemí). Výsledný efekt rovněž klesá v čase.

JEL Codes: F12, F13, F14, O24, O30.
Keywords: BMA, international trade, meta-analysis, publication bias, tariffs, trade costs.

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1. Introduction

Trade is a keystone of economics. It allows us to exchange things we have for things we want. We have seen periods of protectionism in history, but the lesson learned is that limiting trade benefits no one. Conversely, the abolition of trade barriers leads to an increase in both trade and welfare. Countries have therefore entered into trade agreements. The multinational World Trade Organization (WTO) oversees the global rules of trade between nations. Its main function is to ensure that trade flows as smoothly, predictably, and freely as possible. Yet current developments globally are leading in a different direction. Since February 2020, the United Kingdom is no longer part of the European Union (EU), and since mid-2018, a trade war has been going on between China and the USA, two of the world's largest economies. The USA imposed tariffs not only on China, but also on other trading partners. In reaction, China imposed tariffs on US imports. The extent of the trade cost increase caused by the current increased trade tensions is unclear. For example, Stephens (2015) warns that there is a risk of returning to a beggar-thy-neighbor trade policy as we saw in the 1930s, which resulted in recession.

Economists have been investigating international trade for decades. They have been searching for a variety of variables that have a significant effect on international trade. The growing literature on international trade provides evidence that trade costs have a negative impact on trade volume. Such findings confirm the historical studies investigated by Anderson and Van Wincoop (2004), who showed that integration leads to a reduction in trade costs. According to Estevadeordal et al. (2003) and De Bromhead et al. (2019), higher transportation costs were the main determinant of the collapse of world trade in the 1930s.

Trade costs do not relate solely to tariffs and transportation. We can group them into several groups, including policy costs (currency, tariffs, security, etc.), distribution costs, and transportation costs. Currency is investigated not only from a currency area perspective (see, for example, Havránek, 2010; Polák, 2019), but also from an exchange rate perspective (see, for example, Ćorić and Pugh, 2010). A non-financial focus is also crucial. Studies such as Baier and Bergstrand (2001) show that liberalization of international transportation services promotes international trade to the same extent as tariff liberalization. This supports an up-to-date world trade strategy where the role of governance and infrastructure is more important than the role of borders. An importer or exporter encounters trade costs during the whole process of trade, not only at borders. The costs start with collecting information about market conditions and end with making the final payment. Minimizing trade costs through the facilitation of merchandise and services trade logistics, both inbound and outbound, is currently the center of attention.

The model used most commonly in academia to empirically estimate the effect of trade costs on international trade is the gravity equation. The gravity framework has undergone significant development since it was first introduced in the second half of the 20th century. The key papers in this area, such as Head and Mayer (2014) and Anderson and Van Wincoop (2003), point to the weaknesses of some of the approaches used and suggest remedies to overcome the issues. To empirically evaluate the existing literature, consisting of more than 70 papers, we apply a meta-analytic framework to investigate the effect of trade costs on bilateral trade flows, focusing on the methodology for determining whether different approaches produce different results in reality.

We build upon Head and Mayer (2014), who focused quantitatively on the elasticity of trade with respect to trade costs and made the first attempt to aggregate the findings. We further extend their dataset by collecting additional studies and explanatory variables. In addition, we focus on possible publication bias. Our results suggest that the literature suffers from publication bias, which causes the results in the primary research to be exaggerated. Using empirical methods (the funnel asymmetry test), we estimate the size of the underlying effect beyond publication bias to be between -0.9 and -2.0, close to the median value. Publication bias is also significant in explaining the heterogeneity among the estimates. Although publication bias is an issue, we do not identify any publication characteristics, such as journal quality or when the study was published, that systematically influenced trade cost elasticity. We identify several properties that have a significant impact on the estimated size of trade costs. From a methodological perspective, how zero trade flows are addressed and whether the study uses country fixed effects are important factors. The dataset characteristics are also important – there are differences between estimates based on import and export data and estimates from different data sources. We also find statistically significant differences between estimates from aggregated (country-level) and disaggregated (sector-level) data and estimates from panel data and cross-sectional data. It is also important to use control variables, such as distance and a dummy for trade agreements.

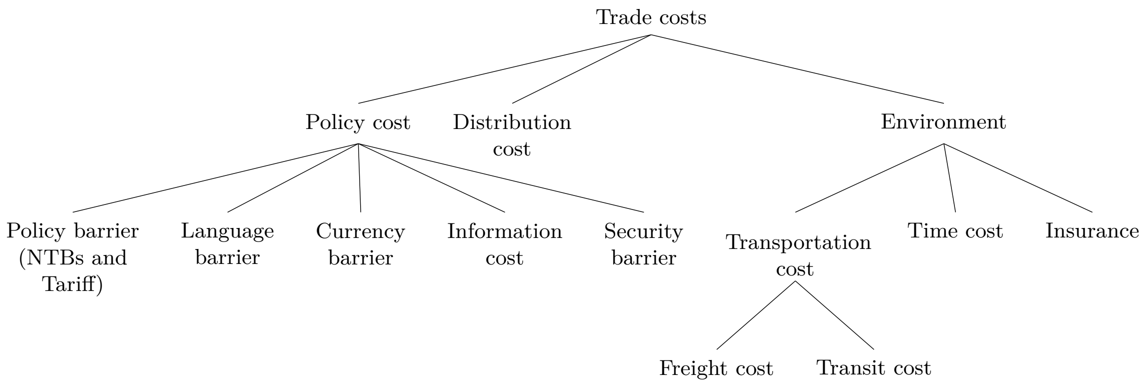
The structure of this paper is as follows. Section 2 discusses potential discrepancies between different kinds of trade costs. Section 3 describes how trade costs are investigated empirically using the gravity framework. Section 4 presents the data collected from the studies. Section 5 discusses publication bias, and Section 6 discusses our results – the key drivers of the heterogeneity of trade cost estimates. Finally, Section 7 concludes.

2. The Importance of Trade Costs

In general, we can define *trade costs* as all costs that are necessary to get a good to a final consumer, except the marginal cost of the production of the good itself. Trade costs include transportation costs, policy barriers, legal and regulatory costs, and distribution costs. In the area of international trade, we mostly think about the bilateral costs, but there are also country-specific trade costs. The latter are getting more and more important nowadays and new methods have been developed to evaluate their impact in structural gravity models – see, for example, Heid et al. (2017) and Beverelli et al. (2018). Trade costs are reported mostly in terms of their ad valorem tax equivalent. Anderson and Van Wincoop (2004) highlight the importance of trade costs with the statement that the *"tax equivalent of representative trade costs for rich countries is 170 percent. This includes all transportation, border-related and local distribution costs from foreign producer to final user in the domestic country. Trade costs are richly linked to economic policy. Direct policy instruments (tariffs, the tariff equivalents of quotas and trade barriers associated with the exchange rate system) are less important than other policies (transportation infrastructure investment, law enforcement and related property rights institutions, informational institutions, regulation, language)."* Figure 1 shows one possible division of trade costs.

Policy costs or policy barriers to trade are intuitive; they include tariffs, quotas, license fees, exchange rates, and security issues. Anderson and Van Wincoop (2004) note that even though it should be simple to determine how high the policy costs of trade are, they are difficult to examine empirically because of missing and incomplete data. The unavailability and poor quality of data with respect to the policy costs of trade is surprising, since it has been known for hundreds of years that open trade promotes welfare. Researchers often use the United Nations Conference on Trade and Development's Trade Analysis & Information System (TRAINS) dataset, since it is easily accessible, but there are other measures and indexes, as noted in Hoekman and Nicita (2008), for example.

Figure 1: The Division of Trade Costs



Notes: The figure presents an illustrative division of trade costs as can be found in the literature. NTM non-tariff measures

Distribution costs are costs pertaining to wholesale and retail distribution that affect the final prices of goods in each region or country. Burstein et al. (2003), in their study on distribution costs and real exchange rates, state that distribution costs are key drivers of different prices of the same good in different countries because distribution services are focused on labor and land costs. In addition, their study shows that variation in distribution margins exists even within the same country. We might expect increasing competition and possible arbitrage potential to cause the distribution cost to be the smallest part of the overall cost, but the opposite is true – the margins for distribution are usually the highest.

Environment costs are costs caused mainly by distance. Aside from time costs and insurance, the main component is transportation costs. Direct transportation costs include freight rates (the transit cost itself depends on the type of transportation) and insurance. Indirect transportation costs include the cost of preparing transportation and the cost of having goods in transit. Transportation costs are higher for heavier goods such as agricultural products, but according to Limao and Venables (2001), transportation costs are easier to measure than policy costs and are comparable across countries and commodities on average.

Figure 1 and a brief description inspired by the extensive survey of Anderson and Van Wincoop (2004) provide a general picture where the term "trade costs" is very broad and can measure many different factors. On the other hand, the research is limited by the available data; the final empirical research is therefore quite homogeneous in terms of definitions and methodology.

3. Theoretical Background

The gravity equation is widely used in international economics and is said to date back to the 19th century, when Ravenstein (1885) used a gravity-type relationship to study immigration. The model was formalized in the 1960s when Tinbergen (1962) and Pöyhönen (1963) applied it to study the impact of trade policy. In the early models, bilateral trade flows depend on only the GDP of the countries and the distance between them, so the relationship has the same interpretation as in physics:

$$T_{ij} = G \frac{Y_i^{\alpha} Y_j^{\beta}}{D_{ij}^{\theta}} \tag{1}$$

where T_{ij} is the trade flow from region or country i to destination j, and Y_i and Y_j are the economic sizes of the regions or countries (mostly represented by GDP). D_{ij} is the distance between the regions or countries, G replaces the gravity constant and hence represents all other bilateral indicators, and coefficients α, β, and θ stand for the elasticities to be estimated.

The first theoretical foundations of the gravity equation were provided by Anderson (1979) and Bergstrand (1985). At the beginning of the 21st century, the most influential work by Eaton and Kortum (2002) and Anderson and Van Wincoop (2003) gave the gravity framework a more solid foundation. Eaton and Kortum (2002) derived the gravity model from a Ricardian supply-side framework, while Anderson and Van Wincoop (2003) derived it from an Armington demand-side framework (CES production) and emphasized the importance of the general equilibrium effects of trade costs. Although these studies approach the subject from different perspectives, the results are almost the same. Arkolakis et al. (2012) showed that many more frameworks can be used to derive the gravity equation.

We present the gravity equation based on the Armington framework following Anderson and Van Wincoop (2003), since that form is commonly used in the most recent studies analyzing the impact of different trade costs on international trade.[1] The complete generalized gravity system that explains exports (X_{ij}) from country i to country j is described according to Yotov et al. (2016) in equations 2 to 4:

$$X_{ij} = Y_i E_j \left(\frac{\tau_{ij}}{\Pi_i P_j} \right)^{1-\omega} \tag{2}$$

$$\Pi_i = \left(\sum_{j=1}^{C} E_j \left(\frac{\tau_{ij}}{P_j} \right)^{1-\omega} \right)^{\frac{1}{1-\omega}} \tag{3}$$

$$P_j = \left(\sum_{i=1}^{C} Y_i \left(\frac{\tau_{ij}}{\Pi_i} \right)^{1-\omega} \right)^{\frac{1}{1-\omega}} \tag{4}$$

where ω is the broadly defined *trade cost elasticity* and τ_{ij} is the total bilateral trade cost.

Equation 2 is the structural gravity equation that governs bilateral trade flows. It consists of a size term $Y_i E_j$ and a trade cost term $\frac{\tau_{ij}}{\Pi_i P_j}$. The size term is measured as exporters' and importers' incomes. The innovation introduced by Anderson and Van Wincoop (2003) consists in the multilateral resistance terms P_j and Π_i, which differentiate the theory-founded gravity models from earlier versions. These remoteness terms represent the ease of market access for importers and exporters.

To provide econometric estimates for the effect of distance and other bilateral indicators and measures of trade costs, trade economists use the multiplicative nature of the gravity equation and apply a log form of Equation 1. Because of the remarkable predictive power and intuitive form of the gravity model, most of the gravity-related literature is empirical. Moreover, as stated above, the

[1] This is not the Armington elasticity, which is defined as the relationship between import and domestic prices as competitors. See, for example, Bajzik et al. (2020) for details.

empirical applications were predecessors of the theoretical foundations. The log-linear form of Equation 2 for any time t can be rewritten as follows:

$$\ln X_{ij,t} = \ln E_j,t + \ln Y_i,t + (1-\omega)\ln \tau_{ij,t} - (1-\omega)\ln P_{j,t} - (1-\omega)\ln \Pi_{i,t} \tag{5}$$

The specification of Equation 5 is the most frequently used version of the empirical gravity equation. Yet some obvious challenges arise when estimating this equation. First, the multilateral resistance terms P_j and Π_i are theoretical and are not directly observable. Baldwin and Taglioni (2007) emphasize the importance of proper control for the multilateral resistance terms; failure to control for them is called the "Gold Medal Mistake." One remedy is the application of directional (exporter and importer) fixed effects; additionally, when using panel data, exporter-time and importer-time fixed effects are necessary. However, fixed effects absorb all observable and unobservable country-specific characteristics. Trade costs, which we are interested in, cannot be easily captured by a single number, and the decomposition of it represents another challenge. The bilateral trade costs term τ_{ij} is disaggregated using a group of observable variables that have become standard in the empirical gravity equation, for example, distance, a common border, and tariffs. So, the final model that is estimated in primary research and that we use to collect the estimates has the following form:

$$\begin{aligned}\ln X_{ij,t} = {} & \alpha_0 + \alpha_1 \ln E_j,t + \alpha_2 \ln Y_i,t + \beta_1 \ln Distance_{ij} + \beta_2 Language_{ij} + \beta_3 Border_{ij} + \beta_4 Currency_{ij,t} + \\ & + \beta_5 RTA_{ij,t} + \beta_6 \ln\left(1 + tariff_{ij,t}\right) + \varepsilon_{ij,t}\end{aligned} \tag{6}$$

where the error term is ε_{ij}. Some of the variables capture time-invariant properties: *Distance* is the distance between trading countries, *Language* is a dummy variable for a common official language, and *Border* is a dummy variable for a common border. Then we have *Currency*, which is a dummy for the same currency at time t and is typically used to estimate the benefits of currency unions.[2] The last two variables are policy variables: *RTA* is a dummy variable for the presence of any trading agreement at time t, and $tariff$ is the tariff that country j (the importer) imposes on trade from country i at time t. β_6 **is analyzed in detail in the empirical part of this study and, in line with the common practice in the literature, we further use "trade cost" as the label for tariffs.** Tariffs constitute the "price" of a trade, so in some empirical studies tariffs are replaced by shipping costs, for example.

The gravity equation – either the simple version or its derived form – has frequently been used in various areas of international trade. Researchers have used it to explain the relationship between trade flows and other variables. They use it because it is a simple way to calculate welfare gains from trade. Head and Mayer (2014) emphasize that the elasticity of trade or the import ratio are sufficient statistics (when their macro restrictions hold) for such calculation, and these values can be estimated by applying the gravity equation to international trade.

4. Dataset

Data collection is a crucial part of every meta-analysis, because the quality of the data affects the quality of the results. We use the results of primary studies for our meta-analysis, and for simplicity, we further use the term "trade costs" for the "elasticity of trade with respect to bilateral trade costs." This implies that it measures how bilateral trade is affected by a change in tariffs or price equivalent. As mentioned earlier, because of the popularity of the gravity equation in recent years, interest in analyzing international trade has been increasing. This enables us to obtain an extensive dataset. To the best of our knowledge, a meta-analysis that properly investigates studies related to the elasticity

[2] See, for example, Polák (2019) for the largest meta-analysis of the euro currency union.

of trade with respect to trade costs has not been conducted, although Head and Mayer (2014) indirectly suggest such a study when discussing the policy impact of the elasticity of trade with respect to trade costs in their cookbook. They build on the dataset from Disdier and Head (2008) and collect almost 160 studies estimating trade effects, but relatively few papers estimate trade cost elasticities.

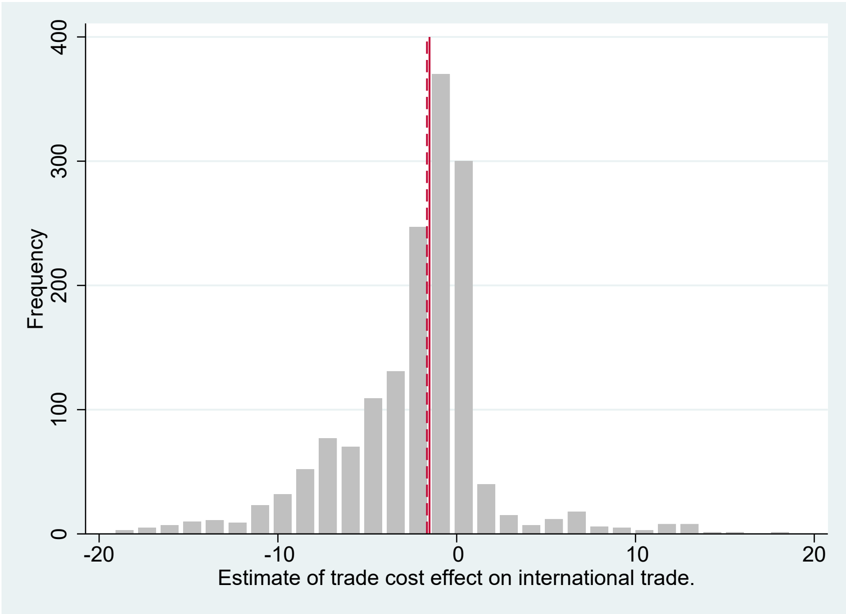
The data for this study are collected from all studies on the trade cost effect that we could find. We started with the update of the dataset created by Disdier and Head (2008). We not only coded new variables, but also verified the validity of the dataset itself. Since the dataset is more than ten years old, we searched for new studies to enlarge the sample using the RePEc database and Google Scholar to obtain both published and unpublished studies. We used combinations of the keywords "gravity", "trade cost", "trade and quota", "non-tariff", "NTB", "freight cost", "freight charge", "transit cost", "shipment cost", and "tariff", and we searched titles, keywords, and abstracts. We stopped the search of primary studies in September 2019 and did not include any new studies after that date. We excluded those studies with no empirical parts (from which we could not obtain any estimates for the meta-analysis) and downloaded those that might estimate trade costs.

To create a homogeneous dataset suitable for meta-regression analysis, we applied the following criteria. (a) We included only empirical studies using the gravity framework presented in Section 3 and Equation 6 to analyze the trade costs. (b) We excluded all estimates analyzing only bilateral trade within a country, since our study is focused on international trade. (c) We included only studies written in English and German, as these were our language limitations. (d) We included only estimates with a reported estimation precision (standard error, p-value, or t-statistic), because we need the precision in the form of the standard error to know how important the estimate should be in the meta-regression analysis and also for publication bias investigation. We collected all estimates from every study to obtain the largest possible dataset and to remain as unbiased as possible. Some authors highlight their preferred estimate, but in many cases it is impossible to select a single estimate per study without making additional assumptions (e.g., precision, model, or method suitability).

Outliers in terms of trade elasticity and standard error are treated by winsorizing at the 5% level. The final dataset contains 1,609 estimates from 71 studies. Only 21 studies are working papers and unpublished studies; the majority of the papers are published in refereed journals (22 of them in the top 100 economic journals according to RePEc). The list of studies included in the dataset is available in the Appendix. The majority of the gravity estimates are reported by studies that use regressions derived from the basic Equation 1. The primary studies from which we collect the estimates use different methods to estimate trade elasticity with respect to trade costs. Sometimes, instead of tariffs, price information such as the wage, the exchange rate, shipping costs, or freight costs is used. We separate the estimates into two groups based on the definitions of the explanatory variable along with other differences to determine whether they are a significant determinant of the final effect. These differences are coded using 54 variables. The data were collected by the main author of this paper; the co-authors then randomly checked some of the data collected by the other author to minimize mistakes caused by manual entry and interpretation of the data, following Havránek et al. (2020).

The overall mean reported trade cost elasticity estimate is -2.23 and the overall median estimate is -1.43. This difference might have been caused by studies that report many estimates (some studies report only one estimate, while the maximum number of estimates in a study is 136). To compensate for the effect of large studies, we weight the estimates by the inverse of the number of estimates reported and hence give the same weight to each study. This procedure results in a mean trade cost elasticity of -1.61, which is close to the median. The weighted number is more

Figure 2: Distribution of Trade Cost Elasticity Effects



Notes: The figure represents a histogram of the estimates of the trade cost elasticity coefficient reported in the individual studies without outliers (estimates with an absolute value greater than 20). The solid vertical line indicates the median of all the estimates. The long-dashed line indicates the median of the median estimates from the individual studies.

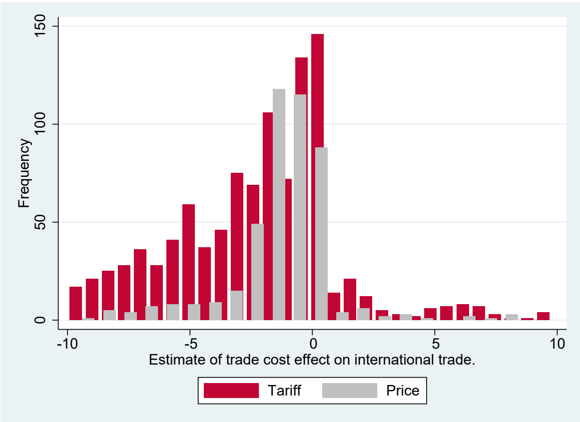
informative because it is not driven by robustness checks and large studies, for example. We further show that the number is exaggerated because of publication bias and that the true trade cost elasticity is much closer to zero.

Figure 2 depicts the histogram of the collected estimates of trade cost elasticities. The histogram shows that the majority of the estimates are negative: only approximately 17% of the estimates are positive (which is theoretically implausible). One-third of the estimates are very close to zero – within the interval (-1,1). Some extreme outliers are included in the data; we therefore excluded values with an absolute value greater than 20 from the chart. The elasticity varies not only between studies, but also within studies. To understand the heterogeneity, we collected 54 variables to capture the differences between the estimates.

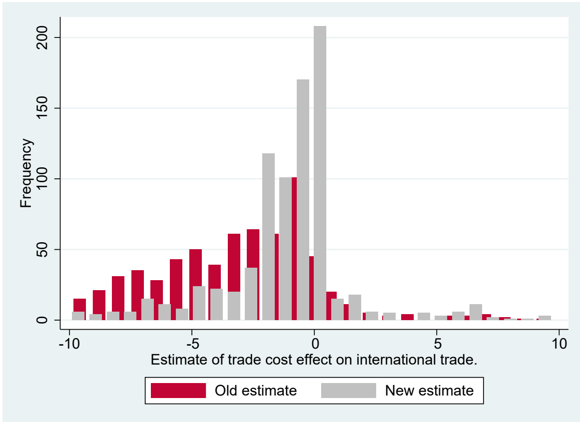
Systematic differences between the collected estimates were identified when we created different groups of estimates; some of them are shown in Figure 3. These groups are formed of characteristics that we code for in the dataset and use to explain the drivers of the variance among the reported estimates. For instance, there is a difference between estimates for which different types of explanatory variables are used – the mean of the estimates based on tariffs is double the mean of the estimates based on prices. The mean of the estimates based only on import data is -2.1, while the mean of the estimates based on export data is -1.0 (less than half). The mean of the estimates from panel series data is -2.0, while the mean for cross-sectional data is -2.6. Somewhat interesting is the difference in the estimates prior to 2014 (those collected by Head and Mayer, 2014) and the estimates after that point. The mean of these “new estimates” is only -1.0, while the mean for the “old estimates” is -3.8. These patterns in the data might help explain the heterogeneity, but we cannot be sure whether these differences are correlated with other factors or are fundamental. We investigate the heterogeneity using quantitative methods in Section 6 with the collected variables.

Figure 3: Key Patterns in the Data

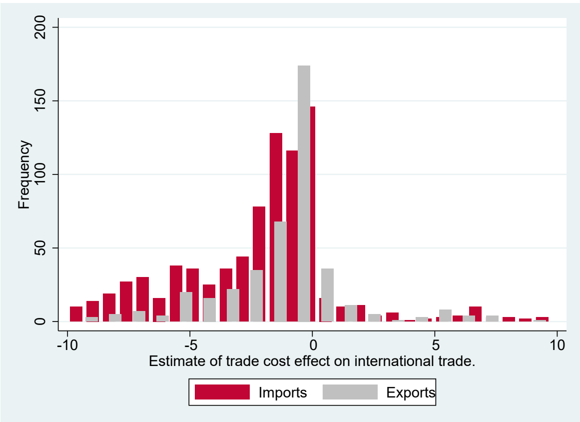
(a) Key Variable



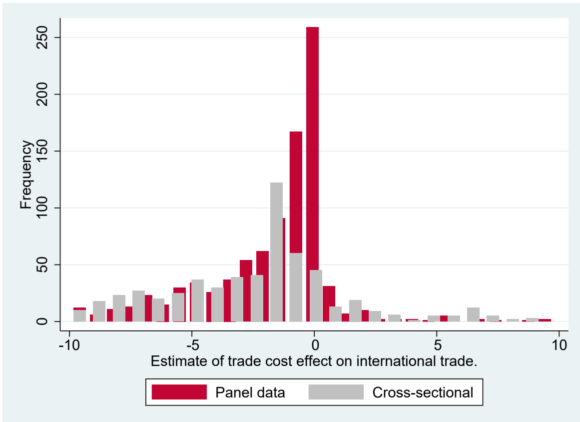
(b) New vs. Old Estimates



(c) Dependent Variable



(d) Data Dimension



Notes: Estimates smaller than -10 and larger than 10 are excluded from the figures for more representative histograms, but the estimates are included in all the statistical tests and the empirical estimation. Old estimates are those collected by Head and Mayer (2014); new estimates are from other studies. The variables shown here are chosen by expert judgment to illustrate the differences in the data; not all of them have been proven to be significantly different from each other.

Table 1 presents all the variables that our dataset captures from primary studies and provides variable definitions and basic summary statistics. We follow previous studies such as Polák (2019) and Havranek et al. (2015) in the variable definitions and variable grouping for better understanding. The collected variables should allow us to determine the drivers of heterogeneity and how choices made by researchers influence the final results, and to address the best known methodological issues with the gravity equation, as described by Baldwin and Taglioni (2007) and Head and Mayer (2014).

Table 1: Description of Regression Variables

Variable	Description	Mean	SD
Trade cost	"Estimate of the trade cost effect on international trade"	-2.23	4.21
se	Estimated standard error of the trade cost.	0.86	1.04
Price	=1 if the trade cost effect is estimated using prices not tariffs.	0.29	0.45
Data characteristics			
Mid year	The mid year of the sample on which the gravity equation is estimated (the base is the sample minimum: 1,870).	1994	16.62
Panel data	=1 if panel data are used in the gravity equation.	0.6	0.49
Disaggregated	=1 if the data are disaggregated.	0.57	0.49
No. of obs.	The logarithm of the number of observations included in the gravity equation.	9.2	2.8
No. of years	The logarithm of the number of years.	1.4	1.3
Countries surveyed			
US	=1 if the trade cost effect is estimated for the US (or combinations of country groups)	0.56	0.5
Canada	=1 if the trade cost effect is estimated for Canada (or combinations of country groups)	0.51	0.5
Japan	=1 if the trade cost effect is estimated for Japan (or combinations of country groups)	0.61	0.49
EU	=1 if the trade cost effect is estimated for the EU (or combinations of country groups)	0.51	0.5
OECD	=1 if the trade cost effect is estimated for OECD countries.	0.31	0.46
Emerging	=1 if the trade cost effect is estimated for transition or developing countries.	0.41	0.49
Sector examined			
Agriculture	=1 if the trade cost effect is estimated for the agriculture sector.	0.5	0.5
Animals	=1 if the trade cost effect is estimated for animal husbandry.	0.28	0.49
Transportation	=1 if the trade cost effect is estimated for the transportation industry.	0.39	0.49
Services	=1 if the trade cost effect is estimated for the service sector.	0.3	0.46
Raw materials	=1 if the trade cost effect is estimated for raw materials.	0.37	0.48
Manufacture	=1 if the trade cost effect is estimated for the manufacturing or production sector.	0.67	0.47
Specification characteristics			
Model	=1 if the model is based on naive and not structural gravity	0.09	0.29
Total trade	=1 if the researchers sum export and import trade flows before taking the logarithm form	0.2	0.4
Imports	=1 if the researchers measure only import flows	0.56	0.5
Exports	=1 if the researchers measure only export flows	0.29	0.45
No internal trade	=1 if within-country trade flows are estimated using production data	0.24	0.42
Asymmetry	=1 if the estimate measures international trade flows in one direction	0.44	0.5
Instruments	=1 if the instrument variable is used to correct for the endogeneity of GDP	0.17	0.37
OLS	=1 if the gravity equation is not estimated by OLS (reference category: OLS).	0.29	0.45
PPML	=1 if the researchers applied the Poisson pseudo maximum likelihood method to estimate the gravity equation.	0.1	0.3

Continued on next page

Table 1: Description of regression variables (continued)

Variable	Description	Mean	SD
Data source			
TRAINS	=1 if the researchers used data from the TRAINS database.	0.14	0.35
COMTRADE	=1 if the researchers used data from the COMTRADE database.	0.22	0.41
WITS	=1 if the researchers used data from the WITS database.	0.19	0.38
IMF	=1 if the researchers used data from the IMF database.	0.07	0.25
Treatment of multilateral resistance			
Control for MR	=1 if the gravity equation accounts for multilateral resistance terms.	0.54	0.5
Remoteness	=1 if the remoteness term is included.	0.23	0.42
Openness	=1 if the openness of the economy is included.		
CFE	=1 if the destination fixed effect is included.	0.52	0.5
Year FE	=1 if the year fixed effect is included.	0.3	0.46
Sector FE	=1 if the sector fixed effect is included.	0.39	0.49
Ratios	=1 if the trade flow is normalized by trade with self.	0.18	0.38
Treatment of zero trade flows			
Zero omitted	=1 if observations of zero trade flows are omitted.	0.18	0.38
Zero plus one	=1 if the researchers add one to the overall observations of zero trade flows.	0.08	0.26
Control variables			
FTA	=1 if the gravity equation controls for free trade agreements.	0.25	0.43
Language	=1 if the gravity equation controls for common language.	0.44	0.5
Adjacency	=1 if the gravity equation controls for adjacency.	0.33	0.5
Distance	=1 if the gravity equation also measures the distance effect on international trade.	0.53	0.5
Actual	=1 if the actual road/sea distance is used instead of the great-circle formula.	0.16	0.37
Publication characteristics			
journal	=1 if the study is published in a top-ranked journal	0.3	0.46
isWP	=1 if the study is a working paper (reference category: published in a peer-reviewed paper)	0.33	0.47
firstpub	Year when the study first appeared in Google Scholar. (base 1985)	25.37	7.57
impact	Recursive discounted RePEc impact factor of the journal (collected in October 2019).	3.14	3.27
lnyearcits	Log of the mean number of Google Scholar citations (collected in October 2019).	1.95	1.94
new estimate	=1 if the estimate is not part of the Head and Mayer (2014) dataset	0.56	0.47

Notes: SD = standard deviation. All variables except for citations and the impact factor are collected from studies estimating the trade cost (the search for studies was terminated on September 1, 2017, and the list of studies is available in the Appendix). Citations are collected from Google Scholar, and the impact factor is collected from RePEc. Values are rounded to the closest hundredth.

Dependent variable Tariffs vs. prices. Equation 6 shows an example of a model that is empirically estimated in a primary study. Some studies use proxy or alternative variables for tariffs, such as the price of shipping, wages, freight cost, or trade transaction costs. All these variables are expressed in terms of prices and hence are comparable. However, we code (dummy price=1) those which are not exactly tariffs. This allows us to investigate if there are differences between the estimates for tariffs and other similar costs.

Data characteristics The dataset directly affects the final results; therefore, controlling for dataset characteristics helps us understand the heterogeneity of the final results. Larger datasets should provide more precise estimates of the final effects. Thus, we calculate the logarithm of the number of observations in the dataset and the number of observations per year. The dummy variable "panel" indicates whether the source dataset has panel characteristics. One might think that only panel data should be used to estimate trade costs, but only approximately half of the estimates use panel data. Some of our estimates use long time frames, and due to the reduction in trade costs in the past, we wonder whether the trade costs vary over time. To answer this question, we code the midpoint of the sample. Following Anderson and Van Wincoop (2004), who indicate that aggregated data yield different results than granular data when used in the gravity equation, we use a dummy that is equal to 1 if the data are disaggregated at the sector or firm level. More estimates are based on disaggregated data, since studies using aggregated (country-level) data report fewer estimates as well.

Data source The data source is one obvious possible source of heterogeneity, and we use dummy variables to control for different data sources: the UNCTAD Trade Analysis Information System (TRAINS), the United Nations Commodity Trade Statistics Database (UN Comtrade), and the databases of the International Monetary Fund (IMF). These databases are used for the majority of the estimates; the rest are calculated using data from the OECD and other databases.

Countries surveyed The next category for the variables is a coding analysis of trade costs using data from different regions and countries. One reason for doing such an analysis is the general experience of obtaining different effects when analyzing developed and emerging countries or more integrated groups of countries. We include several dummy variables on the basis of frequency of exploration in primary studies: the US, the EU, the OECD, Japan, Canada, and emerging countries (including both transition and developing economies). The reference category for the dummies is the remaining countries and combinations thereof or the entire world.

Sectors examined In the data characteristics section, we mentioned that researchers also use granular data. Some primary studies estimate the trade costs for different sectors of the economy, as these costs may vary substantially. The authors of primary studies generally follow two different approaches. The first approach is either to not consider sectoral heterogeneity at all or to consider only one of many sectors. The second approach is to disaggregate the effect of trade costs by sector (e.g., Caliendo and Parro, 2014). We decided to define dummy variables for the following sectors: agriculture, animals, transportation, services, manufacturing, and raw materials. The reference category for the dummies is a mix of all the sectors.

Specification characteristics We collected estimates from studies that estimate trade costs using the gravity equation. Results from other frameworks would not be easily comparable. Baldwin and Taglioni (2007) describe the most obvious mistakes that researchers make when applying the gravity framework or making methodological adjustments. The best known is the "silver medal mistake", where the simple sum or the average of imports and exports is calculated before taking the logarithm.[3] Furthermore, following Polák (2019), we test whether models based on exports

[3] Since the gravity equation is always estimated in logs, authors use the log of the sum of bilateral trade as the response variable instead of the sum of the logs, because the log of the sum (incorrect method) overestimates the sum of the log (correct method).

perform better than those based on imports, as suggested by Head and Mayer (2014). The reference category for the dummies might be strange, but it uses both imports and exports. Another point is the PPML estimation method, which is aimed at solving the problem of heteroskedasticity of the trade data, but also solves the problem of zero trade flows.

Treatment of multilateral resistance Multilateral resistance has been discussed ever since Head and Mayer (2000) included a remoteness term to control for the distance between trade partners, but the issue was highlighted by Anderson and Van Wincoop (2003), who proposed a non-linear estimation method to control for multilateral resistance. Baldwin and Taglioni (2007) note that multilateral interactions between countries have positive effects on trade by raising the interest of firms in entering new markets; authors should control for such interactions when investigating international trade. Several methods that use dummy variables for these effects are discussed in the literature. Another remedy for multilateral resistance (used even unintentionally) is the time-varying fixed effects method for the gravity equation introduced by Harrigan (1993). More than half of the primary studies apply some type of fixed effects: country fixed effects capture systematic differences in the financial environment across countries (for example, bankruptcy laws) and sector fixed effects (issuing various kinds of industries) control for systematic differences in risk and performance across sector types. Variable year fixed effects control for differences in bilateral trade across years (as many authors consider panel data).

Control variables Control variables should be part of every gravity equation and typically include dummies for common language, common border, and free trade agreement, but many other variables have been considered. Some of these variables cannot be included in the regression if they are constant for country pairs, and a specific fixed-effects method of estimation is used. We use "0" for FTA and Language if these control variables are omitted even though they could be included. For distance, we control not only for its inclusion in the model, but also for the way it is measured – whether the actual distance or the great-circle formula, which measures the distance between the centers of two countries, is used. The latter is easier to calculate but, according to Head and Mayer (2014), leads to upward bias in the estimated effect.

Treatment of zero trade flows If two examined regions do not trade with each other, a zero value is present in the dataset. This might appear to be acceptable, but since trade volume is a dependent variable, such observations can cause problems for the log-linear form of the gravity equation. The simplest solution is either to drop these zero trade observations or to replace zeros with ones. Silva and Tenreyro (2006) indicate that not considering zero observations causes significant bias when using OLS estimation. Other methods (such as the Tobit model and Poisson pseudo maximum likelihood, PPML) solve problems with zeros, and approximately 18% of the studies use these methods to avoid problems with zero trade values.

Publication characteristics Publication bias is an inseparable part of meta-analysis. We code the publication status of each study (working paper or published in refereed journal), and we control for journal quality following Polák (2017) using the RePEc database. Following Havranek et al. (2018b) we also code which studies are published in the top 100 journals in economics. We use RePEc Recursive Discounted Impact Factors, which reflect not only where the study was published, but also the quality of citations, which are split by their age in years (i.e., one for the current year). The main advantage of the RePEc database is that it covers nearly all economic journals and working paper series. Another publication characteristic is the number of citations in Google Scholar. We can test for a relation between the reported size of the trade cost effect and how such result is used. The year of publication can also be used to detect some trends in the results, either because new and more precise estimation methods are developed or simply because people are becoming more efficient in every area, including international trade.

The variables we collected and described are intended to explain the variance in the gathered trade cost elasticities. We collected a total of 54 study, model, and data characteristics, and a large number of possible combinations of these variables can be used in the regressions. We do not know a priori which ones we should include. We use Bayesian model averaging (BMA) to apply the most unbiased method for variable selection and follow recent trends in meta-analysis.[4]

5. Publication Bias

Testing for publication bias is an essential part of every meta-analysis. Publication bias generally describes the situation in academic research where reported estimates do not correspond to the statistical prediction, that is, the situation where the probability that an estimate is reported in a primary study is dependent on either the precision or the magnitude of the estimate. Statistically insignificant results are usually under-reported, as are coefficients with unexpected or theory-inconsistent signs. This occurs if researchers are motivated to prefer estimates that fulfill certain criteria. For trade costs, the expected sign is negative – the higher the cost, the lower the trade volume. Assume that the true trade cost elasticity is negative; when we consider a large number of different data sources and apply different methods, both positive and statistically insignificant estimates should still be present.

The most common and frequently used method for testing for publication bias in meta-analysis is the funnel asymmetry test (FAT); see, for example, Stanley and Doucouliagos (2010) for more details. This method assesses the relationship between the size of an effect and its precision – usually the inverse of the standard error. This relationship is usually presented graphically as a funnel plot, which is a scatter plot in which the size of the trade cost elasticity is plotted on the horizontal axis and its precision is plotted on the vertical axis. The test is based on the inverted funnel shape that we would expect if no publication bias were present. The most precise estimates should be close to the true mean elasticity, and estimates further from the true value are expected to be imprecise, more dispersed, and symmetric around the mean. 4 shows two funnel plots. The left panel shows all the collected estimates, and the right panel shows just one observation per study. In both cases, the most precise estimates are close to zero but far from the median value. The shape is not symmetric; therefore, we should conduct a more precise test for the magnitude of the publication bias.

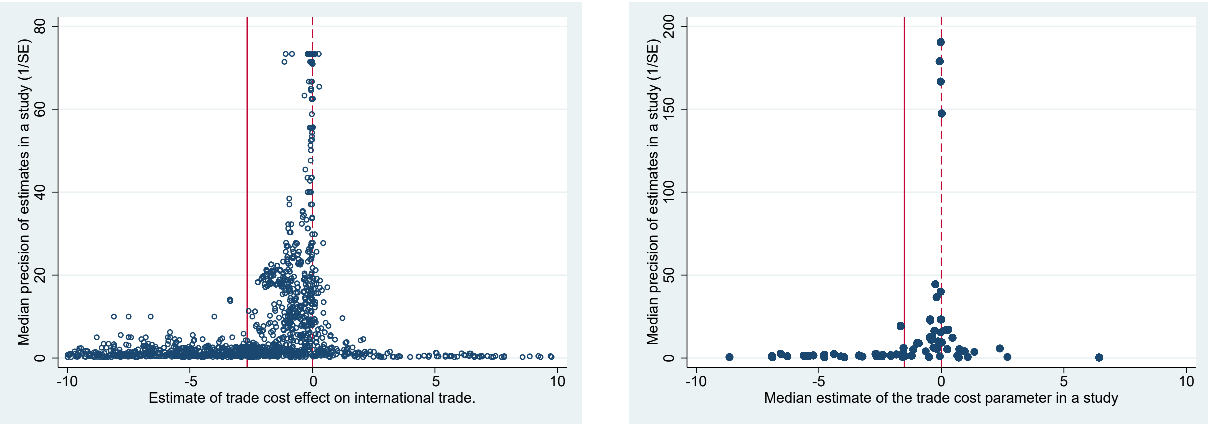
The funnel plots of our data are presented in 4. Panel (a) shows the funnel plot for the trade cost effect of all the estimates, while panel (b) shows the funnel plot for the median estimates reported in the primary studies. The funnel plot is a graphical test and provides only an indication of the possible bias that we should test for empirically. However, we can make several observations. First, the two funnels are not symmetric and the estimates are not evenly distributed – the left side is much heavier. Second, the most precise estimates are distributed around zero (approximately one-third of all the estimates are close to zero), but these values are not close to the median or average. Third, the funnel plot is not hollow. Last, the funnel with all the estimates appears to have more peaks (groups of precise estimates), which implies heterogeneity in the trade cost effect. We expect heterogeneity based on the charts and statistics presented in Figure 3.

The funnel comparison in 5 shows the difference between estimates based on different identifying variables (within the structural gravity model). Panel (a) depicts estimates that use tariffs/freight

[4] See, for example, Polák (2019), Havranek et al. (2018b), Havranek et al. (2018a), and Havranek and Irsova (2017).

Figure 4: Funnel Plots

(a) All Estimates (b) Median Estimates for Each Study



Notes: A funnel plot is a scatter plot where the estimate (the size of the trade cost effect) is plotted against its precision (the inverse of the standard error). The vertical solid line denotes the zero value and the dashed line the mean value. Estimates smaller than -10 and larger than 10 are excluded from the figures for more representative plots, but the estimates are included in all the statistical tests and empirical estimations.

rates, and panel (b) shows those based on other prices. These variables are used to estimate the same value but might lead to such heterogeneity that we should consider them separately (Head and Mayer, 2019). Both funnel plots are heavier on their left side than on their right side, which indicates the possible presence of publication bias caused by researchers who prefer more negative estimates and disregard positive ones.

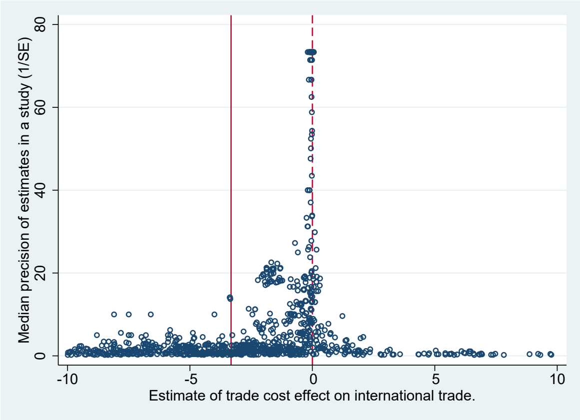
The funnel plot helps us illustrate the data gathered and form hypotheses about the presence of publication bias, but empirical tests are necessary to determine the magnitude of the bias. The main assumption is that the methods used to estimate trade costs yield a symmetric distribution; therefore, the estimates and the standard errors should be independent from a statistical perspective (Stanley and Doucouliagos, 2010). If no bias existed, there would be no correlation between the estimates and their standard errors. Significant correlation, on the other hand, indicates the presence of publication bias. To test for funnel asymmetry and independence, we follow Stanley (2005) and use the following equation:

$$Tradecost_{ij} = Tradecost_0 + \beta SE\left(Tradecost_{ij}\right) + \varepsilon_{ij}, \tag{7}$$

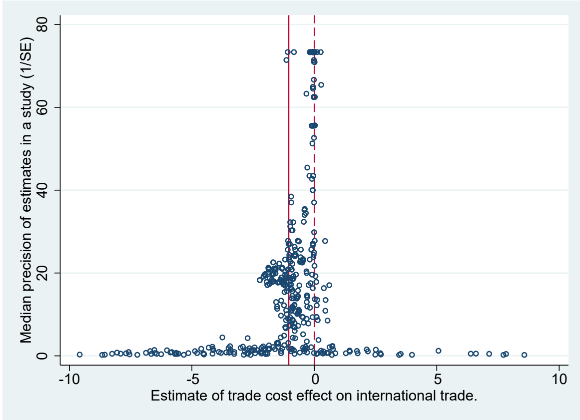
where $Tradecost_{ij}$ is the i-th estimate of the elasticity recorded in the j-th study, $SE\left(Tradecost_{ij}\right)$ denotes the standard error of the elasticity estimate, $Tradecost_0$ is the mean elasticity corrected for possible publication bias, β measures the magnitude of the publication bias, and ε_{ij} is a normal disturbance term. Stanley (2005) noted that if the data are not affected by publication bias, the estimation effects will vary around the true effect $Tradecost_0$. If the true elasticity was zero (signifying no trade cost effect) but 5% of the estimates were positive and statistically significant, the estimated β would be close to two, indicating that researchers would require their t-statistics $(Tradecost/SE\,(Tradecost))$ to be at least two (Havranek et al., 2015). Following the recommendation of Reed (2015) we use multiple estimation methods. We are also aware of the limitations of this procedure raised by Alinaghi and Reed (2018), but like, for example, Stanley et al. (2008) we

Figure 5: Funnel Plots by Identifying Variables

(a) Tariff/Freight Rates



(b) Exchange Rates/Producer Prices



Notes: A funnel plot is a scatter plot where the estimate (the size of the trade cost effect) is plotted against its precision (the inverse of the standard error). The vertical dashed line denotes the zero value and the solid line the mean value. Estimates smaller than -10 and larger than 10 are excluded from the figures for more representative plots, but the estimates are included in all the statistical tests and empirical estimations.

do not divide both sides of the regression by the standard error.

The results of the test presented in Table 2 come from several specifications of Equation 7, and all are linear. Since the estimates from each study j are not likely to be completely independent, we use a clustering procedure to control for intra-study correlation. In all specifications (except the plain OLS), we find a statistically significant and negative coefficient for the standard error, which is interpreted as publication bias, and a significant and negative intercept, which is the mean trade cost elasticity corrected for publication bias. The overall mean elasticity in the data is -2.2, but after the correction, the value changes to -1.5 - -0.7. In any case, the effect is smaller, and this result is robust across all specifications.

Table 2: Funnel Asymmetry Test Results for the Whole Dataset

	OLS	FE	BE	Precision	Study	IV
SE	-0.929**	-0.972***	-1.383***	-2.419***	-1.344***	-1.853***
(publication bias)	(-2.30)	(-5.62)	(-3.79)	(-4.64)	(-3.55)	(-2.64)
Constant	-1.616***	-1.575***	-0.769**	-0.260**	-0.797***	-0.727
(corrected mean)	(-4.88)	(-9.46)	(-2.10)	(-2.11)	(-3.50)	(-0.73)
Observations	1,609	1,609	1,609	1,609	1,609	1,609
rmse	3.288	2.438	2.203	0.961	2.821	3.470

Notes: OLS = ordinary least squares. FE = study-level fixed effects. BE = study-level between effects. Precision = the inverse of the reported estimate's standard error is used as the weight. Study = the inverse of the number of estimates reported per study is used as the weight. IV = the inverse of the square root of the number of observations used by researchers is used as an instrument for the standard error (the correlation between this instrument and the standard error is 0.3). Standard errors in parentheses. Standard errors are clustered at the study level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

The first column of Table 2 reports simple OLS regressions. The second column shows the fixed effect regression with study-level fixed effects to account for study-level characteristics. The third column uses between-study variance instead of within-study variance, which reduces the mean by half but almost doubles the magnitude of the publication bias. The next two columns use weights in the regression. Following Stanley and Doucouliagos (2017), the precision (the inverse of the standard error) is used to account for the heteroskedasticity in the regression. The second type of weighting is by the inverse of the number of observations reported in a study, which gives each study the same weight in the final results – studies with more precise estimates or a greater number of estimates do not dominate the results. The last column builds on the instrumental variable (IV) approach, where the inverse of the square root of the number of observations is used as the instrument for the standard error. The IV approach is widely used in meta-analysis as a robustness check, since the standard error is estimated jointly with the effect size in the primary studies. An intuitive instrument is based on the number of observations, since a greater number of observations should lead to more precise estimates. Then, we consider several modifications (such as the square root, logarithm, and count) to find the instrument with the largest correlation with the standard error. Our instrument is not ideal, since the correlation is only 0.3. This approach does not provide a significant estimate of the mean trade cost elasticity and shows very strong publication bias.

Table 3: FAT-PET for Different Identifying Variables

	OLS	FE	BE	Precision	Study	IV
A: Tariff						
SE	-0.839	-1.015***	-1.567***	-2.247***	-1.424***	-2.264***
(publication bias)	(-1.64)	(-4.75)	(-3.79)	(-3.86)	(-3.15)	(-3.13)
Constant	-2.040***	-1.844***	-0.899**	-0.477**	-1.018***	-0.459
(corrected mean)	(-4.19)	(-7.78)	(-2.03)	(-2.56)	(-3.27)	(-0.34)
Observations	1,143	1,143	1,143	1,143	1,143	1,143
rmse	3.575	2.582	2.222	1.584	2.944	3.977
B: Price						
SE	-0.866***	-0.849***	-0.180	-1.496***	-0.634	-0.142
(publication bias)	(-8.86)	(-4.30)	(-0.29)	(-4.26)	(-1.09)	(-0.19)
Constant	-0.861***	-0.871***	-0.721	-0.482**	-0.468**	-1.297**
(corrected mean)	(-3.47)	(-7.34)	(-1.57)	(-2.16)	(-2.21)	(-1.98)
Observations	466	466	466	466	466	466
rmse	2.250	2.040	1.743	0.730	2.302	2.377

Notes: OLS = ordinary least squares. FE = study-level fixed effects. BE = study-level between effects. Precision = the inverse of the reported estimate's standard error is used as the weight. Study = the inverse of the number of estimates reported per study is used as the weight. IV = the inverse of the square root of the number of observations used by researchers is used as an instrument for the standard error (the correlation between this instrument and the standard error is 0.3). Standard errors in parentheses. Standard errors are clustered at the study level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

We previously noted that combining trade cost estimates that use the price as the identifying variable and those that use tariffs might not be optimal. To explore the presence of publication bias in these two approaches, we estimate Equation 7 for these two subgroups of estimates separately and present the results in Table 3. In the key specifications, we again find a significant presence of publication bias and a corrected mean. The corrected mean for tariffs is approximately twice the size of that for prices – for tariffs, the mean trade cost elasticity is approximately -1.8 and for prices, it is -0.9 if we use the fixed effects model as the most reliable model and the rest of the specifications for robustness purposes. These results are in line with 3a and with the means of these two groups. The

IV approach does not produce any significant results, but the instrument is weak.

6. Why do Trade Costs Vary? Modeling Heterogeneity

In Section 4, we presented Figure 3 and discussed several characteristics of primary study designs that might influence the reported estimates of trade cost elasticity. These characteristics are clearly not the only aspects; many others may play a crucial role. To model the heterogeneity, we collected 54 variables coding data characteristics, countries surveyed, sectors, model specification details, data source, approach to multilateral resistance, treatment of zero trade flows, and publication characteristics – see Table 1 for the full list. To model the relationship, we used the trade cost estimate as the dependent variable and all the characteristics as independent variables. This can be formally expressed in Equation 8 as an extension of Equation 7:

$$Tradecost_{ij} = \alpha + \beta SE\left(TCelasticity_{ij}\right) + \gamma X_{ij} + \omega_{ij}, \tag{8}$$

where $TCelasticity_{ij}$ represents the i-th estimate of trade cost elasticity reported in study j, X_{ij} is a vector of the independent variables described in Section 4, and γ is the corresponding vector of estimates explaining the diversity of trade costs from primary studies. β represents the publication bias, and α (the intercept) is the mean elasticity corrected for publication bias that cannot be interpreted alone, only with the rest of the variables.

The large number of potential explanatory variables raises another issue – model uncertainty. Although there might be reasons for some of the variables to be important determinants of trade cost elasticity, we do not know for sure ex ante which variables are important and which study design characteristics do not influence output and only add noise to the data. If we performed the regression with all the variables, we would reduce the precision of our estimate by including considerable noise in the data. A common approach to addressing this problem is stepwise general-to-specific, a method for reducing the number of explanatory variables based on their level of significance. However, this process could exclude some important variables by accident. In recent years, increased computational power has led to the development of new model averaging techniques.

We use model averaging to address model uncertainty and minimize bias. We run a very large number of regressions with different combinations of variables and then aggregate the results of these models using weights. A great introduction to this approach is provided by Moral-Benito (2015), and we can further refer the reader to Steel (2019), who provides a survey of the most important methodological approaches to model averaging in economics and discusses the widely used BMA technique, which we also use to examine the heterogeneity among trade cost estimates.

The BMA and frequency model techniques are suitable for running regressions on different subsamples of a dataset to assess the robustness of each estimated coefficient. Each regression takes time, and the time complexity increases with the addition of each variable. To simplify the problem, we restrict the model space using BMA. BMA estimates the model and calculates the posterior model probability (PMP), which is an indicator of how well the model fits the data, similar to R^2. The PMP is calculated for each model estimated, and the values are used as weights for the final estimated coefficients. BMA does not calculate the standard error for each coefficient, but reports the posterior inclusion probability (PIP) for each coefficient. The PIP represents the likelihood of inclusion in the final model. The closer it is to 1, the more relevant the variable is for the final model. The general details of BMA are described in several studies, e.g., Eicher et al. (2011) and Wright (2008). For the estimation itself, we use the BMA package in the R software presented and described by Feldkircher and Zeugner (2009). BMA is also very frequently used among meta-analysts – see, for example, Meriluoto et al. (2019), Polák (2019), and Gechert et al. (2019) for similar applications.

Figure 6 graphically captures the BMA results: each row represents one explanatory variable. The variables are sorted by importance (by PIP value in descending order). Each column captures the results of one regression model, and the width of the column represents the PMP, sorted from the highest value starting on the left. The cells capture the sign of the coefficients on each variable in the given model: a white cell indicates that the variable is not included, red indicates a negative sign, and blue indicates a positive sign. The figure shows how stable (in terms of sign) each variable is across the estimated models.

In the previous part, we showed that publication bias is present in the trade cost literature, and the first conclusion we can draw from the BMA is that the variable capturing publication bias (the standard error of an estimate) is the variable with the highest PIP when modeling the heterogeneity in the reported estimates. Publication bias is a serious issue, and these results confirm that it is not driven by data characteristics or model properties that were not part of Equation 7, which we used in the previous part. However, publication bias is not the only key driver of heterogeneity. A few other variables have a PIP very close to 100%. The BMA results are reported in Table 4, along with the results of an OLS regression based on Equation 8 for robustness purposes. For the robustness check, we used the variables selected by the BMA with a PIP greater than 50% and then performed OLS with clustered standard errors. The results are consistent, and all the variables used are significant at the 5% significance level.

Data Source and Characteristics Several variables that code the data characteristics used in the primary studies were found to be important drivers of the trade cost elasticity estimate. Our results suggest that panel data lower the elasticity – estimates using panel data show stronger effects of trade costs on trade. This finding is fully in line with the key patterns found in the data and presented in Figure 3d. Data disaggregation has the opposite effect on the estimate – more granular data (industry level or even firm level) leads to a smaller effect of trade costs (closer to zero). In other words, data for the whole economy (aggregated) indicate that trade costs have a large effect on trade. Furthermore, the larger the number of years included in the dataset, the more positive the estimate.

Another key pattern in the data – the difference between estimates based on price or tariffs as the identifying variable captured by Figure 3a – is not confirmed by the BMA analysis, and the PIP of this explanatory variable is very low.

Countries surveyed We do not have prior expectations about such variables, but three of the six variables coding the countries present in the dataset systematically influence the size of the trade cost elasticity estimates. If Canada is included in the dataset, the trade costs are more positive. If Japan is included, they are very negative. If all OECD countries are part of the dataset (approximately one-third of the estimates collected), the trade cost elasticity estimate is less positive. However, the PIP of this variable is only 0.7, which is at the edge of our threshold for variables that are considered to be important. For the dataset that includes all countries, the effects would not offset each other, so the selection of the countries used to estimate trade costs is important.

Specification characteristics One of the variables coding the differences in model specification related to data type was found to be a significant driver of heterogeneity in the trade cost elasticity estimates. We identified this variable previously when presenting the key pattern in the data – the difference between estimates using import and export data as the explanatory variable, captured by Figure 3c. Data based on export flows imply more positive trade cost elasticity. Polák (2019) argues that export data are more reliable than import data or total trade data. We confirmed that this difference plays an important role in the estimation process and is a source of bias.

Another important specification characteristic is the use of country-level or country-pair fixed effects. This approach is one remedy for multilateral resistance (discussed below) and is also an important driver of heterogeneity. If country-level fixed effects are used, the trade cost elasticity estimate is more positive, indicating that trade costs do not substantially influence trade.

Control of zero trade flows Zero trade flows often occur in large datasets covering many countries. Several methods can be used to address such data points, and the choice of method affects the trade cost elasticity estimate. If zero trade flows are replaced with one, the results are more positive than if zero trade flows are not considered. Notably, less than 10% of our trade cost elasticity estimates use this approach. The results are not significantly different when the PPML method is used to estimate the gravity equation.

Treatment of multilateral resistance Anderson and Van Wincoop (2003) describe why the treatment of multilateral resistance is important when estimating the gravity equation. We identified several study properties that have a significant impact on the trade cost elasticity estimate. If the study controls for multilateral resistance, the estimates are more positive. The same effect is observed for normalization of trade flows with trade itself (gravity is estimated using ratios). Another approach is to use remoteness terms, but this method does not affect the final results of the primary studies.

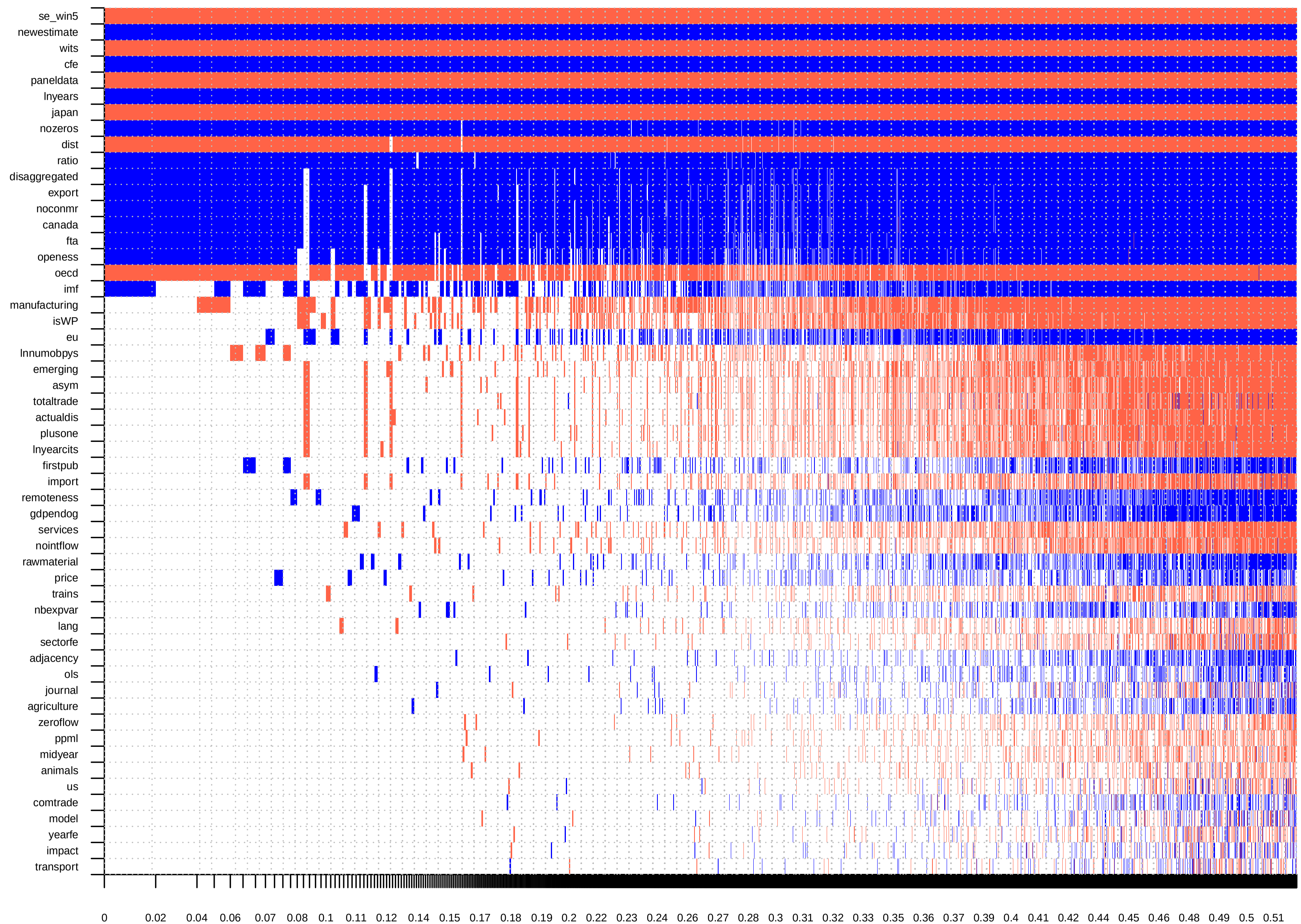
Control variables The gravity equation provides a large number of control variables, but some cannot be used if a large number of fixed effects are employed (for example, the use of a time-invariant control variable for distance and country-pair fixed effects at the same time). Several variables were found to have a significant impact on the trade cost elasticity estimate. More positive results are obtained from models that include controls for FTA and country openness. Country openness is rarely included, but Balavac and Pugh (2016) demonstrate the importance of country openness and the terms of trade with respect to trade volumes. The basic control variable is the distance between countries, but not every researcher includes it. If distance is controlled for, the trade cost elasticity is more negative. The method used to measure distance does not matter.

Publication characteristics Although we identified serious publication bias, the publication characteristics we collected do not contribute to the explanation of the heterogeneity of the estimates. No difference is observed between published studies and working papers or between results published in top economic journals and those published elsewhere. Interestingly, the estimate of trade cost elasticity does not depend on the year in which the study was published (suggesting that there is no research cycle). On the other hand, the only publication characteristic that was found to be important pertains to patterns in the data – the difference between new and old estimates, as shown in Figure 3b. The estimates included in Head and Mayer (2014) are more negative than those from studies published after that date. If we further consider the fact that datasets that include more years of data produce less negative trade cost elasticity estimates, our results indicate that the effect of trade costs is decreasing over time.

6.1 Best Practice Implied Elasticity

In the following paragraphs, we attempt to estimate the mean implied elasticity of trade costs given the best practices. The definition of "best practices" is subjective, since the best approach is unclear

Figure 6: Model Inclusion in Bayesian Model Averaging



Notes: These are the estimation results of equation 8 based on the best 5,000 models. Response variable: the t-statistic of the euro coefficient (the coefficient estimated in a gravity equation on the dummy variable that equals one). All moderators are divided by the standard error of the euro coefficient estimate. Columns denote individual models, and the variables are sorted by posterior inclusion probability in descending order from the top. Blue color (darker in grayscale) = the variable is included and the estimated sign is positive. Red color (lighter in grayscale) = the variable is included and the estimated sign is negative. White color = the variable is not included in the model. The horizontal axis measures the cumulative posterior model probabilities. Numerical results of the BMA estimation are reported in Table 4. A detailed description of all the variables is available in Table 1.

Table 4: Explaining the Differences in the Estimates of Trade Costs

Response variable:	Bayesian model averaging			OLS		
Estimate of τ	Post. mean	Post. SD	PIP	Coef.	Std. er.	p-value
se (publication bias)	-0.96	0.069	1	-0.966	0.154	0
price	0.019	0.096	0.054			
new estimate	2.794	0.454	1	2.912	0.337	0
Data characteristics						
Mid year	0	0.001	0.018			
Panel data	-2.578	0.378	1	-2.746	0.625	0
Disaggregated	0.73	0.253	0.951	0.781	0.396	0.053
No. of obs.	-0.013	0.034	0.161			
No. of years	0.738	0.144	0.999	0.788	0.241	0.002
No. of vars.	0.001	0.007	0.038			
Countries surveyed						
US	-0.004	0.072	0.015			
Canada	1.222	0.545	0.887	1.58	0.478	0.002
Japan	-1.898	0.404	0.993	-2.088	0.399	0
EU	0.204	0.374	0.28			
OECD	-0.681	0.506	0.702	-0.996	0.453	0.031
Emerging	-0.079	0.229	0.131			
Sector examined						
Agriculture	0.004	0.038	0.02			
Animals	-0.003	0.039	0.015			
Transportation	0	0.02	0.011			
Services	-0.037	0.14	0.087			
Raw materials	0.024	0.104	0.066			
Manufacture	-0.197	0.27	0.402			
Specification characteristics						
Model	0	0.05	0.013			
Total trade	-0.215	0.664	0.114			
Imports	-0.091	0.314	0.094			
Exports	1.345	0.484	0.914	1.571	0.308	0
No internal trade	-0.041	0.179	0.068			
Asymmetry	-0.111	0.331	0.125			
Instruments	0.043	0.163	0.087			
Data source						
TRAINS	-0.018	0.106	0.041			
COMTRADE	0.001	0.034	0.014			
WITS	-2.068	0.249	1	-2.079	0.323	0
IMF	0.591	0.723	0.463			
Treatment of multilateral resistance						
Control for MR	0.957	0.387	0.908	1.069	0.3	0.001
Remoteness	0.049	0.18	0.089			
Openness	0.665	0.443	0.753	0.932	0.536	0.087
OLS	0.005	0.045	0.023			
CFE	1.204	0.24	1	1.14	0.273	0
Year FE	-0.01	0.089	0.026			
Sector FE	-0.001	0.034	0.013			
Ratios	0.959	0.337	0.973	0.948	0.41	0.024
Treatment of zero trade flows						
Zero flow in the data	-0.004	0.045	0.019			
Zero omitted	1.521	0.395	0.981	1.713	0.381	0
Zero plus one	-0.104	0.328	0.112			
PPML	-0.004	0.052	0.018			
Control variables						
FTA	0.85	0.416	0.862	1.137	0.265	0
Language	-0.009	0.068	0.03			
Adjacency	0.008	0.064	0.026			
Distance	-1.489	0.37	0.98	-1.656	0.29	0
Actual	-0.1	0.322	0.113			
Publication characteristics						
journal	0.001	0.065	0.021			
isWP	-0.237	0.422	0.296			
firstpub	0.005	0.018	0.095			
impact	0	0.004	0.013			
lnyearcits	-0.036	0.119	0.104			
Constant	-2.851	NA	1	-3.544	0.637	0
Studies	71			71		
Observations	1,609			1,609		

Notes: Response variable: the t-statistic of the euro coefficient (the coefficient estimated in a gravity equation on the dummy variable that equals one). All moderators are divided by the standard error of the euro coefficient estimate except for publication year, which is interacted with the SE in the original model. PIP = posterior inclusion probability. SD = standard deviation. VIF = variance inflation factor. A detailed description of all the variables is available in Table 1.

for some of the variables.

For each variable presented in Table 1, a preferred value is selected (or the value is left unchanged for a given estimate if the study does not have a preference for the value of the variable), and the implied elasticity is computed as the mean predicted estimate of the elasticity. This approach creates a synthetic study with the best practice methodology using a very large number of observations and the most recent data, following previous meta-analyses.

This study selects sample *maxima* for mid-year data (more recent data), panel data, disaggregated data, the number of observations per year, whether the study was published, the number of citations, the impact factor, country fixed effects, and whether the study used dummies for control variables. Sample *minima* are used for the dummy variables representing the dependent variable (exports), total trade (summing trade flows before taking logs), and the presence of a control for multilateral resistance. For all the other variables, the actual values of the sample are kept.

The results are presented in Table 5. The overall mean elasticity is reported in the last row. The column labeled "Difference from mean" shows the difference between the calculated predictions and the simple means described in Section 4. The results vary substantially because of the heterogeneity present in the data – the overall mean elasticity of approximately -0.63 is not significantly different from zero. The precision of our best practice estimate reflects the uncertainty in the estimates of the regression parameters of the OLS model. However, even higher uncertainty might be related to the definition of the best practice values of several variables, which would make the confidence intervals even wider.

Table 5: Best Practice Predictions of Trade Cost Elasticity

Sample	Estimate	95% conf. int.		Difference from mean
Old studies	-2.154	-4.328	3.887	1.753
New studies	0.640	-2.205	6.006	1.993
Full sample	-0.626	-3.098	4.986	1.884

Notes: This table presents the estimates of the trade cost coefficient for selected groups implied by BMA and OLS and our definition of best practice. That is, we take the regression coefficients estimated by BMA (Table 4) and predict the values of *trade cost* conditional on aspects of the methods and data. Difference from mean = the difference between these estimates and the simple means. The confidence intervals are approximate and constructed using the standard errors estimated by OLS.

7. Conclusion

International trade is currently under pressure from increased protectionist measures taken by large world economies. Economists have been investigating the factors influencing international trade for decades. The most commonly used gravity framework has become a standardized tool for trade cost analysis. From a theoretical perspective, any barriers to trade will harm trade. The question is how serious the tariffs and price measures imposed on traded goods are. To answer this question, we use meta-analytic techniques to analyze more than 1,600 trade cost elasticity estimates from over 70 studies that used the gravity framework. These estimates range from -78.6 to 77.0, with a mean of -2.66 and a median of -1.52. To explain this substantial heterogeneity, we collected an additional 54 characteristics related to each estimate that represent precision, study and model design, dataset source and properties, control variables used in the estimation process, and the characteristics of the publication itself and its impact in the academic community.

We built upon Head and Mayer (2014), who focused quantitatively on the elasticity of trade with respect to trade costs and made the first attempt to aggregate the findings. They computed mean and median estimates of the trade cost coefficients and compared the overall effect with separate summary statistics for particular groups created based on study properties (type of gravity equation, type of identifying variable). We further extended the dataset by collecting additional studies and explanatory variables. In addition, we focused on whether possible publication bias could lead to exaggerated results.

Trade wars are bad for international trade, but the literature suffers from publication bias – estimates are tuned or selected to be statistically significant and in line with economic theory. The results of graphical tests were supported by empirical methods (the funnel asymmetry test), which estimated the size of the underlying effect beyond publication bias to be approximately -1.4, close to the median value. Publication bias was also significant in explaining the heterogeneity among the estimates. Publication bias is an issue, but we did not identify any publication characteristics, such as journal quality or when the study was published, that systematically influenced trade cost elasticity.

We identified several properties that have a significant impact on the estimated size of trade costs. From a methodological perspective, how zero trade flows are addressed and whether the study uses country fixed effects are important factors. The dataset is also important – there are differences between estimates based on import and export data and estimates from different data sources. Due to the data heterogeneity, conditional estimates (based on the preferred combination of explanatory variables) of trade elasticity have such large confidence intervals that the results are not significantly different from zero.

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Appendix A: List of Studies

Table A1: List of Studies

Study	Head and Mayer (2014)	WP
Adam (2019)	No	Yes
Ahn et al. (2011)	Yes	No
Anderson and Marcouiller (2002)	Yes	No
Anderson et al. (2018)	No	No
Arkolakis et al. (2012)	Yes	No
Asche et al. (2018)	No	Yes
Baier and Bergstrand (2001)	Yes	No
Bas et al. (2017)	No	No
Békés et al. (2012)	No	Yes
von Below and Vézina (2016)	No	Yes
Bergstrand (1985)	Yes	No
Bergstrand (1989)	Yes	No
Berman (2009)	No	Yes
Berman et al. (2012)	Yes	No
Besedeš and Cole (2017)	No	Yes
Blonigen and Wilson (2010)	Yes	No
Caliendo and Parro (2014)	Yes	No
Cipollina et al. (2013)	No	No
Cipollina et al. (2016)	No	No
Costinot et al. (2011)	Yes	No
Coughlin and Novy (2012)	No	No
De (2010)	No	No
De Melo and Solleder (2018)	No	Yes
de Sousa et al. (2012b)	Yes	No
Dutt and Traca (2010)	Yes	No
Eaton and Kortum (2002)	Yes	No
Egger and Pfaffermayr (2003)	Yes	No
Egger and Průša (2016)	No	No
Emlinger et al. (2006)	No	Yes
Erkel-Rousse and Mirza (2002)	Yes	No
Estevadeordal et al. (2003)	Yes	No
Fink et al. (2005)	Yes	No
Flach and Unger (2018)	No	Yes
Fontagné et al. (2005)	No	No
Francois and Woerz (2009)	Yes	No
Fugazza and Nicita (2011)	No	Yes
Fuller and Kennedy (2019)	No	No
Gervais et al. (2011)	No	Yes
Hayakawa (2014)	No	No
Hayakawa (2013)	No	No
Head and Ries (2001)	Yes	No
Heid et al. (2017)	No	No
Hertel et al. (2007)	Yes	No
Hou et al. (2017)	No	Yes
Hugot et al. (2016)	No	Yes
Hummels (1999)	Yes	Yes
Cheong et al. (2018)	No	No
Chevassus-Lozza et al. (2005)	No	No
Jacks et al. (2010)	No	No

Continued on next page

Table A1: List of Studies (continued)

Study	Head and Mayer (2014)	WP
Jakab et al. (2001)	Yes	No
Jaroensathapornkul (2017)	No	No
Kinzius et al. (2018)	No	No
Lai and Trefler (2002)	Yes	Yes
Lanati (2013)	No	Yes
Liapis (2011)	No	Yes
Martinez-Zarzoso and Nowak-Lehmann (2003)	Yes	No
Matyas et al. (2004)	Yes	No
de Sousa et al. (2012a)	No	No
Mazhikeyev and Edwards (2013)	No	Yes
Melo et al. (2012)	No	Yes
Keita (2016)	No	No
Nahuis (2004)	Yes	No
Novy (2006)	No	Yes
Novy (2013)	No	No
Olper and Raimondi (2009)	No	No
Owen and Winchester (2014)	No	No
Robertson and Estevadeordal (2009)	No	No
Romalis (2007)	Yes	No
Sanjuan et al. (2017)	No	Yes
Tharakan et al. (2005)	Yes	No
Thursby and Thursby (1987)	Yes	No
Xu (2000)	Yes	No
Zhang and Nguyen (2018)	No	No

Notes: WP = working paper, Head and Mayer (2004) = studies included in that study

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