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A two-step procedure for Generating Domestic and Asymmetric International Trade Costs when Data are Scarce

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A two-step procedure for Generating Domestic and Asymmetric International Trade Costs when Data are Scarce *

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Abstract

The practice of trade cost measurement faces several challenges related to data quality, methodology and theory; but the major issue is that of data scarcity. Due to these facts both domestic and asymmetric trade costs have been ignored despite being a feature of modern trade models. This paper offers a two-step procedure to tackle these limitations and fill the gaps between theory and practice. The results of this work show that domestic trade costs proportionally grow with economic size, and that international trade costs are highly asymmetric especially when trading pair sizes differ. Counterfactual simulation results that ignore domestic frictions and adopt symmetric international trade cost measures show over-predicted welfare and trade changes as a response to policy shock in larger sized countries rather than smaller countries. After the proper treatment of trade costs in the simulation, results improve.

JEL: F13, F14, F21, F40,

Keywords: trade costs, measurement, domestic frictions, asymmetric costs, international trade, gravity, trade policy simulations

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1 Introduction

Trade costs undoubtedly play one of the key roles in explaining the major aspects involved in international economics (Obstfeld and Rogoff, 2000). However , practice shows that collecting or measuring data on trade costs is a difficult task for various reasons. The main difficulty is presented by the data quality and scarcity. Trade cost records from existing sources are fragmented; country, time and product coverage is limited, and they also differ from source to source. From the measurement side, data quality and data scarcity are again the major hurdle. The direct measurements may also suffer from various mixed bag issues (Swann, 2010), stringency issues (Chen and Novy, 2011), or an atheoretical base (Fugaza, 2013; Baldwin, 2000). The solution which is normally used by many empirical studies is to rely on the assumptions that the internal trade of countries is frictionless (as there is no information available on domestic trade frictions, i.e. their existence is ignored) and international trade costs are symmetric (since they are usually measured with symmetric variables like geographic distances etc.).

Recent studies like Anderson and Yotov (2010) provide evidence suggesting the opposite, in that trade costs exist in domestic trade and that international trade costs could be asymmetric. Romando, Rodriguez-Clare, Saborio-Rodriguez (2016) take a step further and show that in the presence of domestic frictions, modern trade model (i.e. Krugman, Eaton-Kortum, Anderson-Armington, or Melitz's model) predictions are more in line with observable data than they would otherwise be. Putting methodology aside, both studies derive trade costs as observable measures from a structural gravity framework using province/metropolitan level bilateral trade data. Unfortunately, the data used by such studies is a rare type of data as it is only collected by a few (developed) countries; if it exists in many other countries it is not public accessible.

In this paper I offer a methodological procedure to deal with the data-scarcity problem and to compute domestic and international trade costs for multiple countries/regions by solving a structural gravity model as a system. This method produces observable trade cost measures that fit actual observable trade data and satisfies theoretical conditions set by the unique relationship among observable and un- observable variables suggested by a chosen structural gravity framework. However, the method still requires some knowledge of domestic trade costs in at least one country[1].

I perform the measurement in two steps. The first step is to compute domestic trade costs for a country using bilateral trade among regions of the country. The second step is to compute international and domestic trade costs using bilateral trade, amongst and within countries, relative to domestic trade costs of the chosen country from step one.

I provide an example of the two-step method for illustrative purposes. For that I use the Anderson-Armington structural gravity framework. As a first step, I solve the model using province level trade data for Canada[2]. For the second step, I use country level trade data from the GTAP8 database for 134 countries.

The trade cost measurements derived from this calculation support the idea that trade costs in both domestic and international trade cost structures are highly asymmetric. Average domestic trade costs across all 134 countries are about 1.5 (in tax-equivalent terms) and general trends suggest that their levels increase with the country's expenditure/output size (this is also consistent with Romando et al. (2016) results. International trade costs are 2-3 times higher than domestic trade costs (as expected) but, more importantly, they are asymmetric and this asymmetry varies substantially amongst the pairs. There is a common trend here – international trade costs are twice as high for trade flows from smaller countries to larger countries as in the opposite direction (i.e. from a larger to a smaller country). While international trade costs are more or less symmetric between similar sized pairs of countries, their level increases when the size of the country

[1] The method will work at any level of (dis)aggregation (region, city etc.) and not only at country level. Most of the open sources unfortunately provide trade data at country level only.

[2]Data is taken from the 2003 flows of Anderson and Yotov (2010) only. I use Canadian trade data as it was the only readily available reliable source. However, I alternatively re-perform the measurements using data for the US to show that the method provides a unique solution, and that the same trade cost measures, if the chosen countries are relatively similar, stays the same. See the robustness check section for relevant discussion.

pairs get bigger.

This paper contributes to a growing body of literature on trade cost measurement practice using structural gravity models. This list includes the authors Anderson and Yotov (2010), Anderson, Milot and Yotov (2011), Agnosteva, Anderson and Yotov (2017), Novy (2007; 2013), and Novy and Chen (2013). Unlike the previous studies, I perform a computation of trade costs using this two-step procedure. Domestic trade costs for the reference country in the second step of the procedure are provided by the solutions from the first step and are not assigned or estimated. By including a modified Head-Ries Index in the system, which provides a unique relationship of domestic and international trade costs for each pair and completes the list of necessary restrictions in the system, the method provides domestic trade cost measures without the need for data on internal trade flows for each country or non-symmetric international trade cost measures. Thus, using this method makes it possible to construct trade cost measures in the absence of data on domestic bilateral trade (excepting that for the reference country). This study also contributes to the empirical literature on trade policy simulation. I show that counterfactual exercises without factoring in all trade costs could result in misleading results. I also show that gravity estimated trade costs come up short in at least two aspects: (1) they capture only half of the trade costs and (2) they produce symmetric measurements. Counterfactual exercises result in higher domestic trade and welfare costs for larger sized countries, i.e. they are both being overestimated.

The rest of the paper is organized as follows: Section 2 provides an overview of the relevant literature; Section 3 describes a structural gravity model; Section 4 describes the two-step procedure; Section 5 discusses the data and provides the main results; Section 6 provides the robustness check results, and; Section 7 provides concluding remarks.

2 Relevant Literature

Trade costs are a key in resolving many great puzzles with regard to international economics. According to Obstfeld and Rogoff (2000), trade costs themselves are a puzzle. This is because we know little about trade costs and their nature. Trade costs are seen as costs unrelated to the true cost of making goods (and services) but they still form a part of the final price, if not the major part according to some sources[3]. Anderson and van Wincoop (AvW, 2004) state that "transportation costs (both freight costs and time policy barriers, tariffs and non-tariff barriers), information costs, contract enforcement costs, costs associated with the use of different currencies, legal and regulatory costs, and local distribution costs (wholesale and retail)" are the main sources of trade costs. Which source best explains trade costs? What are the trade costs levels? By how much do trade costs increase the prices of goods we buy every day? Many more questions like these are still unanswered. As it gets more difficult to learn about the true cost of products and services (which are now enhanced by complex global supply chain linkages, flow of intermediates, and migration of capital and labour) difficult it becomes more difficult to understand what part is actually represented by trade costs. An incredible amount of work has done by many world institutions, research groups and separate individuals in recent decades, in recording, collecting, measuring and analysing trade costs. However, the picture is not yet complete. A number of limitations exist when it comes to the availability, quality, measurement, modelling, and simulation practices of trade costs data. I also discuss some of the main issues which I feel are important in this section.

The quality and availability of data is a major hurdle. Information on various types of trade costs is available from plenty of sources, for example: World Integrated Trade Solution (WITS), Direction of Trade Statistics (DoTS), Business Environment and Enterprise Performance Surveys (BEEPS) etc.[4]. Trade cost data in the existing databases are

[3]Anderson and Yotov (2010) suggest that trade costs in goods trade between the US and Canada increase the prices by 80% on average.

[4]See Bagai & Wilson (2006), and more recently Moise & Bris (2013), reviews of existing trade cost

records (i.e. factual records of tariffs, freight rates and transport costs), direct proxies (i.e. the custom clearance time in days, technical efficiency index between 0-10, etc.) or indirect proxies (i.e. implicit derivations of trade costs like Trade Restrictiveness Indexes). However, trade cost data from the above sources have quality issues. Records on trade costs and direct proxies are fragmented, with limited country or time coverage, and the records differ across the databases. There are many trade cost records with a zero value, and it is not possible to say whether these are true zero costs or simply data issues. Despite the rich classification of trade costs offered in the existing databases, the trade cost measurements present an incomplete picture.

Due to these data limitations, a number of direct and indirect measurement methods have been developed. Price and quantity ratio methods provide approximate measurements of trade costs; however, these measurements may not be representative of actual trade costs, which is again due to data quality issues (Andriamananjara, Ferrantino & Tsigas, 2004). Econometric estimators with an 'ad-hoc' trade cost structure are commonly used to resolve measurement errors, but they leave behind uncaptured trade costs. I find that gravity estimates explain roughly half of the trade costs. Gravity estimated trade costs are symmetric, which is probably because geographic distance variables are also symmetric [5] but geographic distances and other standard dummy variables still perform quite well. As noted by Chen and Novy (2012), count and scale based trade cost proxies used in the estimations could suffer from stringency bias, or they could omit important variables that were discarded as errors. Moreover, most of the measurement methods were criticised for their weakness (or even absence) of theoretical grounds (Fugaza, 2008; Baldwin, 2000) in favour of theory consistent alternatives. Regarding theoretical measures, recent studies raise concerns about the appropriateness of theoretical assumptions on trade costs in modern trade models (like Melitz,

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[5]This is symmetric because the distance from points a to b is the same as from b to a, but trade costs are not like that as I show in the results section.

Eaton-Kortum, Anderson-Armington models, etc.). The absence of domestic and symmetrical bilateral trade costs are the two most concerning assumptions, as they are in direct contrast to empirical findings that suggest the very opposite[6]. Commonly used, theory-based, Trade Restrictiveness Indexes (TRI) only provide partial coverage of discriminatory policy costs[7]. Besides this, implicit theory consistent measurements require strong assumptions about price/substitution elasticity, the levels of which are unknown for certain with high quality data usually being unavailable. Some of the other issues are well covered in Chen and Novy (2012). In this study I find that trade costs are asymmetric, especially if trading partners have large differences in economy, population and geographical sizes. Trade costs in trade flows from smaller countries to larger countries are twice as large as are flows in the opposite direction. I also find that no domestic trade exists with trade costs of zero value, so domestic trade frictions exist and cannot be captured with common proxies (like internal distances). Domestic trade costs are higher in developed countries and relatively smaller in developing poor countries.

This may also be an important issue arising from above mentioned concerns and that issue related to empirical studies that investigate possible impact of trade policy shocks (i.e. changes in trade costs) without paying greater attention to validity of theoretical assumptions, trade cost data consistency but also on trade cost modelling aspects, which usually left behind the scenes or buried in the appendix parts. Regarding the modelling of trade costs, it is common to use transport margin, mark-up (or market concentration measures) and 'iceberg cost' equations with explicit ad-hoc structures; again this does not capture trade costs well. Iceberg cost equations are used when it is assumed that a fraction of the goods 'melts' away during transit. Would they really dissipate in this manner, or would they generate rent (for instance, licensing)[8])? It is difficult to consider either choice. Trade costs, however, need to be distinguished in simulation settings as

[6] Jacks, Meissner & Novy (2010) argue that most non-tariff barriers affect domestic trade and Egger and Nigai (2012) claim that international trade costs are asymmetric.

[7] Andriamananjara, Ferrantino & Tsigas (2003, 2004), Kee, Nicita & Olarreaga (2004, 2006, 2009).

[8] Dixon & Jorgenson (2013).

"rent-generating" and "resource" costs, and they clearly define who receives the rents and who makes losses. How to model all of these is another matter. A secondary issue is the modelling of domestic trade costs, which is either totally ignored (due to consistency with the theory – no internal frictions), or partially controlled (with observables like domestic taxes) in many GE/PE simulations[9]. Many countries are in Free Trade Areas, i.e. they have no formal trade barriers, however, discriminatory measures appear in different non-tariff forms internally (TBT/SPS, additional inspections, certifications etc.) which may have more of an impact than import tariffs/quotas. I find that import tariffs and export taxes explain about 1-3% of trade costs. Modelling bias arises when non-tariff measures (NTM) and related hidden costs are modelled as border costs, but similar NTMs can be incurred during exporting or importing stages and not on the border. Finally, heterogeneity across sectors is typically ignored although it is well established that trade costs differ by type of goods and services and by regions within countries (Bernard (2003), Cosara (2015) and Chen (2011).) All of these factors are ignored for simplicity. Such heterogeneity can be measured, even at exporter-importer level and by product type, and I show this in the simulations section. After introducing asymmetric trade costs and internal frictions, I obtain different results from a general equilibrium simulation with a standard trade model than in the simulation where internal frictions are ignored and symmetric trade costs are used. Improper control of trade costs results in overestimated welfare and trade changes – a finding I also make.

In short, trade costs (either domestic or international) are poorly treated by impact studies. This is again due to the low quality of data, which imposes limitations to measurement and modelling (or controlling for them) and explains the results of such studies[10]. The results could differ when proper treatment of trade costs is carried out. This is shown in a few recent studies, and I also show it in this study. For instance, Anderson and Yotov (2010), compute trade cost measurements for Canada with Canadian province

[9] Zhai (2008), Naess, Kirk & Pedersen (2013) for example.

[10] Fugazza et al. (2008)

level trade data under the Anderson-Armington (CES) model. The province level data allowed them to relax theoretical assumptions of frictionless internal trade. Their results show that trade costs in trade between Canadian provinces are quite high (2.95, in tax-equivalent terms), asymmetric and largely unexplained. With the existence of domestic frictions, the study also shows that US-Canada trade costs are as high as 4.7-5.3, in tax-equivalent terms. This measurement is almost three times lower if one is to ignore the existence of internal trade costs[11]. A study carried out by Romando, Rodriguez-Clare, Saborio-Rodriguez (2016) is another good example. They use trade data between metropolitan cities in several developed countries to calibrate internal trade costs under the Eaton-Kortum model. They show that modern trade models (i.e. Krugman, Eaton-Kortum, Anderson-Armington, or Melitz modela) with positive internal trade costs reduce the aggregate scale effects relative to country size. This contradicts what the models suggest (that larger countries get richer, as they exercise the scale effects, than smaller countries get poorer) if domestic frictions are ignored. The study shows that the importance of scale effects was exaggerated while domestic frictions were largely ignored. Their results provide a better explanation as to why, using macroeconomic indicators, some smaller countries are richer than some larger countries and vice-versa. Unfortunately, trade data between the regions of many countries (or between major cities) that have been used by the studies is very scarce (even if it exists it is not publically available or only available for a few countries). This puts a limit on the proper measurement/treatment of trade costs and the possibility of tackling many of the great puzzles in relation to these costs (Obstfeld and Rogoff, 2000).

[11]Head-Ries Indicators for Canada-US reported in Novy(2013) suggest that trade costs between the countries are about 1.7. However, Head-Ries Indicator is a ratio of international trade costs over internal trade costs and only under the standard theoretical solution that domestic trade costs in both countries are 1 (which may be incorrect)would it represent a symmetric measure of trade costs. The method has its own nuances related to the trade cost elasticity parameter and trade data quality, as discussed in Novy(2013).

3 A Structural Gravity Model

I start by explaining a structural gravity theory which includes national product differentiation (Anderson and van Wincoop, 2003). This provides a theoretical base for the methodological procedure introduced in the next section. The theory, at its core, relies on Armington's (1969) assumptions that traded products are differentiated by their origins; it is formally referred to as the Anderson-Armington model. According to this theory, there are $i(j)$ number of locations in the world trading goods and services with each other and within each location. It is important to point out that i and j locations can be within a country or not (so it is best to think of a location as a town, rather than a whole country). Let us now denote bilateral trade costs as t_{ijk} for product k from location i to location j.

It is assumed that $t_{ijk}(\geq 1)$ takes an *iceberg* form[12] with $t_{ijk} - 1$ is representing the *ad valorem* tariff equivalent level of trade costs. The level of trade costs cannot be accurately calculated, thurs t_{ijk} is a product of m number of z type of (un)observable barriers[13].

$$t_{ij} = \prod_{m=1}^{M} \left(z_{ij}^{m} \right)^{\vartheta_m} \tag{1}$$

In the theory, it is assumed that trade costs are *symmetric* if i and j are different (i.e. $t_{ijk} = t_{jik}$), and trade costs are *none* if i and j is the same location (i.e. $t_{iik} = 1 = t_{jjk}$). I deviate from the theory in these two assumptions and instead I make the following assumptions:

ASSUMPTION 1 (A1): If i and j are different locations, regardless of the territorial

[12] Coined by Samuelson (1952), this iceberg theory comes from the idea that during a productâĂŹs journey from i to j, a fraction of the product âĂIJmeltsâĂİ away due to the barriers faced during the travel. This implies that the more barriers that exist between the ij trading pair the larger the fraction of the product that is lost, and vice versa. One good example are transport costs that increase with geographic distance, however, such patterns may not be important for services that do not depend on geography.

[13] Trade costs would typically include transport and policy related costs (tariffs, subsidies and other non-tariff measures), and destination specific distribution, sales tax and retail mark-ups. The origin borne tax/subsidy, quotas and other type of important barriers could create considerable price distortions.

borders, bilateral trade costs between i and j are *assymetric*, i.e. $t_{ijk} \neq t_{jik} \geq 1$.

What A1 suggests is that even if the marginal cost of k is the same across origins ($p_{ik} = p_{jk}$), the consumer prices would differ ($p_{ijk} \neq p_{jik}$) where $p_{ijk} = p_{ik}t_{ijk}$ and $p_{jik} = p_{jk}t_{jik}$[14]. Under this *symmetry*, however, consumer prices would be the same. This is one of the important differences implied by A1. Assymetric trade costs also mean that the income generated from selling, even if it is the same q amount of k of the same location in different destinations, would not be the same: $s_{ijk}p_{ik}q_{ik}t_{ijk} \neq s_{ihk}p_{ik}q_{ik}t_{ihk}$ where s is the share of total amount.

ASSUMPTION 2 (A2): If i and j is the same location, internal trade within that location bears at least some positive *domestic frictions*, i.e. $t_{iik} \geq 1$, but unique for each location, i.e. $t_{ii} \neq t_{jj}$.

Unlike frictionless internal trade assumption, where k from i sold in i at the factory price ($X_{iik} = p_{ik}q_{iik}$), A2 suggests that the price includes $t_{iik} > 1$, i.e. $X_{iik} = p_{ik}q_{iik}t_{iik}$. It is a similar situation for domestic trade in j, $X_{jjk} = p_{jk}q_{jjk}t_{jjk}$ where $t_{jjk} > 1$. Although I use the "$\geq$" sign in A2, it should be considered as "$>$" as domestic trade costs appear even in very small geographic locations (e.g. sales tax, retail margins etc.). I do not exclude the possibility of $t_{iik} = 1$. As each destination market (location) is *unique* (as its population size, earnings, living standards, preferences etc. which cannot be exactly the same as those in another location), their domestic trade costs should be different, i.e. $t_{ii} \neq t_{jj}$. However, domestic frictions for near-identical locations could be similar. In contrast, under frictionless domestic trade, we would think that $t_{ii} = t_{jj}$, which is the most important difference implied by A2.

A1 and A2, however, do not change to the structure of the model. Assuming that the consumer utility at j is given with a Constant Elasticity of Substitution (CES), and

[14]However, it is possible to have $p_{ijk} = p_{jik}$ under assymtrical trade costs iff $p_{ik}/p_{jk} = t_{jik}/t_{ijk}$

keeping A1 and A2 in mind, I still derive the same gravity equation (as in AvW, 2003):

$$X_{ijk} = \frac{Y_{ik}E_{jk}}{\sum_i Y_{ik}} \left(\frac{t_{ijk}}{\Pi_{ik}P_{jk}} \right)^{1-\sigma_k} \tag{2}$$

$$P_{jk}^{1-\sigma_k} = \sum_i \left(\frac{t_{ijk}}{\Pi_{ik}} \right)^{1-\sigma_k} \frac{Y_{ik}}{\sum_i Y_{ik}} \tag{3}$$

$$\Pi_{ik}^{1-\sigma_k} = \sum_j \left(\frac{t_{ijk}}{P_{jk}} \right)^{1-\sigma_k} \frac{E_{jk}}{\sum_i Y_{ik}} \tag{4}$$

where X_{ijk} is the value of product k from i sold in j at the purchase price $p_{ijk}(= t_{ijk}p_{ik})$; Y_{ik} is the total output of k in i; E_{jk} is the total expenditure of j on k; and Π_{ik} and P_{jk} are outward and inward trade resistance terms. They are known as *multilateral trade resistances* (MRTs)[15]. They are known as multilateral trade resistances (MRTs) . It should be noted that due to A1, the inward and outward resistance terms for i(j) are now unequal, i.e. $\Pi_{ik} \neq P_{ik}$. With A2, the MRTs cannot be equal to 1 unless there are no domestic trade costs. Thus, under A1 and A2 combined, MRTs cannot be ignored and trade cannot be explained purely with output and expenditure sizes alone (Anderson, 2010).

Finally, market clearance is the total output of k by i is being equal to the sum of sales of k in all j (including domestic sales at i) and the total expenditure of j is being equal to the sum of purchases of k from all i (including purchases from j itself), i.e. $Y_{ik} = \sum_j X_{ijk}$ and $E_{jk} = \sum_i X_{ijk}$. Total demand is equal to total supply for i, i.e. $Y_i = \sum_k Y_{ik} = E_i = \sum_k E_{ik}$, and the global economic size is $Y = \sum_i Y_i = \sum_i E_i$ which is all standard. This, in

[15]These trade resistances play a special role in the theory. They are interpreted as proportions of trade costs t_{ijk} where Π_{ik} is a portion of trade costs incurred by i and P_{jk} is similarly a portion incurred by j in trade of k in a hypothetical global wholesale market. A higher level of Π_{ik} means a higher cost of trading k from i in j, and vice-versa. Notice that Π_{ik} depends on P_{jk} and P_{jk} on Π_{ik}. This is because there are i number of origins supplying k to j, and cost minimizing j would be inclined (prefer) to buy k from i with lower Π_{ik} – lower *relative* to its level for all other available suppliers. Similar logic is applied on P_{jk} where i would be inclined (prefer) to sell k in j with lower P_{jk} – again lower *relative* to its level for all other available destinations.

short, sums up the main points on the theory (See Anderson and van Wincoop (2003) for more details).

4 A two step procedure to measure t_{ijk}

Equation (2-4) can be solved for trade costs using trade data. For this, one requires bilateral trade data. The trade data should be bilateral and cover both, external (X_{ijk}, X_{jik}) and internal flows (X_{iik}, X_{jjk}). The theory provides an insight into the relationships and linkages among known (observable) and unknown terms in the system, and the system establishes the necessary conditions to obtain a single set of t_{ijk} as observable trade cost measurements. In this section, I demonstrate a two-step procedure to measure t_{ijk}.

The method I introduce to compute trade costs is a two-step process based on a system of equations embedding the gravity equation at its core. Both steps actually deal with the same set of equations, but with one important difference: Step 1 has to be calculated with internal trade data for i while external trade with other locations is kept as one aggregate value j; and Step 2 has to be calculated with country level trade data, which means that the internal trade of country i is now aggregated up to country level, and external trade with the rest of the world is disaggregated into many countries trading with each other as well as with country i. I explain each step individually, starting with Step 1.

Step 1: Country i trades product k with itself. Let us introduce this with new notations: i consists of h (l) locations. Bilateral trade between the locations is denoted as X_{hl}. Each location h(l) also trades with the (aggregate) rest of the world, X_{hj}. The system which computes trade cost for h(l) of country i is

$$\left(\frac{\sum_h Y_h X_{hl(j)}}{Y_h E_{l(j)}}\right)^{\frac{1}{1-\sigma_k}} = \frac{t_{hl(j)}}{\Pi_h P_{l(j)}} \quad (5)$$

$$\left(\frac{X_{hjk}X_{jhk}}{X_{jjk}X_{hhk}}\right)^{\frac{1}{1-\sigma_k}} = \frac{t_{hjk}t_{jhk}}{t_{jjk}t_{hhk}} \tag{6}$$

$$1 = \sum_{l(j)} \frac{t_{hl(j)}^{\tilde{\varepsilon}} X_{l(j)}}{\Pi_h P_{l(j)}} = \sum_{h(j)} \frac{t_{l,h(j)}^{\tilde{\varepsilon}} X_{h(j)}}{P_l \Pi_{h(j)}} \tag{7}$$

Equation (5) is a rearranged (2), collecting observables on one side and unobservables on the other. Anderson (2010) calls it the Constructed Home/Foreign Bias Indicator (CBI) and interprets it as a ratio of trade with frictions over a firctionless trade level. However, I interpret them as a ratio of trade cost over the product of Multilateral Resistances (MRs).

Equation (6) is what is known as the Head and Ries (2001) Index (HRI), but without taking the geometric mean. It is written with international trade flows leading to internal trade flows. Swapping trade flows in HRI with right hand side terms in (2) shows that this is a ratio of international trade costs over internal trade costs. While this indicator is closely related to the gravity concept, it has been used separately from the system and interpreted differently (as a trade cost measure by taking a geometric mean of HRI, while in fact it is still a ratio of international trade costs over internal trade costs). HRI is fully consistent with the structural gravity model and does no harm to the system. Instead, it completes it by establishing link between the dyadic terms (bilateral trade costs).

Equation (7) rearranges OMR and IMR equations into one combined equation. This also means that the sum of weighted CBI by l(j)/h(j) should be equal to the sum of expenditure/output shares, which is 1. I discuss the properties and linkages between the variables in each equation in the system in the Robusness section, using a matrix representation of the system to show that these three equations are all that is needed to obtain a unique solution.

Note that the LHS of (5-7) is given with observables. These are necessary restrictions;

the left side observable values should serve as *conditions* which the right side should satisfy (fit), i.e. the computed trade costs and MRTs should satisfy them. Solving the system results in a set of trade costs ($t^*_{hjk}, t^*_{jhk}, t^*_{jjk}, t^*_{hhk}$) and MR terms ($\Pi^*_h, P^*_{l(j)}, \Pi^*_{l(j)}, P^*_h$).

From there, the aggregate trade costs and MR terms for i can be constructed as:

$$t^*_{ii} = \sum_l \frac{t^*_{il}}{X_i} \quad P^*_i = \sum_l \frac{P^*_l}{X_i} \quad \Pi^*_i = \sum_l \frac{\Pi^*_l}{X_i} \tag{8}$$

Step 2: country i trades product k with itself and with other countries, so j is no longer seen as an aggregate but consists of j number of separate countries. I drop h (l), i.e. aggregate them for i, and continue with country level data. Bilateral trade between countries is given with X_{ij}. The system which allows us to compute trade cost at country-country-product level is

$$\left(\frac{\sum_i Y_i X_{ij}}{Y_i E_j}\right)^{\frac{1}{1-\sigma_k}} = \frac{t_{ijk}}{\Pi_i P_j} \tag{9}$$

$$\left(\frac{X_{ijk} X_{jik}}{X_{jjk} X_{iik}}\right)^{\frac{1}{1-\sigma_k}} = \frac{t_{ijk} t_{jik}}{t_{jjk} t^*_{iik}} \tag{10}$$

$$1 = \sum_j \frac{t_{ij}^{\tilde{\varepsilon}} X_j}{\Pi^*_i P_j} = \sum_i \frac{t_{ij}^{\tilde{\varepsilon}} X_i}{P_j \Pi^*_i} \tag{11}$$

The logic is the same as in the previous system (Step 1), i.e. the left side of each equation is known and the right side should satisfy it. There is one important change: the use of trade costs and MR terms for i, which comes from Step 1. This means that, in Step 2, trade costs and one of the MR terms for i should be kept fixed and introduced exogenourly for country i (this explains why Step 1 is needed in the first place). Solving Step 2 provides with international trade cost measurements (t^*_{ijk}, t^*_{jik}), domestic trade cost measurements (t^*_{jjk}) and MR terms (Π^*_j, P^*_j), simultaneously. No restrictions are imposed on trade costs (such as symmetric and/or frictionless trade assumptions), but A1 and A2 are assumed, however, which doesn't exclude the possibility of getting unit trade cost and/or symmetric trade cost measurements.

5 The Trade Data and Trade Cost Measures

To actually apply the proposed method, I use bilateral trade data from two separate sources. Below, I discuss each set of data separately.

Internal Trade Data (for Step 1). I used internal trade data from Canada as the region i, as internal trade records are generally scarce, but Canadian data used in the study by Anderson and Yotov (2010) is of a good quality. Their work is also based on the same structural gravity framework as the system that I use to solve (2-4)[16].

Thus, their work is consistent with the work I discussed in the previous section from a theory and methodology perspective, and the Canadian domestic trade cost measurements can be compared. There are some differences, of course.

1. I make the assumptions about trade costs (i.e. A1 and A2);
2. In my procedure, I do not perform gravity estimation of trade costs, but purely rely on observable data and the restrictions discussed;
3. I converted their measures given in the NAICS classification to the GTAP classification, using concordance tables from the World Integrated Trade Solution (WITS);
4. I used internal trade flows between provinces for 2003 only, being the latest year in their data.

[16]They estimate the gravity model and obtain estimated trade costs first; my procedure does not involve estimation. Before solving the system, they normalise inward trade incidences for Alberta (PAk = 1); I also normalise OMR for the same province in order to compute trade incidences for each province and internal trade costs simultaneously.

However, the trade data for Step 2 is for 2004, not 2003. Since I observed that there is no big change in overall Canadian trade cost levels from year to year, I used no techniques to extrapolate and predict trade cost levels for 2004 but keep them as is. In Table 1 Part A, I provide summary results of the data used for Step 1. The initial data is given in Canadian dollar terms which I converted to US dollar terms for 2003. In total I included 14 regions: the US (grouping all states), the Rest of the World (ROW) and 12 Canadian provinces/territories[17].

International Trade Data (for Step 2). I used international trade data from the GTAP database (Version 8.1). This version contains trade records of 134 regions in 2004, including trade both amongst and within themselves with standard GTAP product classification into 57 product types. Trade data is bilateral indicating regions of both origin and destination country, and Canada is included in the data set. This includes domestic trade where origin and destination regions are the same, but the domestic trade is aggregate rather than at sub-region level. This is the major difference from the data used in Step 1. The data is valued at agent prices[18]. Agent prices represent final purchaser prices, i.e. it should include all types of trade costs. With the GTAP abbreviations, I construct trade as $X_{ijk} = VIAS_{ijk} + VDA_{ijk}$, where $VIAS_{ijk}$ is international and VDA_{ijk} is internal trade in USD terms [19]. The list of the regions and the products, along with summary statistics, are set out in the Annex, and in Table 1 Part C I provide with summary results of the data used for Step 2. This is larger, both in terms of number of regions and products. Roughly, one third of the data has a zero value. The trade records are in USD terms.

[17]See Anderson and Yotov, 2010, for more details about the data

[18]The values at world prices represent the values of products at producer prices, which contain production taxes, incomes taxes, taxes on domestic and imported intermediates, and producer mark-ups. The values at market prices are the values at the world prices plus transport margins, and export and import duties. The values at agent prices are the values at market prices plus sales and purchase taxes, i.e. prices that final consumers pay. Further discussion on this is provided in McDonald and Thierfelder (2004).

[19] (1) International flows $VIMS_{ijk}$, (2) domestic flows VDM_{ijk}, (3) sales/purchase taxes on international flows $ISTAX_{ijk}$ and on (4) domestic flows $DSTAX_{ijk}$. They are appropriately merged to form international flows $VIAS_{ijk}$ and domestic flows VDA_{ijk} at consumer prices: $VIAS_{ijk} = VIMS_{ijk} + ISTAX_{ijk}$ when $i \neq j$; $VDA_{ijk} = VDM_{ijk} + DSTAX_{ijk}$ when $i = j$

Trade Elasticity. To obtain tariff level measurements of trade costs we require Armington elasticities. These elasticities have to be introduced exogenously to solve the system. While the Canadian trade data comes with trade elasticities at NAICS product level from Broda et al. (2006), I couldn't use them for Step 2 due to various reasons. The main reason was that trade cost measurements with Broda's elasticities were inappropriate (or hard to interpret) and their elasticities for many GTAP products were the same (after converting them from NAICS to GTAP product form). Trade data for Canada in Step 1 and Step 2 aren't exactly the same, as they come from different sources. I encountered similar issues when using Armington elasticities in GTAP8 data. I discuss these inconsistencies with elasticity choice in more detail in the Robustness section. The choice I considered for Step 2 was to calibrate elasticities for each product k to match the actual data (above), in the following way:

$$\widetilde{\sigma_k} = -\left(\frac{ln\left(\frac{X_{cck}X}{X_{ck}E_{ck}}\right)}{ln\left(\frac{t_{cck}}{P_{ck}\Pi_{ck}}\right)} - 1 \right) \tag{12}$$

where c is Canada and X_{cck}, X_{ck} and E_{ck} comes from GTAP8.1. This is not how the Armington elasticity is usually measured but this is what is suggested by the gravity equation (2). To do this we require measurements of unobservable terms. Luckily, t_{cck}, P_{ck} and Π_{ck} are available from Anderson and Yotov (2010). This would be consistent with the work as I used Canadian internal trade data from the same study. The resulting elasticity measurements using (5) range 4.6 to 17.8 (differ by k) with the mean across k at 7.3, which is in the acceptable range according to the literature. The level of the parameter is usually unknown and most studies agree that its level should be from 1 to 20 with its mean around 5-8 (See Anderson and van Wincoop 2004). Summary details of elasticities, σ_{bw} which is from the Broda etal (2006) study and σ_{cal} which is the calibrated parameters, are given in table (1). In the Robustness section, I further discuss the elasticities by comparing and contrasting the results.

Table 1: Summary Statistics (Data and TCMs)

	count	mean	sd	min	max
(a) Step 1 data dimentions (AY, 2010): 14(i) x 14(j) x 19(k) x 2003(t)					
X_{ijk}	3724	15152.85	254478.1	0	7042198
Y_{ik}	3724	475015.1	1951533	.7751938	2.16e+07
E_{jk}	3724	475152.4	1902378	1.550388	2.18e+07
σ_k^{bw}	3724	6.657634	2.319121	4	12
(b) Step 1 results: Canadian TCM					
$t_{can,can}(i=j)$	207	3.115001	1.177779	1.611801	16.11037
$t_{can,can}(i \neq j)$	1658	5.48577	4.002368	2.126495	31.90643
P_{can}	207	.8728235	.1929533	.4785928	1.480409
Π_{can}	207	5.078048	3.35898	1.659933	22.92033
(c) Step 2 data dimentions (GTAP8): 134(i) x 134(j) x 56(k) x 2004(t)					
X_{ijk}	1005536	107.7786	7861.134	0	4563921
$X_{ijk}(>0)$	359779	301.2257	13139.94	.04	4563921
$X_{ijk}(i=j)$	7187	12806.2	92028.94	.10	4563921
E_{jk}	7504	14442.34	94126	0	4598846
Y_{ik}	7504	14442.34	94593.44	0	4629161
σ_k^{cal}	56	7.351946	1.557995	4.61	17.78395
(d) Step 2 results: TCMs for all non-zero flows in GTAP8					
t_{ijk}	359779	3.524408	1.939597	.0003282	261.5363
$t_{ijk}(i \neq j)$	352592	4.79701	3.006914	.0057881	261.5363
$t_{ijk}(i=j)$	7187	3.298707	1.577298	.0003282	14.1699

Domestic and International Trade Costs. In the same table (1) I report the summary statistics of computed trade cost measures (TCMs) from both steps. All TCMs are weighted by trade size. TCMs should be interpreted as 1 plus the tax equivalent level of trade costs. To begin with Step 1 results, there were 2627 (not 3724) bilateral TCMs obtained with the Canadian data. About one third of the data have zero (or missing) values, and thus no measures were produced for those zero lines. The first one, $t_{can,can}(i = j)$, is the trade cost measure for within-province trade and the second $t_{can,can}(i \neq j)$ is for between-province trade. This shows that there is a relative and significant difference between the two. The mean of intra-province TCM is 3,11. This suggests that the product price, averaged accross all products and all provinces, sold within the territory of a province, is as much as three times higher than its production value. Considering the fact that there are no border restrictions for within-province trade and smaller transport distances, this is, a very high non-production cost. However, TCMs for between-province trade suggests that the average domestic trade cost goes up by another 76% (=5.48/3.11) on average due to some inter-provincial barriers. I note that all the trade cost calculations are consistent with the results obtained by Anderson and Yotov (2010). I also obtain OMRs which are 5-6 times higher than the IMR. This is not surprising given that we are using the same data and the same methodology for computing TCMs. I used the average Canadian domestic TCM, OMR and IMR for each product for Step 2 (see the Canadian measures by product in the Annex) and I report the summary statistics of TCMs from Step 2 in table (1). There were 359779 measurements generated (excluding lines with zero trade records which make up about two thirds of all the data). The weighted mean of t_{ijk}, across the whole sample, indicates that trade costs increase the unit values of goods and services by about 2.5 times. There are some outstanding measures I obtain which are as low as 0.0003 and as high as 261, but there are only a few such TCMs so I kept them. If one is to split the sample to international ($i \neq j$) and domestic (i=j) TCMs, then we observable that international trade costs around 38% more than domestic trade, across whole countries and products. While such a difference is expected, it is clear that domestic trade is not frictionless and on average domestic trade increases product cost by 3.3 times.

Figure 1: International Trade costs

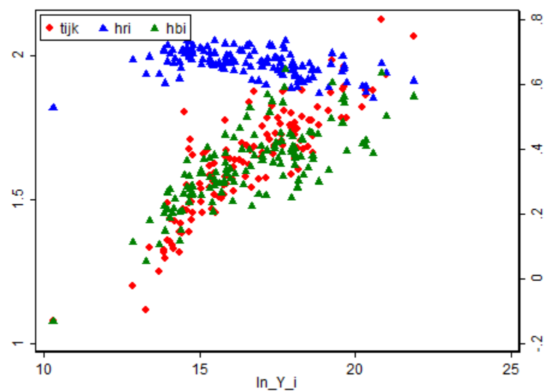
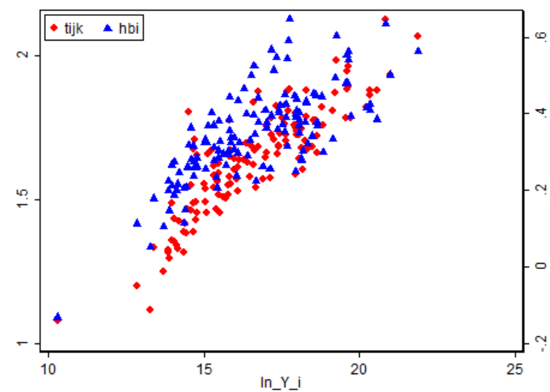


Figure 2: Domestic Trade costs



Trade Costs and Economic Sizes. The summary statistics of TCMs are aggregate results; therefore I performed several correlation analyses. In figure (1-2), I present international and domestic TCMs plotted against economic sizes (with country gross outputs) which shows a clear pattern suggesting that both (ITC and DTC) are growing in conjunction with the economic size of countries. The ITC/DTC level is almost two times lower for small countries like Togo, Rwanda, and Guinea, when compared to large countries like USA, China and Japan. These results are similar to what Romando etal (2016) find. Although, they calibrate ITC/DTC using trade flows between metropolian cities of OECD nations, they find that ITC/DTCs have a positive relationship with country size. I compute TCMs using other alternative methods: the Constructed Bias Index (CBI) and Head-Ries Index (HRI). While I use CBI and HBI to compare and contrast with my own measurements, neither of the two are true indicators of trade costs alone. I start with CBI, which has a strickingly similar correlation pattern with output to TCM. The Constructed Bias Indicator (Anderson, 2010) is equal to a ratio of trade cost over the product of MRs. If $P_i \Pi_j = 1$ then CBI would be an ideal trade cost measure, however, from the results I find (with GTAP trade data) that a product of either pair of MRs, even if i=j are not 1 but are higher, which supports the point. This can also be inferred from the CBI level (in parallel y axis on HRS of in the figures shows CBI level), which are lower than TCM for the same pair. This is purely because the denominator of CBI is higher than 1, otherwise they would be the same. Despite such important differences, values of nominator (i.e. t_{ijk} part) define CBI level and its positive correlation output size (which matches well with TCMs/output correlation). If one ws to denote small economy with S, a large economy with L, and output share with w_{ij}, it must be true that t_{Lj}/Π_L would be larger than t_{Sj}/Π_S, and the following would also be true:

$$\sum_j \left(\frac{t_{Sj}}{\Pi_S P_j}\right) w_{Sj} < \sum_j \left(\frac{t_{Lj}}{\Pi_L P_j}\right) w_{Lj} \tag{13}$$

While CBIs (on the parallel y axis in the figures) show the same pattern, which is a positive relationship between trade costs and country output size, the HRI measures contradict this, suggesting that ITCs and country size have a downward trending relationship. HRI is simply a geometric mean of international trade flows to internal trade flows. Swapping trade flows in HRI with RHS terms in (2) shows that HRI is a geometric mean of international trade costs over internal trade costs. If we ignore DTCs, the geometric mean of symmetric ITCs would be a natural TCM. If this would be true, then the geometric mean of TCMs would also be the same as the HRI. However, as seen from the DTC figure, this is not true. DTCs, even for small economies, are greater than 1. There is no country or product category for which I find DTC=1 using GTAP data. One explanation for negative correlation of HRI to output size are DTCs which grow with country size. Let's denote a small economy with S and a large economy with L. Because DTCs are in the denominator part of HRIs, and because t_{LL} would be larger than t_{SS}, it should be true that $\tilde{t_L} < \tilde{t_S}$:

$$\sum_i \left(\frac{t_{iL}t_{Li}}{t_{ii}t_{LL}}\right) w_{iL} = \tilde{t_L} < \tilde{t_S} = \sum_j \left(\frac{t_{Sj}t_{jS}}{t_{SS}t_{jj}}\right) w_{Sj} \tag{14}$$

Asymmetry in TCMs. It would be too simple to assume that the DTC differences alone explain the falling HRI country size pattern, and which would justify the contradictory pattern. There is also an assymetry issue at play. In table (2) I present a matrix of TCM means with exporters on the x-axis and importers on the y-axis. Numbers 1 to 10 represent a category of exporter/importer countries where 1 is the smallest country (for example Rwanda) and 10 is the largest country (like the USA). For instance, the mean of $t_{1,2}$, being the smallest exporter to the second smallest importer is 1.1, which is almost the same as the mean of $t_{2,1}$ (presented values were rounded to 1 decimal level, but differences are more shown at higher decimals). Further away from the origin (upper left corner of the table), the mean differences become apparent. For instance, the mean of $t_{1,10}$, the smallest exporter to the largest importer, is 7.5, which is two times higher than the mean of $t_{10,1}$. This shows that, for a smaller country, trading with a larger country is more costly than in the opposite direction. This also shows that not all of the TCMs are symmetric, except in the case where the two trading countries are of a similar size. Thus, because ITCs are in the nominator part of HRI, and the smaller countries are facing higher trade costs, relative to larger countries, it would also contribute to the HRI ratio showing a relatively higher HRI level for smaller economies when compared to larger ones.

Table 2: Trade cost Asymmetry

	1	2	3	4	5	6	7	8	9	10
1	1.0	1.1	1.5	2.0	2.1	2.2	2.7	2.9	2.8	3.2
2	1.1	1.0	1.1	1.5	2.0	2.2	2.6	2.9	3.1	3.5
3	1.5	1.2	1.2	1.2	1.8	2.0	3.5	3.0	3.6	3.7
4	1.8	1.5	1.2	1.2	1.3	1.9	2.7	3.1	3.2	3.9
5	2.2	1.8	1.6	1.4	1.4	1.5	2.5	3.2	3.4	3.7
6	2.0	2.1	1.8	1.8	1.5	1.5	1.6	2.7	3.6	3.9
7	2.0	2.2	2.6	2.4	2.0	1.8	1.6	2.1	3.1	3.7
8	2.5	2.8	2.9	3.0	2.9	2.6	1.9	1.8	2.4	3.9
9	3.2	3.4	3.3	3.5	3.5	3.4	3.3	2.6	2.1	3.8
10	7.5	5.3	5.0	5.6	6.1	5.1	5.0	4.8	3.9	3.6

[a] The numbers are bilateral TCMs split up by exporter and importer country sizes up to the value of 10. Columns/rows represent exporter/importer country sizes from smallest (1) to largest (10) in the table.

A Counterfactual Simulation with TCMs. In this section I present counterfactual simulation results with TCMs. For the purpose of scenario analysis, I use Brexit. In 2016, the UK announced that it is leaving the EU. While I use GTAP8 data for 2004 trade and not 2016, this is not an obstacle for the purpose if making a point. The purpose of this exercise is not to show the likely changes in welfare and trade gains from the event but to show the importance of domestic frictions and assymetric international trade costs in such simulations. I have performed many studies of various scenarios of trade policy deals between UK and EU. I simulate one scenario where, in the benchmark case, there are zero tariffs in intermediate/final goods trade for the UK with EU members. In the counterfactual case, the UK imposes a tariff on goods from EU countries, and similarly

EU countries impose tariffs on UK made goods. To model this, I perform two exercises with tariff change between UK-EU members due to Brexit, In one exercise I used computed TCMs, and in the other exercise, I used gravity estimated TCMs. Computed TCMs (or CTCM) are presented in the previous subsection to this. The Estimated TCM (or ETCM) model structure is given in the next subsection.

The simulation model is the same structural gravity model as described in the Theory section, except this time the factory gate price specified as:

$$p_{ik} = \left(\frac{Y_{ik}}{Y}\right)^{\frac{1}{1-\sigma_k}} \frac{1}{\alpha_{ik}\Pi_{ik}} \tag{15}$$

where p_{ik} is the endogenous factory price for k in i, and α_{ik} is the CES preference parameter, and all else defined as in the Theory section. Given the linkages between the equations in the model (the relationship between observable and unobservable elements and satisfactory market clearance conditions imposed with trade, output and expenditure data which is the same as, the GTAP8 data used previously) the simulation work captures all the direct and indirect impacts of the policy shock. The direct impacts come with trade cost change affecting associated trade flows (i.e. changes in trade in UK and EU countries), and hence changes in output and expenditure of regions directly involved with the EU. Indirect effects come through IMR and OMR equations and affect all other non-member partners too. As trade occurs not only in final goods but also in intermediate goods, factory prices would also be affected by the shock, bringing more changes into play in expenditure and output levels. The model simulations have no dynamic properties and do not capture the accumulation of physical capital.

In the figure (below), I present the simulation results given as the percentage changes (relative to the benchmark level) in real GDP, Export, Domestic trade, Factory prices, and OMR and IMR for each of the 134 countries due to the Brexit shock. Each figure presents results from both exercises: with CTCM (blue dots).

Simulation Results with Computed Trade Cost Measures (CTCM). CTCMs were the computed trade cost measurements I obtained using the two step procedure. With the Brexit scenario, the direct effects are shown in the trade flows between UK and EU members. However, the biggest change affects the UK rather than the EU members. UK exports drop by -30% while with a few EU members (like Belgium, Cyprus and France) exports fall by 3-5% at most, and the ROW remains almost unaffected. At the same time, exporting trade costs have increased for the same EU countries as OMR goes up for Cyprus (1), Slovakia (0.6), and Germany (0.2), while importing trade cost increased for the UK (1), and both types of costs increased for MLT (0.3;0.5). With higher UK-EU trade costs, more domestic trade occurs in the countries (as expected) as consumers switch to relatively cheaper domestic goods. Domestic trade increases in Malta (5), Cyprus(4) and the UK (2-3), and the rest of the EU experiences a slight boost. UK factory prices increase the UK(+5), while for EU members this goes in opposite direction: Cyprus(-0.6), Slovakia(-0.5), Germany(-0.2), Belgium(0.2). Real GDP changes suggest that Brexit will not bring any welfare improvement to either side, with noticable results in the following: Malta(-0.9), Cyprus(-0.8) and the UK(-0.3). In general, we find that for the UK: exports drop; a slight increase in domestic trade; higher factory prices and importing costs but exporting costs reduce. From the EU side, smaller members like Malta, Slovakia, and Cyprus are more likely to suffer than larger ones.

Simulation Results with Estimated Trade Cost Measures (ETCM). Estimates were performed with the gravity trade regression model[20]. Exogenous change in UK-EU trade costs (via tariffs), also result in UK exports dropping by about -30%. Larger EU country exports fall (France(20), Belgium(13), Netherlands(10), Germany(11)) but the Rest of the World (ROW) is not affected much. Exporting costs have increased for the same group of countries and they experience these increases at different levels, except the UK where it drops (-0.7). On the importing costs side (i.e. IMR), the importer costs go up: the UK(2.5),

[20]As is standard practice, the dependent variable is a log of the trade values and the independent variables are a log of geographic distances, and dummies for common border, language, and colony. I also included transport, import tariff and export tax variables that are defined in the estimation section below.

France(1); and Belgium(0.8). With higher international trade costs, and domestic trade costs in ETCM captured by internal distances alone, there is a larger substitution effect for the countries: domestic trade increases in the UK by 25 and between 5-9 for Belgium, Netherlands, France, Germany. Factory prices are predicted to reduce in the UK(-1.5), and for the EU as follows: Netherlands(-0.6), Germany(-0.5), Belgium(-0.5). As a result of all of this, welfare changes are higher for the same group of countries, while the biggest reductions occur in the UK(-3.5), Belgium(-1.3), Netherlands(-1), France(-1), and Germany(-0.9). In general, we find that neither the UK nor the EU benefits from the Brexit scenario. The UK's international trade drops, with a correspondingly large in its domestic trade. The reduction in factory prices does cover the losses from increases in trade costs, and as a result, the UK's welfare decreases. A group of the larger EU countries experience an expected negative consequence as their main trade partner (UK) leaves the EU.

From this exercise, we can see that the same simulation exercises (differing only in TCMs) lead to different outcomes. The CTCM results suggest that the UK's exports drop, domestic trade increases slightly, and factory prices and importing costs rise, while exporting costs reduce. Smaller EU members like Malta, Slovakia, and Cyprus suffer more than their larger counterparts (Germany and Belgium). The ECTM results suggest that the UK's international trade drops, but in return there is a large increase in domestic trade. Reduction in factory prices do not cover losses coming with increases in trade costs, and as a result, UK's welfare decreases. The reduction in factory prices does not cover losses arising from the increase of trade costs, resulting in a reduction in the UK's welfare. A group of the larger EU countries experience the expected negative consequences as their main trade partner (UK) leaves the EU. While both exercises show that neither the UK nor the EU side benefit from Brexit, and the direction of changes in both cases is generally similar, there are, however, some contradictory results. First, I notice that the magnitude of changes is much higher for the ETCM simulations relative to the

CTCM exercise. For instance, domestic trade costs for the UK in the ETCM scenario increase BY over 25%, while in THE CTCM scenario, it is no more than 2-3%. This is a very large change for a sizeable economy like the UK from such an event. In fact, based on actual statistical data for the UK's domestic and international trade, we cannot see such dramatic changes in the years following the Brexit decision. This could also be explained by the fact that in ETCM, domestic trade costs are not in control.Increased international trade costs make foreign goods more costly and, because substitutable goods from domestic suppliers in the UK are at factory prices (since there are no domestic trade costs), larger changes occur in the UK's domestic trade rates when compared to the other (CTCM) scenario where domestic trade cost measurements are in use for the UK and other regions. There are other factors that could be in play that cause these changes in factory prices.

There are other striking differences between the exercises. On the EU side, a different group of countries are affected. In the TCMC scenario, we find that smaller members (Cyprus, Malta, and Slovakia) experience greater changes, while in the ETCM scenario it is the larger countries (Belgium, Netherlands, Germany). From the table (flows), we learn that the larger EU countries are the UK's primary trade partners in the EU, and not smaller ones. Therefore, we would expect a larger impact on the bigger countries. The figures show percentage changes in trade and GDP relative to the benchmark level. The pre-simulation levels of trade and GDP size are smaller for smaller EU economies and bigger for the larger ones. The percentage changes presented in the simulation figures are larger for smaller sized countries and smaller for the larger countries. If we were to present the volume changes, it would show the opposite. Thus, we can say that the predicted changes in the ETCM scenario are overestimated for larger countries and underestimated for smaller countries. One other intuitive explanation for these results comes from our findings presented in the previous section – international trade costs are assymetric. Trade costs for flows coming from smaller to larger countries are two times as large as trade cost flows in the opposite direction. Smaller countries like Malta, Slovakia, Cyprus, which already have higher costs of trading in the pre-simulation case, would be hit harder by Brexit and experience higher negative marginal effects, than Germany, Netherlands, Belgium, whose costs of trading with UK are at similar levels.

Figure 3: Change in real GDP

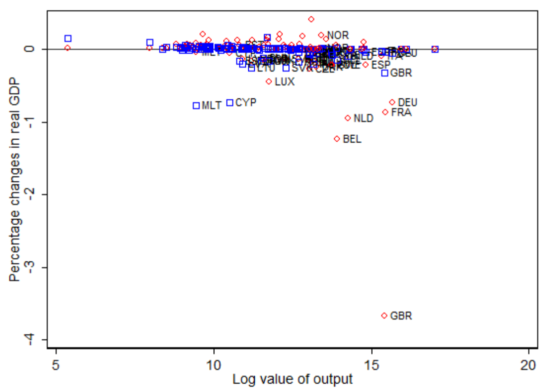


Figure 4: Change in Export

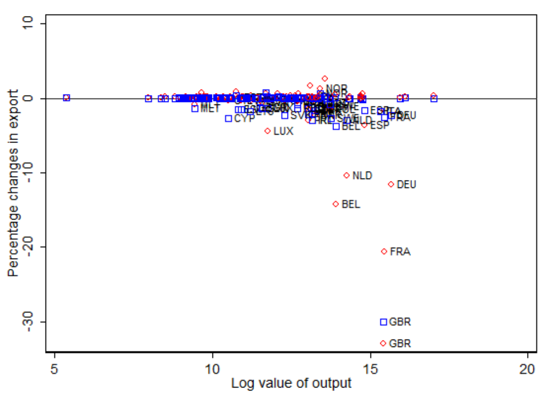


Figure 5: Change in Domestic Trade

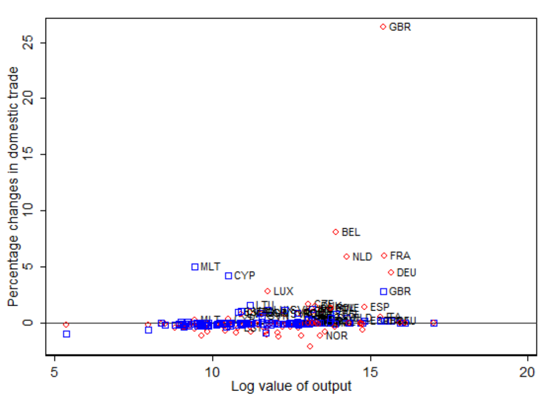


Figure 6: Change in Factory Price

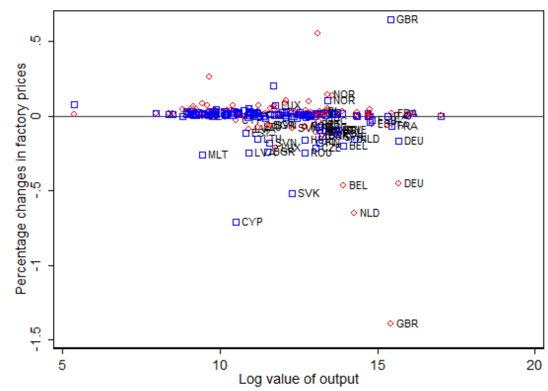


Figure 7: Change in OMR

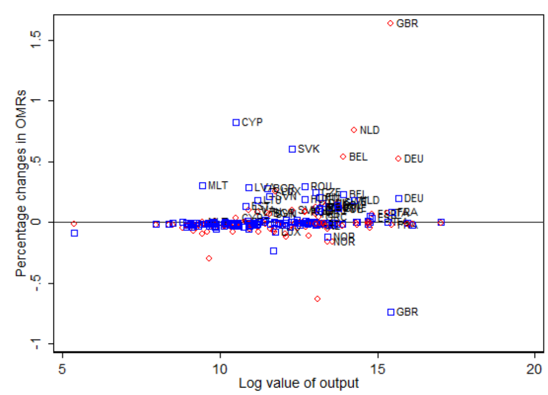
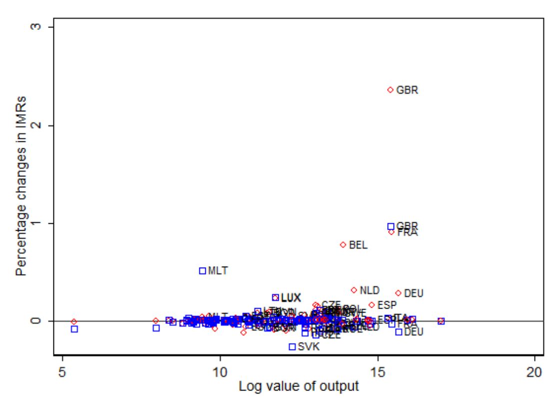


Figure 8: Change in IMR



Regression Analyses. In the previous section, I presented results of the simulation analyses with TCM. The simulation models the shock (the tariff change) by replacing initial TCMs with distorted TCMs (caused by the tariff change). To capture the part of the TCM modelling the tariffs (and controls for other components), the trade cost model (below) has been used. In the simulatation, the trade model has been estimated twice: the benchmark scenario estimates (with pre-Brexit tariff rates) and the counterfactual scenario estimates (where the tariff variable is replaced with post-Brexit rates and all else remains the same):

$$
\begin{aligned}
lnTCM_{ijk} = \beta_0 + \beta_1 ln\left(tran_{ijk}\right) + \beta_2 ln\left(mtax_{ijk}\right) + \beta_3 ln\left(xtax_{ijk}\right) \\
+ \beta_4 ln\left(dist_{ij}\right) + \beta_5 cont_{ij} + \beta_6 lang_{ij} + \beta_7 col_{ij} + \beta_8 same_{ij} + e_{ijk}
\end{aligned} \tag{16}
$$

where on LHS, TCM_{ijk} is the trade cost measure for product k from origin i to destination j (both $i \neq j$ and $i = j$) and, on RHS, the trade cost records are given with transport margins ($tran_{ijk}$), import tariffs ($mtax_{ijk}$) and export taxes ($xtax_{ijk}$) constructed from GTAP8[21] data. The unobservable part is controlled with standard gravity variables, being: weighted geographic distances ($dist_{ij}$), dummies for contiguity ($cont_{ij}$), common colonial history (col_{ij}), common language ($lang_{ij}$), same country trade ($same_{ij}$) and the error term (e_{ijk}). Notice that gravity controls are origin-destination specific (ij) and GTAP trade cost records are at origin-destination-product level (ijk).

In Table (3), I report the estimation results (column 1). Overall, all the coefficients show the expected signs of correlation and all the included variables are statistically significant at the 1% level. The elasticity of trade cost to distance is about 0.063, i.e. if the distances increase trade costs go up by 6.3%. The border adjacency coefficient suggests that the trade costs for geographically neighbouring countries are lower by 9.8%. The

[21]One benefit of the GTAP database is that contains not only trade flow data, but also records on transportation costs, tariffs and taxes. I derived shares of transport, tariff and tax in trade. Because the shares are between 0 (min) and 1 (max), I added 1 before taking logs and including the regression

common language factor reduces trade costs by another 2.2%. Former colonial and historical ties also reduce the costs by about the same level as the latter factor. Sharing colonial history cuts trade costs by 3.3%.

Estimated transport costs elasticity is 2.9 which suggest that unit increases in transport costs would result in a 2.9% increase in overall trade costs[22]. This should not be mistaken with the distance variable which is also interpreted as a transport cost proxy. In this case, in the presence of a direct transport margin variable, the distance should stand for distance related costs other than transportation costs [23]. Import tariffs and export taxes, when applied, increase trade costs by 0.7% each. Relative to other types of trade cost categories, the latter two have the smallest impact on the overall size of trade costs.

[22]Because ln($trans_{ijk}$) is the natural log of one plus the share of transport costs in trade (so the share between 0 and 1) and it is at ijk level, I interpret the estimated coefficienct as trade cost elasticity with respect to transport costs. Similar logic is used in constructing import tariff and export tax variables, and thus they are interpreted in similar way

[23]I tried running the model by excluding each of the variables, however, I did not notice any significant change in the coefficients reported here. Therefore, I believe that distance should not be interpreted as a transport cost proxy.

Table 3: TableA2

	(1)	(2)	(3)	(4)	(5)	(6)
	lnTCI	*lnHRI*	*lnCFB*	*lnTCIf*	*lnHRIf*	*lnCFBf*
	b/t	b/t	b/t	b/t	b/t	b/t
ln_Distance	0.063***	0.089***	0.086***	0.072***	0.089***	0.086***
	(28.66)	(30.90)	(31.60)	(35.26)	(30.90)	(37.12)
Contiguity	-0.098***	-0.155***	-0.141***	-0.095***	-0.155***	-0.129***
	(-10.10)	(-16.63)	(-14.38)	(-10.85)	(-16.63)	(-14.31)
Language	-0.022***	-0.040***	-0.035***	-0.026***	-0.040***	-0.036***
	(-5.33)	(-9.52)	(-8.19)	(-7.26)	(-9.52)	(-9.85)
Colony	-0.033***	-0.043***	-0.038***	-0.035***	-0.043***	-0.034***
	(-3.80)	(-5.85)	(-4.58)	(-4.38)	(-5.85)	(-4.21)
Same	-0.942***	-1.068***	-1.121***	-0.930***	-1.068***	-1.058***
	(-69.08)	(-57.42)	(-64.77)	(-72.30)	(-57.42)	(-68.62)
ln_1_sh_trans_ijk	2.911***	1.864***	3.009***	2.633***	1.864***	2.782***
	(78.46)	(77.69)	(101.01)	(95.14)	(77.69)	(120.88)
ln_1_sh_mtax_ijk	0.671***	0.045**	0.440***	0.681***	0.045**	0.595***
	(23.62)	(3.22)	(25.27)	(30.35)	(3.22)	(43.07)
ln_1_sh_xtax_ijk	0.716***	0.617***	0.926***	0.925***	0.617***	0.889***
	(7.96)	(11.05)	(13.67)	(11.82)	(11.05)	(16.74)
Constant	0.522***	0.446***	-0.490***	0.264***	0.446***	-0.921***
	(8.37)	(7.04)	(-6.88)	(6.79)	(7.04)	(-22.23)
N	270925	270925	270925	359779	270925	359819
R^2	0.546	0.815	0.659	0.516	0.815	0.620

Regressions with HRI/CBI. Because the dependent variable in the model is the new trade cost measure, the obtained coefficients and elasticity estimates might not be correct. Due to this, I ran the model again and replaced the dependent variable with standard trade cost indicators, using the Head-Ries Index (HRI) and the Constructed Bias Indicator (CBI). These measures are relevant as they are found using gravity theory. The estimation results along with the alternative two dependent variables are in column 2-3 of Table (5). I also find that the coefficient estimates are more or less in line with what I find with the TCM. Notice that observations number vary from one to another dependent variable now. I cannot construct HRIs if one of the international trade flows or internal trade flows for an ijk pair is missing. This is the main explanation for having 270925 observations for the HRI column, but this fact does not heavily impact coefficient estimates. I also ran regressions by restricting the observations for TCM/CBI to match HRI observations, without finding any great change.

Decomposition of ITC/DTC. In (9-10), the ITC and the DTC are decomposed and grouped by 4 sectors (1-agriculture; 2-light manufacturing; 3-heavy manufacturing; 4-services). From the ITC decomposition, I find transport costs explain about 5-12%. This rate is higher in the agricultural goods sectors and smaller in the services trade. The other two discriminatory measures contribute to the ITC level by a much lower rate import tariffs add about 2-3% and export taxes only 1%. There is no record of direct measures for internal trade in GTAP8 (import tariffs and export taxes are not used in domestic trade). The standard gravity proxies have done well in capturing other unobservable trade cost components in the TCMs. Distance related costs make up the large part of the ITC – 37-41% – and this does not include transport costs. Border adjacency reduces the ITC level by 5-10%, and having no borders at all means 10-20% lower total trade costs. In the DTC figure, distance related costs explain 10-22% of total costs, which may also capture domestic transport costs.

In figures (9) and (10), I applied reddish colours to the components showing direct trade cost records, the bluish colours on gravity proxy components, and uncaptured or potentially unexplained trade costs are shown in grey. In the ITC figure, we also observe that half (41-54%) of the trade costs are not captured by either of the variables. In the DTC figure, distance related costs explain only 10-22% of total costs, leaving the larger body unexplained. This uncaptured part is usually ignored and left out as a measurement error (e_{ijk}). As TCM is an all-inclusive measure and I want to establish control over all trade costs, even unexplained ones, I do not exclude e_{ijk}. This is also the difference between the ETCM and the CTCM simulation, i.e. the inclusion of e_{ijk} in the CTCM simulation, and this fact alone explains the simulation results. I note that all of the errors were clustered at the *ijk* level. All estimations were performed with the Poisson Pseudo Maximum Likelihood (PPML) estimator (*glm* command in *Stata* with the robust error option).

Figure 9: International Trade costs

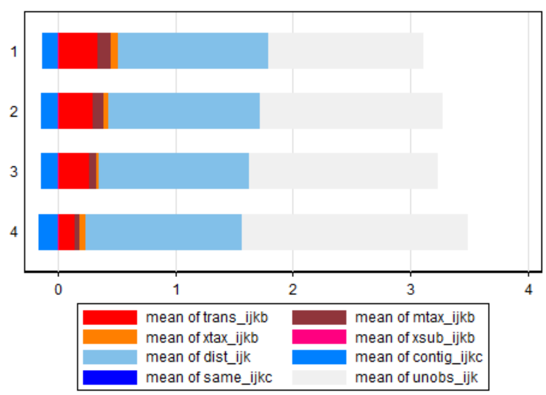
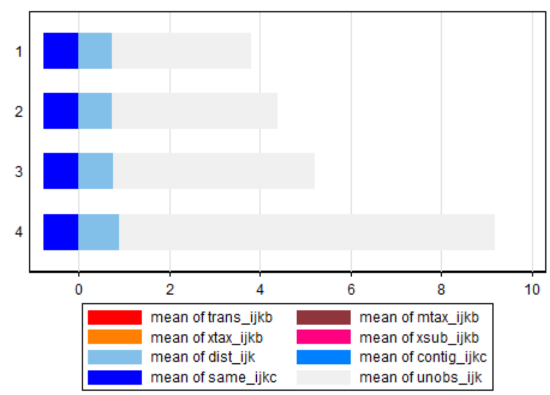


Figure 10: Domestic Trade costs



6 Robustness

Restrictions & a Unique Solution. The proposed two-step method is based on solving (2-4) using actual trade data, and I have provided an illustration of it. There could be a number of different solutions (i.e. range of t_{ij}, Π_i, P_j) that satisfy the left hand of the matrix (with the observable data). However, under a set of principal restrictions given by the system structure (2-4) and known variables (trades, outputs, expenditures), there is only one unique solution (i.e. t^*_{ij}, Π^*_i, P^*_j). To discuss the restrictions, let me represent (2) in a matrix form for a better view, and denote locations with $a, b, c, ..i(j)$:

$$\begin{pmatrix} \frac{X_{aa}Y}{Y_a E_a} & \frac{X_{ab}Y}{Y_a E_b} & .. & \frac{X_{aj}Y}{Y_a E_j} \\ \\ \frac{X_{ba}Y}{Y_b E_a} & \frac{X_{bb}Y}{Y_b E_b} & .. & .. \\ .. & .. & .. & .. \\ \frac{X_{ia}Y}{Y_i E_a} & .. & .. & \frac{X_{ij}Y}{Y_i E_j} \end{pmatrix} = \begin{pmatrix} \frac{t_{aa}}{\Pi_a P_a} & \frac{t_{ab}}{\Pi_a P_b} & .. & \frac{t_{aj}}{\Pi_a P_j} \\ \\ \frac{t_{ba}}{\Pi_b P_a} & \frac{t_{bb}}{\Pi_b P_b} & .. & \frac{t_{bj}}{\Pi_b P_j} \\ .. & .. & .. & .. \\ \frac{t_{ia}}{\Pi_i P_a} & .. & .. & \frac{t_{ij}}{\Pi_i P_j} \end{pmatrix}^{(1-\sigma)} \tag{17}$$

The restriction of the matrix's cell value to 1 is set by (2) itself. Here, in the matrix view, all knowns are collected on one side and all unknowns on the other. Each *cell* value on the right hand of (17) is defined by a corresponding cell value on the left. To be clear, the value of $(\frac{t_{aa}}{\Pi_a P_a})^{(1-\sigma)}$ should be equal to the value of $(\frac{X_{aa}Y}{Y_a E_a})$. Similar logic applies to the rest of the matrix cells. During the computation process, any set of $t_{ij}, \Pi_i, or P_j$ that doesn't match the left side cell values are ignored.

The restriction 2 of the denominator part of the matrix is set by the ratio (3/4). The MR terms are in the denominator parts of each cell on the right side of the matrix. As can be seen from (3), P_j is a function of t_{ij} and Π_i. Dividing both sides of (3) by P_j gives $\sum_i \left(\frac{t_{ijk}}{P_{jk}\Pi_{ik}}\right)^{1-\sigma_k} \frac{Y_{ik}}{\sum_i Y_{ik}} = 1$. Similarly, Π_i in (3) is given as a function of t_{ij} and P_j, and can be rearranged to: $\sum_j \left(\frac{t_{ijk}}{\Pi_{ik}P_{jk}}\right)^{1-\sigma_k} \frac{E_{jk}}{\sum_i Y_{ik}} = 1$.

Since both rearranged equations are equal to one, and it must be true that the ratio of the two is also equal to one, $\sum_i \left(\frac{\sum_i Y_i X_{ij}}{Y_i E_j}\right)^{1-\sigma_k} \frac{Y_{ik}}{\sum_i Y_{ik}} / \sum_j \left(\frac{t_{ijk}}{\Pi_{ik}P_{jk}}\right)^{1-\sigma_k} \frac{E_{jk}}{\sum_i Y_{ik}} = 1$ (which I have used). This is an additional restriction that filters out a number of $\phi_{ij}, \Omega_i, \Phi_j$ which could satisfy restriction 1 but not restriction 2.

The restriction 3 is applied to the nominator part of the matrix and it is given by (10). The theory (2) suggests that a ratio of internal trade over international trade

$\left(\frac{X_{ijk}X_{jik}}{X_{jjk}X_{iik}}\right)^{\frac{1}{(1-\sigma_k)}}$ should be equal to $\frac{t_{ijk}t_{jik}}{t_{jjk}t_{iik}}$, as all other common terms will cancel out (Head and Ries, 2001). The combination of knowns should impose restrictions on the value of dyadic unknowns.

Notice that unlike the previous two natural restrictions, but in combination with them, this suggests that there is a relationship (and dependency) among unknown dyadic terms which are in nominator parts of separate *cells* on the right side of (17). Imposement of $\left(\frac{X_{ijk}X_{jik}}{X_{jjk}X_{iik}}\right)^{\frac{1}{(1-\sigma_k)}} = \frac{t_{ijk}t_{jik}}{t_{jjk}t_{iik}}$ establishes linkages among *cells* of the matrix. Trade cost terms are interlinked with each other not only via MRTs but also via HRI net. There should be few combinations of $\phi_{ij}, \Omega_i, \Phi_j$ left that satifsy all three restrictions.

The restriction 4 is used to assign t_{iik} for a particular i location. This means that in the dyadic ratio (restriction 3), one of the two internal trade cost terms in the denominator part of HRI is now known t_{iik}. This imposes a restriction on the diagonal nominator values (i.e. t_{jjk}) that should also satisfy the previous 3 restrictions. Thus, use of restrictions 1-4 guarantees a single solution to the system. I obtain the level of t_{iik} for a particular i (Canada) using internal trade flow data by solving (2-4). If the assigned t_{iik} were different, i.e. $t2_{iik}$ is higher (or lower) than t_{iik} by *a* scalar, we obtain the results that have been raised/lowered by using the same scalar.

What will happen if different reference country (e.g. the USA) is used? We obtain the same solution (i.e. $t^*_{ijk}, \Omega^*_i, \Phi^*_j$) if, and only if, the assigned $t_{usa,usa,k}$ level would be exactly the same ($t_{usa,usa,k}$) as with the case when $t_{can,can,k}$ has been used, and all else is equal. This is purely because there is a relative levels issue. Let us consider a situation for a particular k, where we use (or we compute with Step 1) $t_{can,can} = 2$, and solve the system (Step 2) and obtain a set of results where $t^*_{usa,usa} = 3$. From there we learn that internal trade cost for the USA is 1.5 times larger than the Canadian internal cost level, and this is a *relative* level. If we instead use $t_{usa,usa} = 3$ in Step 2, and make no other changes, then surely, we obtain a set of trade cost measures where $t^*_{can,can} = 2$. This relative difference does not change in the results; even if either of the chosen internal trade costs differs from the origin by *b* amount, the results would differ by the same amount. Proportional changes lead to proportional shifts but *relative* levels stay the same. Of course, using a different dataset in Step 2, would change this relative pattern.

I should note that all 4 restrictions are *natural* and given with *knowns*. In restriction 1, the values on the left side are purely given by the actual trade data[24]. In restriction 2 the Multilateral Resistance (MR) ratios are equal to 1, which is known and equal to the sum of weighted $\frac{t_{ijk}}{P_{jk}\Pi_{ik}}$. Restriction 3 is the ratio of trade flows ($\left(\frac{X_{ijk}X_{jik}}{X_{jjk}X_{iik}}\right)^{\frac{1}{(1-\sigma_k)}}$) and Restriction 4 would also be suggested by internal trade flow intensity.

Under frictionless domestic trade assumptions, the whole diagonal part of the right side of the matrix is 1 and the above 1-3 restrictions should be enough to get a unique solution. However, domestic trade costs are not the same across all locations, and they should be higher than 1. Unit diagonal restriction to the matrix would be an unsuitable restriction. Instead, a non-diagonal restriction can be imposed to trade costs, for instance, with gravity estimated set of $t_{ijk}^{1-\sigma}$[25]. However, as I have shown in the previous section, estimated trade cost measures are symmetric and only explain a portion of the trade costs.

Armington Elasticity. Should we use calibrated or "off-the-shelf" elasticities? The system can be solved without the Armington elasticities although to obtain tariff equivalent expressions of trade costs, we do require them. The issue I face is that if the elasticity is small (closer to 1) then the TCM becomes too high, and the opposite is true when the elasticity runs toward + ∞. For example, when I choose an elasticity level between 1.8 and 2.4, TCM levels are in the range of 500 - 50000. When I use a number more than 30, the TCM becomes almost 1. These levels are hard to believe and, furthermore, they cannot be compared to any measures found in the literature. This has also been

[24]Known elements are X_{ij}, Y_i, E_j, Y, given by trade records (on both, internal and international flows). Output/expenditure comes from trade flows ($Y_i = \sum_j X_{ij}$; $E_j = \sum_i X_{ij}$; and $Y = \sum_i \sum_j X_{ij}$).

[25]In order to find one unique set of unknowns (i.e. $\phi_{ij}^*, \Omega_i^*, \Phi_j^*$), at least of trade cost terms, has to be assigned. Anderson and Yotov (2010), for example, suggest to estimate trade cost with the standard gravity proxies (distances and a set of dummy terms for common border, language and history), and to normalise one of unknown the MR terms to unity for a particular chosen i, before solving (2-4)

noted in previous studies, e.g. the study by Egger and Bergstrand (2009). Thus, care is required when choosing appropriate levels of elasticities before proceeding interpret the trade cost measures and their relative differences. The reasonable concern becomes: how appropriate are the elasticities used in this work?

The trade elasticities were calibrated (σ_k^{cal}) for this work as I mentioned before, however I could have assigned them, or used "off-the-shelf" elasticities from GTAP8 (σ_k^{gtp}) or from Broda et al. (2006) (σ_k^{broda}), which is used quite frequently in the relevant literature. In Table (6), I show TCMs constructed using alternative elasticity sets. As can be seen, elasticities offered by Broda et al. (2006) represented a "second best" choice for this work. The main issue with Broda's elasticities that they are not given at GTAP classification level, and when they are converted across several product groups, the same level is assigned. Despite that, calibrated elasticities, which are unique for each GTAP product, are similar to those produced by Broda's study. In some product categories (like apparel or leather products) TCMs with Broda's elasticities, are too high to allow interpretation.

The other alternative, Armington's (ESUBM/ESUBD) parameters in the GTAP8 which comes from Hertel et al.'s (2001) paper, were producing unreasonably high TCMs[26]. For this reason, I used calibrated elasticities, although these alternative elasticities were obtained from highly detailed data and rigorous econometric estimation procedures. Regardless of the kind of elasticity used, the exact levels of the elasticities of substitution between domestic and foreign products are again unknown. The main stream of relevant literature agrees that it should be somewhere in the range of 1 to 20; of course, the parameter could be higher than 20 and would most likely differ by product type. Most recent studies find that the global average should be around 8 for traded goods. The calibrated elasticities in this study are on average close to 8, which is also important to note.

[26]The low elasticity estimates are probably due to the highly disaggregated data has been used by Hertel et al. (2001). Egger and Bergstrand (2009) mention that higly aggregated data produce higher elasticity measurements, and vice-versa.

There are actually more important issues that arise with elasticity when it comes to using "off-the-shelf" elasticities. Among others, there are issues related to methodologies for the elasticity measurement. While these issues are of high importance to this work, I will not discuss them extensively here. Most of these issues are well documented (for example, see Bergstrand et al. 2013).

Table 4: Calibrated vs."Off-the-shelf" elasticities

Product name	σ_k^{cal}	t_{ijk}^{cal}	σ_k^{gtp}	t_{ijk}^{gtp}	σ_k^{broda}	t_{ijk}^{broda}
Paddy rice	17.78	2.42	10.20	5.60	7.43	13.62
Wheat	7.68	2.64	8.80	2.17	7.43	2.79
Cereal grains	5.41	3.21	2.60	202.15	5.85	2.81
Vegetables, fruit	7.61	2.42	3.80	14.52	7.43	2.49
Oil seeds	7.87	1.95	5.00	4.33	7.43	2.08
Sugar cane, sugar	11.80	1.64	5.40	4.13	7.43	2.46
Plant-based fibre	11.65	1.76	5.00	6.98	7.43	2.83
Crops nec.	10.10	2.36	6.60	4.49	7.43	3.59
Cattle	5.38	1.30	4.00	1.64	5.85	1.25
Animal products	10.02	1.80	2.60	822.53	7.43	2.44
Raw milk	9.41	1.38	7.40	1.59	7.43	1.59
Wool, silk	12.03	2.45	12.80	2.30	5.81	11.22
Forestry	5.60	2.23	5.00	2.67	6.15	1.99
Fishing	9.11	1.71	2.60	428.06	7.43	2.04
Coal	9.38	1.75	6.00	3.33	12.00	1.47
Oil	7.95	1.67	10.40	1.40	12.00	1.32
Gas	5.46	1.05	34.40	0.98	12.00	0.97
Minerals nec.	7.92	1.94	1.80	599,861.6	12.00	1.47
Bovine meat prod	4.62	2.35	7.80	1.49	5.85	1.81
Meat products ne	5.10	2.36	8.80	1.53	5.85	2.04
Vegetable oils,	8.85	2.19	6.60	3.21	7.43	2.69
Dairy products	8.95	2.03	7.40	2.55	7.43	2.54
Processed rice	14.43	2.35	5.20	55.34	7.43	8.88
Sugar	10.17	2.27	5.40	7.04	7.43	3.42
Food products ne	8.49	2.26	4.00	13.48	7.43	2.67
Beverages, tobacco	7.84	2.72	2.20	32,395.3	6.44	3.81
Textiles	8.15	3.88	7.60	4.44	5.81	8.83
Wearing apparel	8.23	3.42	7.40	4.22	4.35	29.97
Leather products	8.28	8.34	8.20	8.60	5.26	79.72

7 Conclusions.

In trade cost measurement, one faces data quality and data scarcity issues, and makes his/her best trade-off when choosing an appropriate methodological approach and theory framework given the available data at hand. Due to these limitations, domestic trade costs were hard-to-measure and hence largely ignored. International trade costs measured with distances, or similar factors, are symmetric proxies by their nature. The international trade cost measures were also symmetric. Because of this, trade models that deal with policy shocks over-predict the changes in domestic trade (since they have no trade costs) and the welfare changes for larger sized countries while they are under-predicted for smaller countries.

To offer an alternative methodological solution for data scarcity I measure domestic trade costs and asymmetric international trade costs in a two-step process consistent with the theory. I find that trade costs exist in domestic trade and the costs increase in line with the country's economic size. International trade costs are highly dissimilar especially if a trading pair has higher differences in economic sizes; international trade costs are higher if the importer is a larger country and the exporter is a smaller country, and vice-versa. With regard to (symmetric) trade cost proxies like geographic distance, despite their being highly useful, I find that they unfortunately capture only half of all trade costs. After controlling for ignored/uncaptured trade costs, trade models predict smaller changes in domestic trade (since domestic trade costs don't come into play) and larger welfare changes for smaller sized countries (which now face higher international trade costs due to asymmetry), relative to larger countries, given the same trade policy shock. To be clear, the welfare changes represent percentage changes in GDP/trade between pre- and post-policy shock scenarios.

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A Annex

Table 5: Concordances

GTAP	IDnum	SITC-S	HS	DTC	OMR	IMR
PDR	1	3	11	2.14	2.88	1.20
WHT	2	3	11	2.14	2.88	1.20
GRO	3	1	10	3.73	6.16	1.45
V_F	4	3	6,7,8	2.14	2.88	1.20
OSD	5	3	12	2.14	2.88	1.20
C_B	6	3	17	2.14	2.88	1.20
PFB	7	3	8,9	2.14	2.88	1.20
OCR	8	3	13	2.14	2.88	1.20
CTL	9	1	1	3.73	6.16	1.45
OAP	10	3	5	2.14	2.88	1.20
RMK	11	3	4	2.14	2.88	1.20
WOL	12	5	50-62	2.77	6.06	0.81
FRS	13	7	44-46	2.75	3.02	1.64
FSH	14	3	3,16	2.14	2.88	1.20
COA	15	2	27	1.84	2.18	1.33
OIL	16	2	27	1.84	2.18	1.33
GAS	17	2	27	1.84	2.18	1.33
OMN	18	2	25	1.84	2.18	1.33
CMT	19	1	2	3.73	6.16	1.45
OMT	20	1	2	3.73	6.16	1.45
VOL	21	3	12,14,15	2.14	2.88	1.20
MIL	22	3	4	2.14	2.88	1.20
PCR	23	3	19	2.14	2.88	1.20
SGR	24	3	17	2.14	2.88	1.20
OFD	25	3	21	2.14	2.88	1.20
B_T	26	13	22	2.77	4.60	0.99
TEX	27	5	50-63	2.77	6.06	0.81
WAP	28	6	61-62	3.62	10.53	0.59
LEA	29	4	41-43	3.99	9.08	0.81
LUM	30	7	44-46	2.75	3.02	1.64
PPP	31	9	47-49	1.86	2.19	1.28
P_C	32	2	27	1.84	2.18	1.33
CRP	33	18	28-38, 39-40	2.36	3.02	1.18
NMM	34	2	27	1.84	2.18	1.33
I_S	35	11	72-73	2.39	3.74	1.09
NFM	36	11	74-83	2.39	3.74	1.09
FMP	37	11	73	2.39	3.74	1.09
MVH	38	13	84-85	2.77	4.60	0.99
OTN	39	14	86-89	7.80	17.83	0.72
ELE	40	15	85	2.62	4.53	0.96
OME	41	13	84	2.77	4.60	0.99
OMF	42	8	94-96	5.96	16.85	0.88
SRV	43-57	–	–	2.69	4.48	1.17

Note: Concordance table to SITC-HS and HS-GTAP are taken from the UN Statistics. Since trade data from Anderson and Yotov (2010) do not cover services (i.e. no trade cost indicators for services trade), it is assumed that they are equal to the average level of trade cost indicators in goods trade.

Table 6: Canadian Trade Cost Indicators

Sector	IMR	OMR	DTC	ITC	Sigma
Agriculture products	1.45	6.16	3.73	11.78	5.85
Fuels	1.33	2.18	1.84	2.84	12.00
Food	1.20	2.88	2.14	3.99	7.43
Leather and plastic products	0.81	9.08	3.99	8.54	5.26
Textile products	0.81	6.06	2.77	7.89	5.81
Hosiery and clothing	0.59	10.53	3.62	19.05	4.35
Lumber and wood products	1.64	3.02	2.75	4.52	6.15
Furniture and lamps	0.88	16.85	5.96	15.89	4.00
Wood and paper products	1.28	2.19	1.86	2.78	10.08
Printing and publishing	0.69	17.95	6.55	17.96	4.16
Primary metal products	1.09	3.74	2.39	4.82	6.99
Fabricated metal products	0.87	6.87	3.50	8.14	5.56
Machinery	0.99	4.60	2.77	4.68	6.44
Motor vehicles and parts	0.72	17.83	7.80	17.44	4.09
Electrical products	0.96	4.53	2.62	6.04	5.83
Non-metallic minerals	0.98	5.38	2.93	5.76	7.19
Petroleum and coal	1.51	1.87	1.83	2.79	12.00
Chemical products	1.18	3.02	2.36	3.00	7.55
Miscellaneous products	0.82	7.93	3.81	9.52	5.75

Note: Trade cost measures are taken from Anderson and Yotov (2010). They are given in NAICS classification and present measures only for 2003.

Table 7: Trade elasticities: Broda, Hertel, Verikious & Calibrated

ccode	sig1	TCM1	sig2	TCM1	sig3	TCM1
Source	Calibrated					
Paddy rice	17.78	2.42	10.20	5.60	7.43	13.62
Wheat	7.68	2.64	8.80	2.17	7.43	2.79
Cereal grains	5.41	3.21	2.60	202.15	5.85	2.81
Vegetables, fruit	7.61	2.42	3.80	14.52	7.43	2.49
Oil seeds	7.87	1.95	5.00	4.33	7.43	2.08
Sugar cane, sugar	11.80	1.64	5.40	4.13	7.43	2.46
Plant-based fibre	11.65	1.76	5.00	6.98	7.43	2.83
Crops nec	10.10	2.36	6.60	4.49	7.43	3.59
Cattle	5.38	1.30	4.00	1.64	5.85	1.25
Animal products	10.02	1.80	2.60	822.53	7.43	2.44
Raw milk	9.41	1.38	7.40	1.59	7.43	1.59
Wool, silk	12.03	2.45	12.80	2.30	5.81	11.22
Forestry	5.60	2.23	5.00	2.67	6.15	1.99
Fishing	9.11	1.71	2.60	428.06	7.43	2.04
Coal	9.38	1.75	6.00	3.33	12.00	1.47
Oil	7.95	1.67	10.40	1.40	12.00	1.32
Gas	5.46	1.05	34.40	0.98	12.00	0.97
Minerals nec	7.92	1.94	1.80	599,861.60	12.00	1.47
Bovine meat prod	4.62	2.35	7.80	1.49	5.85	1.81
Meat products nec	5.10	2.36	8.80	1.53	5.85	2.04
Vegetable oils,	8.85	2.19	6.60	3.21	7.43	2.69
Dairy products	8.95	2.03	7.40	2.55	7.43	2.54
Processed rice	14.43	2.35	5.20	55.34	7.43	8.88
Sugar	10.17	2.27	5.40	7.04	7.43	3.42
Food products nec	8.49	2.26	4.00	13.48	7.43	2.67
Beverages, tobac	7.84	2.72	2.20	32,395.38	6.44	3.81
Textiles	8.15	3.88	7.60	4.44	5.81	8.83
Wearing apparel	8.23	3.42	7.40	4.22	4.35	29.97
Leather products	8.28	8.34	8.20	8.60	5.26	79.72
Wood products	5.86	3.44	6.80	2.69	6.15	3.15
Paper, publishing	8.64	2.32	6.00	4.25	10.08	1.97
Petroleum, coal	8.91	2.86	4.20	22.02	12.00	2.06
Chemical, plastic	9.02	2.82	6.60	4.66	7.55	3.64
Mineral products	9.58	2.33	5.80	5.53	12.00	1.89
Ferrous metals	8.32	3.14	6.00	5.81	6.99	4.19
Metals nec	5.65	3.08	8.40	1.89	6.99	2.27
Metal products	7.69	3.34	7.60	3.40	6.99	3.94
Motor vehicles	5.72	4.96	5.60	5.19	6.44	3.89

Table 8: Trade elasticities: Broda, Hertel, Verikious & Calibrated (cont.)

ccode	sig1	TCM1	sig2	TCM1	sig3	TCM1
Source	Calibrated					
Transport equipm	6.40	2.93	8.60	2.01	4.09	9.66
Electronic equip	8.11	3.07	8.80	2.75	5.83	5.75
Machinery, equip	7.59	4.11	8.20	3.61	6.44	5.71
Manufactures nec	5.03	3.76	7.60	1.95	4.00	7.61
Electricity	6.76	1.72	5.60	2.33	4.00	8.65
Gas, gas distrib	7.73	1.93	5.60	5.25	4.00	87.58
Water	9.96	2.41	5.60	10.39	4.00	101.25
Construction	6.43	1.63	3.80	9.14	4.00	6.77
Trade	6.23	1.36	3.80	4.31	4.00	3.51
Transport nec	7.16	2.36	3.80	16.90	4.00	12.79
Water transport	6.75	1.99	3.80	9.02	4.00	7.14
Air transport	5.93	2.24	3.80	5.68	4.00	4.86
Communication	6.19	1.59	3.80	3.92	4.00	3.36
Financial service	6.31	1.70	3.80	7.12	4.00	5.60
Insurance	6.44	1.91	3.80	7.73	4.00	6.18
Business service	6.44	1.37	3.80	3.35	4.00	2.90
Recreational ser	6.86	1.56	3.80	5.78	4.00	4.70
Public services	6.19	1.40	3.80	3.88	4.00	3.22
Total	7.99	2.39	6.32	11,313.77	6.58	10.32