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Structural gravity and trade agreements: Does the measurement of domestic trade matter?[☆]

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Economic theory suggests including domestic trade flows when estimating structural gravity models. The inclusion of domestic trade flows helps to identify parameters that cannot be estimated with international trade flows alone. The complication is that domestic trade flows can be measured empirically in different ways. Does it matter which one is used? We compare the three most common approaches to measuring domestic trade and show that they lead to very similar estimates of the parameters that are usually estimated within a structural gravity framework.

1. Introduction

In the past, gravity models have been estimated using data on international trade flows only, but a number of recent papers stress the importance of including intra-national (i.e., domestic) trade flows as well. Data on domestic trade allow to detect domestic-to-international trade diversion effects from trade agreements. As shown by Heid et al. (2021), they also enable the estimation of the effects of non-discriminatory trade policies, such as most favored nation (MFN) tariffs, which are otherwise collinear with various fixed effects usually included in the gravity equation. Finally, they are required as an input for the simulation of country-level gains from trade, for example, by using the formula by Arkolakis et al. (2012).[1]

Because there are no readily available internationally comparable statistics on domestic trade, economists are forced to choose between three approaches that are commonly used to construct domestic trade flows. The first approach consists in calculating domestic trade as the difference between GDP and total exports. In the second approach, domestic trade is obtained by subtracting total exports from total gross production, and the third approach uses information available in input–output tables.

In this paper, we answer the question of whether using these three alternative methods of calculating domestic trade influences the estimation of parameters related to trade policy in a typical structural gravity model.

2. Three methods to calculate domestic trade

Let X_{ij} denote bilateral gross trade flows from country i (the exporter) to country j (the importer). The special case $i = j$ identifies domestic trade flows. Domestic trade flows X_{ii} have been calculated in the literature in three possible ways.

GDP-based method

In the first method, domestic trade is calculated as the difference between GDP of the exporter and the sum of all its bilateral exports to the world $\sum_{j\neq i} X_{ij}$:

$$X_{ii} = GDP_i - \sum_{j\neq i} X_{ij}. \tag{1}$$

This method of constructing domestic trade flows has been used by Yotov (2012), El Dahrawy Sánchez-Albornoz and Timini (2021),

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[1] The various advantages of including domestic trade in the estimation of gravity equations are discussed at length by Yotov et al. (2016) and Yotov (2021).

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and Timini and Viani (2020), among others. The main advantage of using the GDP-based method is the wide country and time coverage. The main criticism is that GDP reports value added whereas trade flows are measured in gross terms.[2]

Production-based method

The second method obtains domestic trade as the difference between gross production in the exporting country $PROD_i$ and the sum of all its bilateral international exports $\sum_{j\neq i} X_{ij}$:

$$X_{ii} = PROD_i - \sum_{j\neq i} X_{ij}. \tag{2}$$

This approach has been used by, for example, Baier et al. (2019), Larch et al. (2019), Borchert et al. (2020), Felbermayr et al. (2020), and Timini et al. (2020). The advantage of this method is that both production and export data are reported in gross terms (instead of value added). Gross production data are also available for a wider set of countries and sectors than input–output tables—but are less prevalent than GDP. Moreover, gross production is usually directly reported in administrative datasets that involve no prior estimation steps.

Input–output tables

In the third method, domestic trade is a sum of elements taken directly from input–output tables. Domestic trade X_{ii} equals the sum of gross output sold by domestic industries to other domestic industries as intermediate input and domestic gross output sold to domestic final consumers.

This last approach has been recently used by Larch et al. (2018), Felbermayr et al. (2018), Felbermayr and Steininger (2019), among others. The main advantage of using input–output tables is that they directly report domestic transactions. However, they have often been "constructed" by resorting to estimation methods (Yotov, 2021). This last characteristic may render their use for further estimation (rather than simulation) questionable, as argued by Borchert et al. (2020). Also, input–output tables have the worst coverage across countries or years.

3. Empirical strategy

Structural gravity models are usually estimated using an equation of the form:

$$X_{ijt} = \exp(\delta_{it} + \gamma_{jt} + b_{ijt}) + \varepsilon_{ijt}. \tag{3}$$

The dependent variable X_{ijt} denotes gross nominal bilateral trade flows between country i and country j in year t. The variables δ_{it} and γ_{jt} are exporter-time and importer-time dummy variables. In trade theory, they account for multilateral trade resistances.[3] In the estimation, they absorb features that vary at the country-year level, such as GDP, per-capita GDP, population, etc. The variable b_{ijt} encloses all bilateral factors that either enhance of hinder trade, and ε_{ijt} is an error term.

In our specifications, bilateral trade factors b_{ijt} include both time-invariant and time-varying components. Among the time-invariant components, we include directional pair fixed effects, which address the endogeneity of trade policy in a flexible way, as done by Baier and Bergstrand (2007), while also allowing for asymmetric trade costs (Waugh, 2010). We focus on two time-varying trade policy variables: trade agreement indicators, whose coefficients measure the semi-elasticity of bilateral trade flows with respect to the presence of a trade agreement, and MFN tariff levels expressed as $\ln(1+\tau_{ijt})$. Tariffs on domestic trade flows are zero; for international trade flows they vary only by importer and year. As shown by Heid et al. (2021), non-discriminatory trade policies such as MFN tariffs can only be identified with domestic trade flows in a typical structural gravity setting.

As is standard in the literature, we estimate the gravity model using a Poisson pseudo-maximum likelihood (PPML) estimator (Santos Silva and Tenreyro, 2006).

Table 1
Co-movement of domestic trade measures across datasets.

	Data			Residuals		
	GDP	TIVA	WIOD	GDP	TIVA	WIOD
GDP	1.0000			1.0000		
TIVA	0.8125	1.0000		0.9172	1.0000	
WIOD	0.7784	0.8848	1.0000	0.9054	0.9403	1.0000

Notes: The table reports correlations between different measures of domestic trade flows. In the three columns on the left, correlations are computed on first-differenced log-levels of domestic trade flows. In the three columns on the right, correlations are calculated on the first-differenced residuals from a regression of log-trade flows from each dataset on exporter-year, importer-year, and exporter–importer dummy variables.

4. Data

4.1. Data sources

International trade data are from the OECD Trade in Value Added (TIVA) database and correspond to gross export values. Domestic trade flows are calculated as described in Section 2. Depending on the method, we use GDP data from the World Bank World Development Indicators (WDI), gross production data from the OECD TIVA database, and input–output table data from the World Input–Output Database (WIOD). For the sum of all bilateral trade, we rely on the precompiled statistics contained in the OECD TIVA database, namely exports of country i to "the world". In this way, we avoid potential biases arising from missing bilateral data. Finally, we use two main data sources for trade policy variables: we retrieve trade agreements from the 2017 version of the Baier–Bergstrand EIA database, whereas tariff levels are from the World Bank WDI.

The final sample is determined by the availability of domestic trade data according to the three alternative methods, i.e., by the overlap among the three different databases used in the computations (WDI for GDP, TIVA for gross production, and WIOD for input–output tables). Our sample covers 39 exporters and 63 importers over a 17-year period (1995–2011).[4]

4.2. Data description

The three methods of calculating domestic trade lead to noticeable differences in the data. In general, the GDP-based measure tends to deliver a higher level of domestic trade than the other two methods, and the TIVA and WIOD measures are more alike, also in their time-series properties. As is apparent from the left panel in Table 1, the correlation between log-growth rates of domestic trade in TIVA and WIOD, at 0.88, is roughly 10 points higher than the correlation of the GDP-based measure with each of the other two measures.

[2] Because GDP is a value-added measure, the difference between GDP and gross exports could yield a negative value for domestic trade. The usual solution to this problem is to either drop negative values, or to transform domestic trade data, so that the negative numbers are eliminated (for example, by interpolating positive values). Negative values do not arise in our sample with aggregate data, however.

[3] See Anderson and van Wincoop (2003) and Yotov et al. (2016) for a discussion on the merits of including multilateral trade resistance terms in the estimation.

[4] In the appendix we also report results from using a square subsample in which we remove all importers who are not in the set of exporting countries.

Table 2
Trade agreements.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
VARIABLES	w/o domestic trade	GDP	TIVA	WIOD	GDP	TIVA	WIOD
Without globalization trend							
TA (BB)	−0.0107	0.292***	0.280***	0.294***			
	(0.0437)	(0.0917)	(0.0784)	(0.0806)			
GSP					0.162*	0.140	0.153
					(0.0845)	(0.0864)	(0.0981)
PTA					0.423***	0.377***	0.394***
					(0.164)	(0.143)	(0.141)
FTA					0.235***	0.250***	0.262***
					(0.0603)	(0.0538)	(0.0577)
CU					0.692***	0.800***	0.880***
					(0.130)	(0.127)	(0.155)
CM					0.637***	0.689***	0.768***
					(0.108)	(0.110)	(0.117)
ECU					0.653***	0.779***	0.895***
					(0.123)	(0.125)	(0.129)
Observations	40,919	41,582	41,582	41,582	41,582	41,582	41,582
$\rho(X,\hat{X})^2$	0.997	1.000	1.000	1.000	1.000	1.000	1.000
With globalization trend							
TA (BB)		0.240***	0.186***	0.188***			
		(0.0679)	(0.0544)	(0.0538)			
GSP					0.174**	0.164***	0.179***
					(0.0685)	(0.0586)	(0.0656)
PTA					0.361***	0.246**	0.248**
					(0.128)	(0.106)	(0.101)
FTA					0.175***	0.147***	0.148***
					(0.0417)	(0.0346)	(0.0355)
CU					0.565***	0.577***	0.634***
					(0.0930)	(0.0858)	(0.0935)
CM					0.482***	0.433***	0.485***
					(0.101)	(0.0866)	(0.0940)
ECU					0.370**	0.306**	0.382***
					(0.153)	(0.126)	(0.132)
Observations		41,582	41,582	41,582	41,582	41,582	41,582
$\rho(X,\hat{X})^2$		1.000	1.000	1.000	1.000	1.000	1.000

Notes: Regressions estimated by PPML. Observations are indexed by exporter, importer, and year. The dependent variable is bilateral trade flows. The explanatory variables are dummy variables for any kind of trade agreement (TA (BB)) and for specific types of trade agreements in the Baier–Bergstrand database. Results in the lower panel (with globalization trend) add interactions of an international border dummy with year dummies to the specification. All specifications include exporter-year, importer-year, and exporter–importer dummy variables. The first column excludes observations with domestic trade. The remaining columns use domestic trade constructed according to the three methodologies described in the text. In the last line, $\rho(X,\hat{X})^2$ denotes the square of the correlation between the dependent variable and fitted values. Standard errors are reported in parentheses. They are clustered by exporter, importer, and year. The superscript *** indicates significance at the 1% level, ** at the 5% level, and * at the 10% level.

5. Results

5.1. Trade agreements

In Table 2 we exhibit the results from regressing trade flows on trade agreement dummy variables using the specification in (3). When domestic trade observations are excluded from the estimation, the average effect of a trade agreement on trade flows is economically insignificant and statistically not different from zero. In line with prior results by Dai et al. (2014), once domestic trade is included, the effect becomes larger and economically significant, capturing diversion from domestic to international trade.

The inclusion of domestic trade has a noticeable effect on the estimates but how they are calculated does not; the estimates in columns 2–4 are strikingly similar across computation methods. When we use the more granular specification shown in columns 5–7, we find larger impacts for certain types of trade agreement but again coefficients for the different computation methods are similar, and statistically indistinguishable.[5] In all cases, the confidence interval for any given computation method contains the point estimates of the other two. In the lower panel of Table 2 we add interactions of an international border dummy with year dummies to the specification, to take into account the potential effect of a world-wide common globalization trend. The ability to do so is one of the advantages of using domestic trade flows. As expected (Bergstrand et al., 2015), the estimated impact of trade agreements is generally lower when this variable is added, given that it absorbs common globalization patterns.[6] The three methods deliver estimates that are even closer than those obtained without a globalization trend.

The possible reason behind these similar results is that most of the differences in computation methods might be captured by the exporter-year, importer-year and exporter–importer dummy variables, which are prevalent in structural gravity estimations. To check this explanation, in the panel on the right of Table 1, we report the correlations of the first-differenced residuals from

[5] In the more granular classification, the trade agreements are classified into one-way preferential trade agreements (GSP), two-way preferential trade agreements (PTA), free trade agreements (FTA), customs unions (CU), common markets (CM), and economic unions (ECU).

[6] All three methods yield decreasing border effects over the period, as well as an increase in trade costs in recession years (2001–2002 and 2009). The GDP-based method yields a somewhat smaller estimate for the globalization trend whereas the other two methods roughly coincide. For example, taking the first year of the sample, trade flows in 1995 were on average 24% lower than in 2011 according to the GDP-based measure, 35% lower according to TIVA, and 38% lower according to WIOD.

Table 3
MFN tariffs.

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	GDP	TIVA	WIOD	GDP	TIVA	WIOD
Without globalization trend						
TA (BB)	0.140***	0.103***	0.105***	0.129***	0.0970**	0.0967**
	(0.0456)	(0.0391)	(0.0399)	(0.0460)	(0.0401)	(0.0406)
MFN tariff	−8.558***	−10.68***	−11.48***			
	(2.781)	(1.773)	(1.897)			
MFN tariff (weighted)				−7.554***	−8.976***	−9.744***
				(2.058)	(1.195)	(1.206)
Observations	38,657	38,657	38,657	38,657	38,657	38,657
$\rho(X,\hat{X})^2$	1.000	1.000	1.000	1.000	1.000	1.000
With globalization trend						
TA (BB)	0.136***	0.100**	0.103**	0.118***	0.0921**	0.0943**
	(0.0438)	(0.0397)	(0.0403)	(0.0428)	(0.0403)	(0.0405)
MFN tariff	−11.53***	−9.990***	−9.921***			
	(2.841)	(2.111)	(2.046)			
MFN tariff (weighted)				−11.39***	−9.031***	−9.081***
				(1.974)	(1.506)	(1.459)
Observations	38,657	38,657	38,657	38,657	38,657	38,657
$\rho(X,\hat{X})^2$	1.000	1.000	1.000	1.000	1.000	1.000

Notes: Regressions estimated by PPML. Observations are indexed by exporter, importer, and year. The dependent variable is bilateral trade flows. The explanatory variables are dummy variables for any kind of trade agreement (TA (BB)) from the Baier–Bergstrand database and the natural logarithm of $(1+\tau)$ where τ is the tariff rate in a given year. We report results for average tariffs (simple mean) and for tariffs weighted by the product import share of each importer. Results in the lower panel (with globalization trend) add interactions of an international border dummy with year dummies to the specification. All specifications include exporter-year, importer-year, and exporter–importer dummy variables. The different columns use domestic trade constructed according to the three methodologies described in the text. Standard errors are reported in parentheses. They are clustered by exporter, importer, and year. In the last line, $\rho(X,\hat{X})^2$ denotes the square of the correlation between the dependent variable and fitted values. The superscript *** indicates significance at the 1% level, ** at the 5% level, and * at the 10% level.

a regression of log-trade flows from each dataset on exporter-year, importer-year and exporter–importer dummy variables. The correlations between these residuals exceed 0.90 in all cases, indicating that the remaining variation in the three datasets becomes very similar after purging the various fixed effects.

5.2. MFN tariffs

Table 3 shows the estimated effect of MFN tariffs on trade flows with domestic trade calculated according to the different methods. In columns 1–3 we report the results from using a country-level tariff rate calculated as a simple average over products and in columns 4–6 those from using an average weighted by product share.

Without the inclusion of a common globalization trend, the GDP-based measure delivers the lowest point estimates for the magnitude of the elasticity, followed by TIVA, and WIOD delivers the highest estimates. As shown in the lower panel of the table, adding interactions of international border and year dummies increases the elasticity estimated from the GDP-based measure and decreases the other two. Overall, point estimates for TIVA, and WIOD are statistically indistinguishable in all specifications. The point estimate for the GDP-based method, on the other hand, falls outside of the confidence intervals of the other two methods in some cases. In particular, this occurs when the MFN tariff rate is computed as a weighted average, leading to an increased precision of the estimates.

5.3. Gravity variables

To compare the estimates of the most-widely used gravity variables, we estimate a specification in which we remove pair fixed effects and include standard gravity variables instead. We also include the international border dummy variable. Results are shown in the online appendix. The results for the distance variable is remarkably similar across approaches, ranging between −0.930 and -0.938. The international border effect varies across methods; it is larger for the GDP-based approach than for the other two methods, which are fairly similar to each other. Moreover, when estimating differential international border effects by year, we find that the world-wide common globalization trend estimated in this way is smaller for the GDP-based approach than for the other two methods.

5.4. Sectoral data

We also estimate the impact of trade agreements separately on trade flows of agricultural goods, manufactured goods, and services. Results are shown in the online appendix. We find that point estimates are almost identical across sectors when the globalization trend is not included. Including a globalization trend reduces the point estimate of trade agreements in the case of the GDP-based method relative to the other two, although estimates cannot be distinguished in the statistical sense.[7]

5.5. Additional results

When trade data are used in general equilibrium models, the database usually needs to be perfectly square (i.e., the sets of importers and exporters need to coincide). In the online appendix we report results from estimations that use a database in which we remove all importers that do not also show up as exporters, leading to a database of 39 by 39 countries.[8] Again, results for trade agreements are remarkably similar across methods.

Finally, in a prior working paper version (Campos et al., 2021), we conduct an additional exercise in which we translate the

[7] The effect of economic unions (ECU) on service trade is an exception. This result may be relevant for research on the effects of deep economic integration on service trade.

[8] The number of observations in this 39-country square database spanning 17 years is $39 \times 39 \times 17 = 25{,}587$.

differences in estimates into a welfare measure using the formula by Arkolakis et al. (2012). To obtain the largest possible impact, we compute the welfare impact from eliminating all trade agreements in the world, using estimated trade impacts and trade elasticities appropriate for each of the three computations of domestic trade. Results do not differ much for the median country. We calculate that removing all trade agreements would reduce welfare in the median country by 1.47% in the GDP-based measure and by 1.09% and 1.15%, respectively, in the TIVA and WIOD-based measures.

6. Concluding remarks

In the comparison of three different ways of measuring domestic trade flows, we find that the estimates for the partial effect of trade agreements on trade flows are very close to each other. The intuitive reason of why this happens is that the collection of exporter-year, importer-year and country pair dummy variables common in gravity equations is effective in eliminating differences across methods. This result is encouraging for applied research, because it suggests that conclusions are robust to the use of different datasets. In particular, our results imply that domestic trade measures based on GDP, which is more widely available than measures that are preferable in theory, are an acceptable alternative to estimate the effect of trade agreements on trade flows.

In conclusion, what matters primarily when estimating the impact of trade agreements, is the inclusion of domestic trade flows, and not the way in which domestic trade is measured.

Appendix A. Supplementary data

Supplementary material related to this article can be found online at https://doi.org/10.1016/j.econlet.2021.110080.

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