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# The Variation of Gravity within Countries

(or 15 Reasons Why Gravity Should Be Estimated with Domestic Trade Flows)

## Abstract

The gravity equation is the workhorse model for analysis of bilateral trade flows. Despite solid theoretical foundations and clear gains from theory-consistent policy analysis, there are still gaps between gravity theory and empirics. This paper focuses on domestic trade flows, and I argue that there are significant benefits from adhering to theory by estimating gravity equations with domestic (in addition to international) trade flows. To this end, I review the contributions from the related literature and I synthesize them into fifteen arguments for using domestic trade flows in gravity estimations. The survey of the literature reveals the need for further theory contributions and new data developments, and points to opportunities for more empirical analysis and policy applications.

JEL-Codes: F130, F140, F160.

Keywords: domestic trade flows, structural gravity, trade policy, estimation.

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The title of this paper was inspired by Saxov's (1952) review of different methods to determine the values of gravity within the Earth, which he titled "The Variation of Gravity within the Earth".

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*"He who loves practice without theory is like the sailor who boards ship without a rudder and compass and never knows where he may cast."*

Leonardo da Vinci (1452-1519)

# Introduction and Motivation

The gravity model of trade is the workhorse framework for both partial and general equilibrium analysis of international trade flows, and it has established itself as the standard tool to quantify the impact of trade and other policies not only at the aggregate, but also at the sectoral and product levels. In addition to its intuitive appeal and remarkable predictive power, the great success of the gravity equation is due to its solid theoretical foundations and the tight connection between gravity theory and empirics. A series of prominent papers demonstrate the benefits of doing theory-consistent empirical gravity work. Notably, Anderson and van Wincoop (2003) show that proper control for the structural multilateral resistance (MR) terms resolves the famous *"Canadian Border Puzzle"* of McCallum (1995). Baldwin and Taglioni (2006) promote theory-consistent gravity applications more generally, by dubbing the failure to properly control for the MRs as the *'gold medal mistake'* in gravity estimations, and by identifying other common empirical mistakes that could be avoided by closer adherence to gravity theory.

Despite the progress that has already been made to do theory-consistent applied work, there are still some clear and important theoretical implications that have been ignored in most of the empirical gravity literature. The focus of this paper is on one such implication – *the use of domestic trade flows*. Even though domestic trade flows are featured in all theoretical gravity models (e.g., from Anderson (1979) to Arkolakis et al. (2012)) and they have been used for a long time to identify the impact of international borders and the so-called 'home bias' in trade (e.g., McCallum (1995)

and Wolf (2000)), the vast majority of gravity applications ignore domestic trade flows and do not include them in the estimating samples. In turn, and consistent with the opening quote, the gap between theory and empirics may lead to some prominent empirical puzzles (e.g., the distance puzzle in trade), inability to estimate the effects of a number policies (e.g., Sanitary and Phytosanitary Standards, SPS) and biases in the estimates of others (e.g., free trade agreements, FTAs, and membership in the World Trade Organization, WTO).

This paper has three related objectives. First, it offers a review of the literature that focuses on the use of domestic trade flows in the gravity model and on the corresponding implications. Second, from a methodological perspective, it argues that there are significant benefits from following theory more closely by estimating the gravity equation with domestic trade flows in addition to international trade flows. Third, from a practical and policy perspective, it demonstrates that the use of domestic trade flows (i) can resolve some prominent empirical puzzles, (ii) leads to significant differences in the estimates of bilateral trade policies, and (iii) delivers estimates of the impact of country-specific policies that cannot be identified in a gravity equation that only relies on international trade flows.

To achieve these objectives, I present fifteen reasons why empirical gravity models should be estimated with data that not only include international but also *domestic* trade.[1] Consistent with the evolution of the related literature, I group the fifteen arguments into three broad categories, which correspond to the three main sections of

[1] Admittedly, some of the fifteen reasons that I present are related to each other and some of them could be combined. However, with the risk of being repetitive, I decided to list them individually either because they address challenges that have been identified separately in the literature (e.g., the distance puzzle vs. the missing globalization puzzle), or because they have different implications for policy analysis (e.g., identifying the impact of WTO vs. identifying country-specific effects of the WTO), or because I have been advised to do so by referees and colleagues who offered feedback on the manuscript (e.g., estimating the effects of country-specific characteristics vs. identifying asymmetric trade costs at the country level).

this paper. Specifically, Section 1 presents what, in my view, are the most important arguments for using domestic trade flows in gravity regressions; Namely, (i) that this is consistent with trade theory on the intensive margin of trade, (ii) that data on domestic trade flows are available, and (iii) that there are good theoretical and empirical reasons to also use domestic trade flows for gravity estimations on the extensive margin of trade.

Section 2 focuses on the implications of using domestic trade flows to quantify trade costs, and I present four arguments for that. First, there is an older and well-developed literature that uses domestic trade flows to estimate the impact of international borders and home biases with the gravity model. Second, a more recent literature relies on intra- and inter-regional trade flows to estimate heterogeneous domestic trade costs. Third, a relatively new strand of the literature focuses the determinants of domestic trade costs, and studies their implications for welfare and development. Finally, the use of domestic trade flows in gravity regressions allows for introducing asymmetries in the bilateral/international trade costs.

Section 3 reviews the implications of domestic trade flows for estimating the effects of various policies with the gravity model, including, (i) identifying the trade-diversion effects of bilateral policies (e.g., preferential trade agreements, PTAs); (ii) estimating the effects of non-discriminatory trade policies (e.g., export subsidies), (iii) identifying the impact of country-specific characteristics on international trade (e.g., institutional quality, production subsidies, technical barriers to trade, TBT); and (iv) obtaining country-specific trade policy effects (e.g., member-specific WTO effects).

Section 4 reviews papers that rely on domestic trade flows to solve some prominent puzzles in the international economics literature, including, (i) *"The Distance Puzzle of International Trade"*, according to which the negative gravity estimates of the impact of distance on trade flows do not decrease (in absolute value) over time, (ii)

*"The Missing Globalization Puzzle"*, according to which the empirical gravity model cannot capture the effects of globalization, (iii) the counterfactual implication of the innovation-led growth literature and trade literature that *"Larger Countries Should be Richer than Smaller Countries"*, and (iv) the puzzle of *"The Missing WTO Effects"*, i.e., that the WTO did not promote international trade. The paper concludes with a discussion of the need for more theoretical contributions to model domestic trade flows, new data sets that include domestic trade, and it points to opportunities to further capitalize on domestic trade flows in applied work.

Depending on their objective, some gravity regressions that only use data on international trade flows may still deliver reliable results. Note, for example, that the exporter and importer fixed effects, which are standardly used in the gravity model to account for the unobservable MR terms, absorb and control for the non-discriminatory and country-specific policy effects in regressions that only use international trade flows. However, the inclusion of domestic trade flows explicitly in the gravity model has two potentially important implications. First, it enables us to tease out the effects of a number of trade determinants that "were hiding" in the gravity fixed effects, thus resolving various puzzles and identification challenges. Second, it may impact the estimates of the effects of bilateral policies and standard determinants of trade flows (e.g., FTAs and WTO membership), which can be identified even without data on domestic trade flows. For these reasons, the main takeaway from this survey is that, whenever possible, gravity estimations should use data that includes domestic trade flows. If data limitations prevent it (e.g., when there is no matching domestic production/sales data at the required sector/time level), then the potential consequences and limitations should be noted up front, and when results are presented the possible bias implications should be discussed or, better, treated in some way.

# 1 Domestic Trade Flows: Theory and Data

This section presents some of the most important arguments to use domestic trade flows in gravity estimations. First, I argue that this is consistent with trade theory on the intensive margin of trade, i.e, the theory that models the volume of bilateral trade flows. Second, I argue that data on domestic trade flows are available. Third, I argue that this is also consistent with trade theory on the extensive margin of trade, i.e, the theory that models the creation and 'death' of bilateral trade links.

> ***Reason 1:*** *The use of domestic trade flows in gravity estimations is consistent with trade theory of the intensive margin of trade.*

Domestic trade flows have been featured in, and in fact are required to close, every structural gravity model, since the first theory foundation of gravity in economics, i.e., Anderson (1979), through the most famous and influential gravity models of Eaton and Kortum (2002) and Anderson and van Wincoop (2003), to the seminal work of Arkolakis et al. (2012) that established the power of the structural gravity model as representative of a very wide class of trade models.[2] Regardless of the underlying theoretical micro-foundations, and regardless of whether the gravity model is derived at the aggregate level (e.g., Eaton and Kortum (2002) and Anderson and van Wincoop (2003)), at the sectoral level (e.g., Anderson and van Wincoop (2004) and Costinot et al. (2012)), or at the firm level (e.g., Chaney (2008) and Redding (2014)), domestic sales are always present in gravity theory as they are required to impose market clearing, i.e., that, at delivered prices, the value of total production should be equal to the sum of total exports and domestic sales. The importance of domestic trade flows in the gravity model is highlighted by the fact that the share of domestic sales

[2] I refer the reader to Anderson (2011), Arkolakis et al. (2012), Costinot and Rodriguez-Clare (2014), Redding (2014), Head and Mayer (2014), and Yotov et al. (2016) for surveys of the theoretical gravity literature.

is one of the two sufficient statistics in the famous ACR formula for the gains from trade of Arkolakis et al. (2012). Finally, either explicitly or implicitly (as part of gross production), domestic trade flows are always required and used to perform general equilibrium experiments and counterfactual simulations with the gravity model.

Despite clear guidance from theory and despite the fact that domestic trade flows are required to perform general equilibrium analysis and counterfactual simulations, their use in estimating gravity models has been very limited and most gravity estimations are still performed with samples that only include international trade flows. One possible explanation for this is that, following Tinbergen (1962), the gravity equation is often viewed and applied simply as an intuitive, a-theoretical estimating equation, i.e., without adhering to its theoretical foundations. Another possible explanation for not using domestic trade flows for gravity estimations has been the lack of data. While it is true that datasets on international trade flows are more widely available and have better coverage,[3] it is also true that there are a number of datasets that offer consistently constructed international *and domestic* trade flows.

***Reason 2:*** *Data on domestic trade flows are available.*

Borchert et al. (2020b) review several notable efforts to construct consistent data on international and domestic trade flows and they introduce the U.S. ITC's International Trade and Production Database for Estimation (ITPD-E) as the most recent and comprehensive effort in that direction.[4] The ITPD-E covers 243 countries, 170

[3]For example, the most prominent international trade database, COMTRADE, offers data on international trade flows at the 6-digit HS level. Domestic trade flows data are not available at such disaggregated level.

[4]The ITPD-E can be downloaded for free at the USITC's gravity portal , and I refer the reader to Borchert et al. (2020b) for a detailed description of the data, the methods, and original sources used to create the ITPD-E. Earlier datasets that include domestic trade flows that are suitable for gravity estimations include the World Bank's Trade, Production and Protection (TPP) database, c.f., Nicita and Olarreaga (2007) and the CEPII's Trade, Production and Bilateral Protection (TradeProd) database. However, both of these datasets only focus on manufacturing and have been terminated

industries, and 17 years over the period 2000-2016. Domestic trade flows are constructed as the difference between gross production and total exports.[5] Importantly, the data are constructed from reported administrative ("raw") data at the industry level covering the broad sectors of agriculture, mining and energy, manufacturing, and services. Thus, in addition to detailed and comprehensive industry coverage and wide country coverage, the most appealing feature of ITPD-E is that it includes consistently constructed international and domestic trade flows that are suitable for estimation. Borchert et al. (2020a) test the suitability of ITPD-E for gravity estimations.

Measuring and promoting export diversification have been important objectives for many international organizations, e.g., the World Bank, the International Monetary Fund (IMF), and the Inter-American Development Bank (IDB), and most national governments. Analyzing the extensive margin of trade, i.e., the analytic image of export diversification, also has a central place in the academic literature: from a theory perspective, e.g., Helpman et al. (2008); from an estimation perspective, e.g., Santos Silva et al. (2014); from a policy perspective, e.g., Cadot et al. (2011); and from a measurement/index perspective, e.g., Hummels and Klenow (2005). Capitalizing on three influential strands of the trade literature,[6] Anderson and Yotov (2020)

(in 2004 and 2006, respectively). Two other datasets that include domestic trade flows are the GTAP Database and the World Input-Output Database (WIOD). As argued by Borchert et al. (2020b) however, due to their 'constructed' nature, the GTAP and the WIOD datasets are suitable for simulation analysis but not for estimations.

[5]Two alternative methods to construct domestic trade flows for gravity estimations are to use GDP data (e.g., Yotov (2012), Timini and Viani (2020), and El Dahrawy and Timini (Forthcoming)) or to rely in input-output (I-O) linkages (e.g., Larch et al. (2018), Felbermayr et al. (2018), and Felbermayr and Steininger (2019)). The main advantages of using gross production data over GDP data are (i) that this is consistent with the data on exports, which are also reported on a gross basis, and (ii) that this allows for construction of sectoral domestic trade flows. The main advantages of using gross production data over relying on I-O links are (i) wider country coverage and (ii) wider sectoral coverage. Campos et al. (2021) offer a review of the different methods to construct domestic trade flows and study the implications for gravity estimates.

[6]First, their model nests the standard gravity equation, c.f., Anderson (1979), Eaton and Kortum (2002), Anderson and van Wincoop (2003), and Arkolakis et al. (2012). Second, they incorporate bilateral investment/dynamics in the spirit of Arkolakis (2010), Head et al. (2010), Chaney (2014), Mion and Opromolla (2014), Sampson (2016), Crucini and Davis (2016), and Anderson and Yotov

build a short-run gravity model of the extensive margin and introduce the notion of the *domestic extensive margin.*

> ***Reason 3:*** *The use of domestic trade flows in gravity estimations is consistent with trade theory of the extensive margin of trade.*

An important implication from the explicit account for the domestic extensive margin in Anderson and Yotov (2020) is that this allows for an alternative comparison and quantification (in relative terms, i.e., "pound-for-pond") of the export-diversification performance between large vs. small countries. The intuition is that since smaller and poorer economies produce less products, the standard export-diversification measures, which are constructed as counts and levels, put the small countries at disadvantage. To test the importance and validity of their methods, Anderson and Yotov (2020) build a new data set of consistently constructed data on the domestic and the international extensive margins and they deploy it to study the impact of integration in Europe, demonstrating that the empirical analysis is not possible without the domestic extensive margin. From a broader perspective, the introduction of the domestic extensive margin allows for identification of the effects of a number of policies, which are discussed later in this paper, and whose impact is impossible to obtain within a properly specified empirical gravity model that only employs data on the external extensive margin.

# 2 Implications for External & Internal Trade Costs

The use of domestic trade flows has implications for the identification and measurement of both domestic trade costs as well as international trade costs. In particular,

(2020). Third, they account for action on the extensive margin of trade following Melitz (2003), Helpman et al. (2008), Chaney (2008), and Redding (2011).

with respect to domestic trade costs, the use of domestic trade flows allows for the measurement of heterogeneous domestic trade costs and for analysis and systematic decomposition of the impact of their determinants. With respect to international trade costs, the use of domestic trade flows allows for the introduction of country-specific bilateral trade cost asymmetries.

The use of domestic trade flows in gravity estimations is not new in the trade literature. A number of influential papers have used domestic trade flows to quantify the impact of international borders and to measure the so-called *'home bias'* in trade, i.e., the stylized fact that countries trade disproportionately more domestically as compared to trading internationally. For example, McCallum (1995) uses domestic trade flows to establish the famous *'Canadian Border Puzzle'*,[7] which later is resolved (also with the use of domestic trade flows) in the seminal paper of Anderson and van Wincoop (2003). Around the same time, Wolf (2000) also uses domestic trade flows, but this time to quantify the *'home bias'* effect in the United States.

> ***Reason 4:*** *The use of domestic trade flows allows for estimation of the effects of international borders and home biases.*

Estimating the impact of international borders and quantifying the 'home bias' in trade have attracted significant attention in the trade literature and have been the object of interest for a series of excellent papers.[8] An important result from this literature is the presence of enormous international borders/home bias effects in trade.

[7]The puzzle refers to the finding that Canada's provinces trade disproportionately more with each other than with the U.S. states, even after controlling for size and bilateral distance.

[8]For example: for analysis of the 'home bias' in the United States see Wolf (2000), Mayer and Head (2002), Hillberry and Hummels (2003), Millimet and Osang (2007), Head and Mayer (2010), Hillberry and Hummels (2012), Yilmazkuday (2012); for the European Union see Nitsch (2000), Chen (2004), and Head and Mayer (2010); for OECD countries Wei (1996); for China see Young (2000), Naughton (2003), Poncet (2003, 2005), Holz (2009), and Hering and Poncet (2009); for Spain see Llano and Requena (2010); for France see Combes and Mayer (2005); for Brazil see Fally et al. (2010); for Germany see Lameli et al. (2013) and Nitsch and Wolf (2013); for Canada see Agnosteva et al. (2019); and Anderson et al. (2018b) for the world.

For example, most recently, and using data on aggregate manufacturing, Anderson et al. (2018b) estimate that, even after controlling for the impact of geography (i.e., distance and contiguity) and multilateral resistance, international borders drive a wedge of 92% between domestic and international trade. Another important implication of this literature is that domestic trade is not frictionless and domestic trade costs can be substantial. In part due to data limitations, the focus of the early literature on particular countries, and when the data included more countries or regions the impact of international borders was constrained to be uniform across them, thus missing on the opportunity to investigate the heterogeneity of domestic trade costs and to study their determinants and their implications for welfare and policy an analysis

Many theoretical trade papers assume that domestic trade is frictionless and treat countries as point masses. This is in stark contrast with reality, where differences in domestic distance and infrastructure are just two simple and clear examples that domestic trade is not frictionless and, more importantly, that domestic trade costs could be quite heterogeneous across countries. Ramondo et al. (2016) relax the assumption of frictionless domestic trade and use distance between metropolitan areas within countries to construct heterogeneous domestic trade costs.[9] Due to lack of data on trade flows between metropolitan areas, Ramondo et al. (2016) do not estimate but instead *calibrate* heterogeneous domestic trade costs. However, as argued in Section 1, data on domestic trade flows are now more widely available and, therefore, the gravity model can be used to *estimate* heterogeneous domestic trade costs.[10]

> ***Reason 5:*** *The use of domestic trade flows allows for estimation of heterogeneous domestic and regional trade costs.*

[9]Ramondo et al. (2016) show that the presence of heterogeneous domestic trade costs, in turn, solves the puzzle from the macro and trade literatures that *"Larger Countries Should be Richer than Smaller Countries"*. I describe this puzzle and its solution in more detail in Section 4.

[10]While it is true that the gravity model can only ever identify relative trade costs, it also true that the model can be used to estimate heterogeneous domestic trade costs.

Capitalizing on a newly-constructed dataset for services trade, Anderson et al. (2018a) estimate structural gravity with domestic trade flows to obtain domestic trade costs for 12 sectors and 28 countries. Their main findings with respect to domestic trade frictions are that they are widely heterogeneous, both across sectors and across countries. Agnosteva et al. (2019) complement the calibrated inter-regional trade cost measures of Ramondo et al. (2016) and the estimated country-sector specific domestic trade costs indexes of Anderson et al. (2018a) by estimating a gravity model that simultaneously delivers estimates of intra-regional trade costs, inter-regional trade costs, and international trade costs for Canada's provinces. In addition to confirming previous findings of substantial inter-regional trade frictions, the new implication from the analysis of Agnosteva et al. (2019) is that trade frictions are large and very heterogeneous even *within* Canada's provinces. To underscore the importance of domestic trade frictions for welfare analysis, Ramondo et al. (2016) derive an augmented ACR formula that accounts for heterogeneous domestic trade frictions.

Understanding the determinants of domestic trade costs and properly linking them to draw inference about international trade and welfare is important for many reasons. A relatively new but quickly developing strand of the literature focuses on the determinants of domestic trade costs and their implications for welfare and development within the new quantitative trade models. For example, Anderson and Yotov (2010) use intra-provincial and inter-provincial sales to study the impact of trade liberalization (i.e, the Agreement on Internal Trade, AIT) within Canada. Donaldson (2016) studies the implications of intra-national trade costs in the form of railroad network in India for productivity and welfare. Cosar and Demir (2016) and Cosar and Fajgelbaum (2016) consider the impact improvements in transportation infrastructure and internal geography when trade must pass through gateway locations with a focus on Turkey and China, respectively. While the aforementioned studies focus on

specific countries, the use of domestic trade flows within the structural gravity model allows for a systematic analysis of the determinants of domestic trade costs and their implications for welfare and development.

> ***Reason 6:*** *The use of domestic trade flows allows for a systematic analysis of the determinants of domestic trade costs.*

Anderson et al. (2018a) employ a structural gravity model and proxies for domestic geography, infrastructure, and development to proxy for domestic trade costs in services trade. Beverelli et al. (2018) estimate the impact of institutional quality and quantify its implications for development within the same structural gravity model. Most recently, Gurevich et al. (2021) build a new dataset on domestic language proximity and use common domestic language as a proxy for within-country cultural ties in a structural gravity setting. An interesting aspect of language as a domestic trade barrier is that changes in domestic language proximity are also almost always automatically associated with changes in international language proximity. For example, changes in domestic language proximity within Canada (e.g., by making Canada's province Quebec fully bilingual)[11] will impact Canada's trade in at least three ways. First, this should increase inter-regional trade between Quebec and the other provinces and territories in Canada. Second, this will lead to the standard indirect trade-diversion effects on trade with the rest of the world, which are captured by the general equilibrium links in the structural gravity model. Finally, this will also have a direct positive impact on bilateral trade costs between Canada and its English-speaking foreign partners.

The use of domestic trade flows in structural gravity estimations also has potentially important implications for the estimates and measurement of international

[11] Much of Quebec's population speaks only French, while the prevailing language in the rest of Canada is English.

trade costs, e.g., to allow for asymmetric international trade costs. Two influential papers, Waugh (2010) and Fieler (2011), highlight the relevance of country-specific asymmetries in international trade costs that are related to economic development. In a traditional gravity model, i.e., one that is estimated only with international trade flows, such country-specific trade cost asymmetries are controlled for by exporter and importer fixed effects. If, however, domestic trade flows are introduced as additional observations in the dependent gravity variable, then it is possible to identify country-specific trade cost asymmetries in international trade costs.

> ***Reason 7:*** *The use of domestic trade flows allows for country-specific asymmetries in the vector of international trade costs.*

Felbermayr and Yotov (2021) illustrate this point by allowing for country-specific trade cost asymmetries in a structural gravity estimation with domestic trade flows by introducing an interaction between a border dummy variable, which takes a value of one for international trade and is set to zero for internal trade, and GDP per capita. Due to the bilateral nature of the border dummy, its interaction with GDP per capita is of bilateral dimension too. Thus, the impact of this interaction can be identified even in the presence of the full set of exporter and importer fixed effects. In combination with the common/uniform estimate of this interaction term,[12] the variation of GDP per capita across countries will result into an asymmetric vector of bilateral trade costs. Consistent with the main messages of Waugh (2010) and Fieler (2011), the estimates of the asymmetric trade costs from Felbermayr and Yotov (2021) reveal that poor countries face larger obstacles to trade as compared to rich countries.

[12] In principle, the estimates of the interaction term can be allowed to vary by income group too. This could introduce additional heterogeneity in the impact of economic development on trade.

# 3 Implications for Identification of Policy Effects

While, as demonstrated in the previous section, domestic trade costs have been the object of study in a number of influential papers, it turns out that almost all gravity models that are not concerned with the estimates of the so-called 'home bias' or the corresponding international border effects in trade ignore the use of domestic trade flows. This section argues that the use of domestic trade flows plays a very important role for the identification of the effects of various trade policies, including both re-evaluations of the effects of bilateral trade policies that have already been studied with gravity models as well as identification of the effects of non-discriminatory trade policies and country-specific policies that have not been possible before, i.e., without the use of domestic trade flows.

Traditionally, the trade diversion effects of free trade agreements (FTAs) have been an important consideration for many policy makers and popular observers, e.g., because many believe that trade diverted from non-member countries reduce their terms of trade and, ultimately, welfare. The basic theory underlying these concerns is well-known and dates back to Viner (1950), and all theoretical gravity models can capture trade diversion through general equilibrium (GE) channels in simulation analysis. However, in effect, the GE simulations 'impose/assume' trade-diversion effects from non-members by construction. Thus, the question of whether FTAs indeed divert trade from non-member countries is really an empirical one. Dai et al. (2014) demonstrate that the empirical gravity model is well suited to capture trade-diversion effects and, most importantly for the current purposes, the introduction of theory-consistent internal trade flows plays a central role in quantifying the trade-diversion effects of FTAs.

***Reason 8:*** *The use of domestic trade flows allows for identification of*

*the trade-diversion effects of bilateral trade policies.*

Dai et al. (2014) show that the use of domestic trade flows in gravity estimations allows for simultaneously identifying three different trade diversion effects: (i) diversion of exports to third countries toward exports to FTA partners; (ii) diversion of imports from third countries to imports from FTA partners; and (iii) diversion of domestic sales toward international sales to FTA partners. Two important, and related, results stand out from their analysis. First, they estimate a very strong impact of FTAs on diversion of domestic sales toward international trade. Such trade-diversion effects cannot be identified if gravity is estimated with international trade flows only. Second, on a related note, the estimate of the impact of FTAs increases significantly (about three times in their case) when the same gravity specification is estimated with domestic trade flows in addition to international trade flows.[13] The explanation for this result is that the inclusion of domestic trade flows in gravity estimations allows for explicit account of the diversion effects of FTAs from domestic toward international sales. The broader implication of these results is that when the effects of bilateral trade policies are estimated without taking into account the trade-diversion effects from domestic sales, then the former (e.g., the effects of FTAs in gravity models) may be biased downward.

As prominently noted by Head and Mayer (2014), *"In the presence of importer and exporter fixed effects a variety of potentially interesting trade determinants can no longer be identified in a gravity equation. Notably, (1) anything that affects exporters' propensity to export to all destinations (such has having hosted the Olympics or being*

[13]The increase in the estimates of the effects of FTAs when domestic trade flows are introduced in gravity estimations is confirmed by Baier et al. (2019), who obtain agreement-specific, pair-specific, and even directional (i.e., on exports and imports) estimates of the effects of FTAs. Campos et al. (2021) also confirm this result when domestic trade flows are constructed using GDP data or I-O links instead of data on gross production.

*an island), (2) variables that affect imports without regard to origin, such as country-level average applied tariff, and (3) sums, averages, and differences of country-specific variables."* (pp. 157-158). Heid et al. (2021) propose a simple solution to this problem by arguing that, consistent with theory, the gravity model should be estimated with data that include not only international trade flows but also *domestic* sales.

> ***Reason 9:*** *The use of domestic trade flows allows for identification of the effects of non-discriminatory trade policies on bilateral trade flows.*

The use of domestic trade allows for identification of the effects of non-discriminatory trade policies even in the presence of importer and exporter fixed effects. The reason is that such trade policies apply only to international trade flows (and not to domestic sales), while the fixed effects are defined for both international as well as intra-national observations. To demonstrate the effectiveness of their methods, Heid et al. (2021) obtain estimates of the effects of Most Favored Nation (MFN) tariffs and "Time to Export" (TTE) as representative non-discriminatory policies on the importer and the exporter side, respectively. However, their methods can be extended to quantify the impact of any non-discriminatory trade policy, e.g., export subsidies.

Beverelli et al. (2018) capitalize on the use of domestic trade flows and extend the methods of Heid et al. (2021) to demonstrate that the structural gravity model can be used to identify the impact on international trade of any *country-specific* variable and not only of policies that are targeted specifically at trade.

> ***Reason 10:*** *The use of domestic trade flows allows for identification of the effects of country-specific characteristics on bilateral trade flows.*

From a methodological perspective, Beverelli et al. (2018) demonstrate that the identification of the effects of country-specific characteristics, as opposed to non-discriminatory trade policies, is not a trivial extension of the analysis of Heid et

al. (2021) due to a series of collinearity issues within a properly specified structural gravity model. For example, while it is possible to identify the impact of non-discriminatory trade policies separately on exports vs. imports, Beverelli et al. (2018) show that it is only possible to identify the differential impact of country-specific variables on international *relative* to internal trade, and they propose further adjustments (via interaction terms) that allow for separating the directional effects of country-specific characteristics on exports vs. imports.[14] Motivated by the extensive literature on the links between institutions and trade,[15] Beverelli et al. (2018) apply their methods to study the impact of institutional quality on trade.[16] However, their analysis can readily be applied to study the differential impact on international vs. domestic sales of any country-specific policy or characteristic, e.g., national tax policies, sanitary and phytosanitary standards, production subsidies, etc.

It can be argued that membership in the World Trade Organization (WTO) or the European Union (EU) would benefit the overall trade of their members and not only the trade with other members of these organizations. Furthermore, there are various reasons to expect that the impact of joining a large international organization such as

[14]It should be noted that any country-specific policy or characteristic also has uniform/non-discriminatory effects on international and domestic trade, e.g., an improvement in productivity will impact production and affect both domestic and international sales. Such uniform effects are controlled for via the exporter(-time) and importer(-time) fixed effects in standard gravity regressions. Thus, the use of domestic trade flows allows for identification only of the differential effects of country-specific policies/characteristics on international *relative* to domestic trade.

[15]For example, North (1981), North (1990), La Porta et al. (1997), Acemoglu et al. (2001), Acemoglu and Johnson (2005), and Pascali (2017) show that high-quality institutions are the primary determinant of economic performance. In addition, many papers have focused on the direct impact of institutions on trade, e.g., Anderson and Marcouiller (2002), Yu et al. (2015), de Groot et al. (2004), Dutt and Traca (2010), de Jong and Bogmans (2011),Gil-Pareja et al. (2017), and Álvarez et al. (2018). In order to identify the impact of institutional quality within the gravity model, some of these papers have constructed bilateral institution variables as a combination of the institutional indexes on the importer and exporter side, which leads to difficulties in the interpretation of the estimates, while others have not controlled properly for the multilateral resistances, which may lead to biases in the gravity estimates. As demonstrated by Beverelli et al. (2018), the use of domestic trade flows simultaneously addresses both of these concerns.

[16]They obtain positive, large, and significant estimates of the effects of institutions on trade.

the WTO or the EU may have very heterogeneous impact across different members, e.g., depending on the time that the country joined or various other country-specific characteristics. On a related note, it may also be expected that certain policies that are uniform to the EU, e.g., certain tax or institutional regulations that apply to each member, may have very different effects on the international trade of individual member states. Whether the above hypotheses are true is an empirical question, and it can be answered with the use of domestic trade flows in the gravity model.

> ***Reason 11:*** *The use of domestic trade flows allows for identification of the country-specific effects of trade policies.*

Building on the analysis of Larch et al. (2019), who solve the puzzle of the *"The Missing WTO Effects"* (which is described in the next section), Felbermayr et al. (2020) use domestic trade flows to obtain *country-specific* effects of the impact of WTO membership. Specifically, they estimate a whole distribution of country-specific WTO effects on the exports of each WTO member state, i.e., the WTO effects on the exports of Bulgaria vs. Germany vs. US, etc. The main finding of Felbermayr et al. (2020) is that the effects of the WTO on the exports of its members have been widely heterogeneous. An important implication of this result is that the average estimates of the effects of various policies that are obtained standardly with the gravity model may mask significant cross-country variation. The use of domestic trade flows to obtain heterogeneous partial equilibrium policy estimates also has two broader implications. First, the heterogeneous partial effects would translate into corresponding welfare effects that are also heterogeneous. An immediate policy implication is that, for example, in response to trade liberalization certain EU members may benefit less than others which, in turn, may increase inequality and motivate transfer payments within the European Union. Second, from a methodological perspective, the full

distribution of country-specific policy estimates that are obtained from the gravity model can be used as the dependent variable in a second-stage analysis that studies the reasons for and the determinants of the heterogeneous policy effects.

# 4 Implications for Solving Some Prominent Puzzles

Proper account for domestic trade flows and domestic trade costs has led to solutions of several puzzles from the international economics literature, including: (i) *"The Distance Puzzle of Trade"*, (ii) *"The Missing Globalization Puzzle"*, (iii) *"The Puzzle that Larger Countries Should Be Richer than Smaller Countries"*, and (iv) *"The puzzle of the Missing WTO Effects"*.

One of the most prominent mysteries in the trade literature, known as *"The Distance Puzzle of Trade"*, is that despite significant improvements in transportation and communication, the estimated effects of physical distance on international trade flows have remained constant over time. In an influential meta-analysis project, Disdier and Head (2008) investigate the trends in the variation of 1,467 estimates of the effects of distance on trade within the gravity model from 103 papers to conclude that *"the estimated negative impact of distance on trade rose around the middle of the century and has remained persistently high since then."*(p. 37).[17]

Recognizing that the structural gravity model can only identify *relative* trade costs, Yotov (2012) argues that the impact of distance on international trade should be measured relative to the change in domestic trade costs and demonstrates that, once this is done, the distance puzzle disappears.

***Reason 12:*** *The use of domestic trade flows leads to a solution to "The*

[17]A number of excellent papers provide alternative solutions and explanations for the distance puzzle. See, for example, Buch et al. (2004), Carrère and Schiff (2005), Brun et al. (2005), Boulhol and de Serres (2010), Lin and Sim (2012), Carrère et al. (2013), Larch et al. (2016).

*Distance Puzzle of International Trade".*

The main idea of Yotov (2012) is that, assuming that the effects of improved transportation and communication have been spread relatively evenly in the world, studies that use only international trade flows cannot identify the diminishing impact of distance on international trade costs because this impact is identified relative to other international trade costs, which at the same time are also decreasing. Therefore, he argues that the effects of distance on international trade costs in structural gravity models should be measured relative to domestic trade costs. Mechanically, the simple (but theory-consistent) adjustment that Yotov (2012) proposes is to estimate the gravity equation with domestic, in addition to international, trade flows. Once this is done, the *"Distance Puzzle"* is solved, i.e., the gravity estimates of the negative impact of distance on trade is decreasing steadily over time.[18]

Bhavnani et al. (2002) define the *"Missing Globalization Puzzle"* as *"the failure of declining trade-related costs to be reflected in estimates of the standard gravity model of bilateral trade"* (p.1). The same authors conclude that *"globalization is everywhere but in estimated gravity models"* (p.3). Extending the analysis of Yotov (2012), Bergstrand et al. (2015) demonstrate that when estimations are performed with the use of domestic trade flows, the gravity model of trade is in fact well-suited to capture globalization effects.

***Reason 13:*** *The use of domestic trade flows allows for solving "The Missing Globalization Puzzle".*

To account for the impact of globalization, Bergstrand et al. (2015) specify an

[18]The decreasing estimates of the distance effects are robust to a number of sensitivity experiments, including alternative solutions to the distance puzzle. More recently, Borchert et al. (2020b) extend the analysis of Yotov (2012) to demonstrate that the use of domestic trade flows resolves the distance puzzle with more rigorous specification of domestic trade costs, while Anderson and Yotov (2020) provide theoretical foundations for the solution of the distance puzzle.

empirical gravity model that includes domestic trade flows, and where the effects of globalization are captured by a series of time-varying indicator variables for international borders, i.e., dummy variables that take a value of one for international trade and are equal to zero for domestic trade in each year. The idea is to capture the evolution of international borders over time. The main finding of Bergstrand et al. (2015) is that the impact of international borders has fallen steadily over time. Thus, the *'The Missing Globalization Puzzle"* is solved. An important policy implication of the analysis of Bergstrand et al. (2015) is that if the common globalization trends and effects are not properly accounted for in gravity regressions, then the effects of FTAs and other policy variables may be over-predicted. Anderson and Yotov (2020) build a short-run gravity model that offers a theoretical foundation for the solution of the *"The Missing Globalization Puzzle"*, and conclude that globalization was in fact always present in the gravity model, it was just hiding in the country-specific fixed effects that are standardly used in gravity estimations to account for the structural multilateral resistances.

As prominently noted by Ramondo et al. (2016), the presence of *'scale effects'* in innovation-led growth models (e.g., Jones (1995) and Kortum (1997)) as well as in new quantitative trade models, including the gravity model (e.g., Krugman (1980), Eaton and Kortum (2001) and Melitz (2003)), leads to the counterfactual implication that larger countries should be richer than smaller ones, and *"even though small countries tend to gain more from trade than large ones, these gains are not large enough to neutralize the underlying scale effects."* (p.1). Ramondo et al. (2016) demonstrate that when domestic trade frictions are properly accounted for, these counterfactual implications disappear.

***Reason 14:*** *The use of domestic trade flows allows for solving the puzzle*

*that "Larger Countries Should Be Richer than Smaller Countries".*

To solve this puzzle, Ramondo et al. (2016) challenge the standard treatment of domestic trade as frictionless and the assumption of countries being single point masses. Instead, they allow for domestic trade frictions by treating each country as a group of regions that face trade costs for trading with each other. The model generates economies of scale due to the assumption that technology levels are proportional to country size. However, the key innovation, i.e., the introduction of domestic trade frictions, mitigates these scale effects because the larger countries are composed of more regions and have larger domestic trade costs. In turn, the larger domestic trade costs work against the country size advantage and neutralize (at least part of) the scale effects. The main result from Ramondo et al. (2016) is that the introduction of domestic trade costs cuts in half the elasticity of productivity with respect to country size, thus getting closer to the data and resolving the puzzle that *"Larger Countries Should be Richer than Smaller Countries"*.

The World Trade Organization (WTO) and its predecessor, the General Agreement on Tariffs and Trade (GATT) are often referred to as the most successful international efforts to facilitate global trade. At the same time, in a seminal paper, Rose (2004) relies on a gravity model to argue that membership in the GATT/WTO is not associated with enhanced trade, and that there is no strong empirical evidence that the GATT/WTO has systematically played a strong role in encouraging trade. Thus, posing the puzzle of *"The Missing WTO Effects"*.[19] Larch et al. (2019) show that when gravity is estimated with domestic trade flows the puzzle is solved.

***Reason 15:*** *The use of domestic trade flows allows for solving the puzzle*

[19] A number of excellent papers have proposed different solutions to the puzzle of *"The Missing WTO Effects"*. For example, see Helpman et al. (2004), Subramanian and Wei (2007), Tomz et al. (2007), Eicher and Henn (2011), Chang and Lee (2011), Roy (2011), Dutt et al. (2013), Cheong et al. (2014), and, most recently, Esteve-Pérez et al. (2020).

*of "The Missing WTO Effects".*

To demonstrate the crucial role of domestic trade flows in resolving the puzzle, Larch et al. (2019) start the analysis with a specification that implements all recent developments in the empirical gravity literature except for using domestic trade flows.[20] Consistent with the main result of Rose (2004), the estimate of the impact of GATT/WTO is economically small and not statistically significant. The only difference in the main specification of Larch et al. (2019) is the introduction of domestic trade flows. Once domestic trade flows are properly accounted for, the estimate of GATT/WTO becomes positive, large, and highly statistically significant, thus solving the puzzle. Consistent with the results of Dai et al. (2014) regarding the trade diversion effects of FTAs, the explanation for the positive GATT/WTO effects is diversion from domestic sales. In addition to affecting the estimate of the impact of GATT/WTO on trade with other member countries, the introduction of domestic trade flows allows for identification of the non-discriminatory impact of GATT/WTO commitments, i.e., between member and non-member countries. Larch et al. (2019) find these effects to also be positive and statistically significant.

# 5 Concluding Remarks

The objective of this paper was to demonstrate the advantages of estimating structural gravity equations with domestic, in addition to international, trade flows. To this end, I reviewed the related literature and synthesized it into fifteen arguments in support of the use of domestic trade flows in the empirical gravity model. Even though our profession has already made significant progress to recognize and capitalize on some

[20]The gravity model is estimated with panel data, the PPML estimator, exporter-time fixed effects, importer-time fixed effects, and pair fixed effects. See Yotov et al. (2016) for discussion of best practices for gravity estimations.

of the benefits from using domestic trade, there is still room for improvements in the theoretical treatment of domestic trade flows as well as need for better datasets that combine consistently constructed international and domestic sales. In turn, such developments will open new avenues for empirical analysis and applications.

As argued in Section 1, the standard structural gravity model already incorporates domestic trade flows. Furthermore, as demonstrated in the subsequent sections, adhering more closely to theory has led to a number of empirical contributions. Despite this progress, there is still need and potential for theoretical contributions that explicitly take into account the fundamentally different nature in the 'gravitational pull' within countries vs. within regions vs. internationally. The heterogeneity in the pull of gravity (within Earth) has been documented in physics for a long time, e.g., Saxov (1952), and different methods have been proposed to model it. Yet, many international trade studies still treat countries as point masses with frictionless domestic trade. Better modeling and understanding of domestic trade costs, and especially of the structural links between domestic, regional, and international trade costs, should have at least two major implications for empirical analysis. First, this will lead to improvements in the quantification of the partial and GE effects of various domestic policies and their implications for trade, development, and welfare. Second, this will be particularly useful for (*ex ante* or *ex post*) analysis of the impact of regional policies, including Brexit, the possible Scottish separation, and the Catalan independence as some extreme examples.

Significant advances have already been made to develop a number of datasets that include domestic trade flows. Over time, these datasets have improved by covering longer time periods, more countries, more sectors, and more disaggregated industries. While further extensions across each of these dimensions would be very welcome, I believe that the most important dimension where the domestic trade data lags signif-

icantly behind the corresponding international trade data is the level of aggregation. Specifically, I expect large payoffs from the creation of very disaggregated (e.g., at the 6-digit HS level) domestic trade datasets for at least three reasons. First, availability of more disaggregated data will improve estimation efficiency. Second, some domestic policies with potential implications for international trade (e.g., antitrust decisions) are targeted and implemented at a very disaggregated level. Third, combined with the sectoral separability of the structural gravity model, availability of consistent data on international and domestic trade flows will enable general equilibrium analysis at the product level. Such analyses are missing in the literature, but may have significant policy implications as there is ample evidence that the GE policy effects are large.

The use of domestic trade flows has led to solutions to some prominent empirical puzzles, to re-evaluation of the effects of some bilateral trade policies, and to the ability to identify the impact of others. From an applied and policy perspective, I see several avenues for further contributions. First, a major implication from the use of domestic trade flows for gravity estimations is that, by capturing the diversion effects from domestic trade, this leads to larger estimates of the effects of FTAs and WTO membership. I expect that this result will apply more generally when the effects of any bilateral policy (e.g., sanctions) are re-evaluated with domestic trade flows. Second, the effects of many country-specific policies and characteristics, e.g., mega sporting events, have already been estimated with a-theoretical gravity specifications, i.e., without properly controlling for the structural MR terms. The use of domestic trade flows allows for re-evaluation of the effects of such policies within a theory-consistent empirical gravity model. Third, and probably most exciting and promising, the use of domestic trade flows allows for identification of the impact of policies that have not been studied within the structural gravity model. Production subsidies and various country-specific tax policies are just two prominent examples. Finally, I expect that

the development of better theories and improved datasets will open new research avenues and stimulate further empirical work.

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