The Gravity Model of Trade

Often referred as the “workhorse” of international trade, the gravity model is prominent in the empirical literature of applied international trade analysis. Among the arguments that could explain/support the use of the gravity model, there are four that are particularly relevant for our purposes. First, the gravity model of trade is intuitive to understand. Following the metaphor of Newton’s Law of Universal Gravitation, it predicts that international trade between two countries is directly proportional to the product of their economic size, and inversely proportional to trade frictions between them. In simpler words, the bigger (smaller) the economies of two countries, and the easier (harder) it is for them to trade with each other, the more (less) we expect them to trade. Second, it is referred to as a structural model with solid theoretical foundations, which makes it appropriate for counterfactual analysis, such as measuring the effects of trade policies as we aim to do with the effects of South-North versus South-South agreements. Third, model has a flexible structure, which will allow us to construct a specification tailored to our research. Finally, fourth, it holds consistent and remarkable predictive power, both with aggregate and sectoral data (Yotov *et al.*, 2016).

Through the decades, the gravity equation has been regularly upgraded in the theoretical and empirical literature. Of relevance, the simple intuition of the gravity model was theoretically extended by Anderson to note that, after controlling for size, the increase or decrease is *relative* to the average barriers of the two countries with all their partners, which are referred as “multilateral resistance” (Anderson, 1979). The more trade barriers or resistance to trade exists with other countries relative to a given partner, the more a country is pushed to trade with said partner. Anderson also introduced the assumptions of product differentiation by place of origin, and Constant Elasticity of Substitution (CES) expenditures ,or the Armington-CES assumption (Yotov *et al.*, 2016; Chatzilazarou and Dadakas, 2023), which led us to today’s generalized form of the gravity equation, as developed and popularised by Anderson and van Wincoop (Anderson and van Wincoop, 2003).

Do I need to add more on the theory underlying the Gravity Models of Trade?

Equally important, several empirical developments have strengthened the gravity model and inform our choice of methodology: Exporter-time and importer-time fixed effects are used to account for the multilateral resistance terms in a gravity estimation with panel data (Olivero and Yotov, 2012); As the gravity model is often estimated with an OSL estimator, zero-trade flows were dropped from the sample when trade was transformed into a logarithmic form. Also, trade data is recognized to suffer from heteroscedasticity (Yotov *et al.*, 2016). To solve for zero-trade flows and heteroscedasticity, the Poisson Pseudo Maximum Likelihood (PPML) estimator has been proposed to estimate the gravity model, avoiding potential biases (Silva and Tenreyro, 2006; Santos Silva and Tenreyro, 2011); Country-pair fixed effects has been proposed to account for the unobserved endogeneity of trade policy (Baier and Bergstrand, 2007). It is worth nothing that the inclusion of exporter-time and importer-time fixed effects will absorb all observable and unobservable time-varying country-specific characteristics that could affect the dependent variable, while the country-pair fixed effects will absorb observable and unobservable bilateral time-invariant characteristics that could affect trade costs; The inclusion of intra-trade flows as well as international trade flows is proposed to correctly estimate the effects of non-discriminatory trade policy, allowing for consumers to choose products from both international and domestic sources (Dai, Yotov and Zylkin, 2014; Heid, Larch and Yotov, 2017); Year-intervals instead of data pooled over consecutive years should be used to allow for adjustment of trade flows to policies that might not have immediate effects (Baier and Bergstrand, 2007; Anderson and Yotov, 2016); And finally, to account for the effects of globalization forces that may biased the estimates of trade policies, a set of globalization dummies are recommended to control for the effects of globalization in the gravity model (Yotov, 2012; Bergstrand, Larch and Yotov, 2015). Based on the theoretical and empirical best-practices found in the relevant literature, we employ the following gravity equation using a PPML estimator and a balanced panel data approach with multiple exporters, multiple importers and time as our benchmark model:

Where denotes the value of exports from an origin country to a destination country ; and are, respectively, exporter-time and importer-time fixed-effects; is a country-pair fixed-effect; and are our main variables of interest, which, respectively indicate if and are members of a PTA at time and, to account for potential “phase-in” effects over time of the PTA, at time ; is a set of dummies that equal 1 for international trade and 0 for domestic trade observations at each time ; and is an error term.

In contrast with our main interest of research, which are the potential heterogenous effects of PTAs on different members for different types of agreements, this benchmark model, specifically , would provide the average “total” partial effect of PTAs on trade after accounting for lagged effects, but it cannot provide the effects for a given agreement, country-pairs o specific country members to a specific agreement. As such, three successive expansions can be implemented to capture heterogeneity in PTA effects as proposed by Baier *et al*. (Baier, Yotov and Zylkin, 2019):

Equation (2) can be implemented to account for heterogeneous effects of PTAs at the level of the specific agreement, by allowing for distinct average partial effects for each individual agreement, using superscript to index by agreement and also allowing for agreement-specific lags: .

Equation (3) can be implemented to account for heterogeneous effects at the level of each country-pair within a specific agreement, by allowing each to denote a pair of countries which are members to an agreement , and treating and as the same pair. We get a set of agreement-country pairs specific estimates:

Finally, equation (4) can be implemented to account for heterogeneous effects at the level of each country within a country-pair member to a specific agreement, by allowing to denote direction-specific unique country-pairs ) which are members to an agreement , and treating ) only as the effect on trade flows where is the exporter and is the importer, which gives us two estimates for each country-pair, one for each direction. We also add an “asymmetric” country- pair fixed effect , also varying with each direction. The set of unique direction-specific estimates are given by .

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**Extended Benchmark Model with PTA Types**

You want to modify the benchmark model to allow for different types of PTAs (NN, NS, SS) while still keeping the same overall structure. Here’s how you can adjust the model:

**Equation (1) with PTA Types:**

(3)     Xij,t=exp⁡(ηi,t+ψj,t+γij+β1,NNPTA\_NNij,t+β2,NNPTA\_NNij,t−5+β1,NSPTA\_NSij,t+β2,NSPTA\_NSij,t−5+β1,SSPTA\_SSij,t+β2,SSPTA\_SSij,t−5+∑tbt)+ϵij,t(3)\ \ \ \ \ X\_{ij,t}=\exp(\eta\_{i,t}+\psi\_{j,t}+\gamma\_{ij}+\beta\_{1,NN}{PTA\\_NN}\_{ij,t} + \beta\_{2,NN}{PTA\\_NN}\_{ij,t-5} + \beta\_{1,NS}{PTA\\_NS}\_{ij,t} + \beta\_{2,NS}{PTA\\_NS}\_{ij,t-5} + \beta\_{1,SS}{PTA\\_SS}\_{ij,t} + \beta\_{2,SS}{PTA\\_SS}\_{ij,t-5} + \sum\_{t} b\_t)+\epsilon\_{ij,t}(3)     Xij,t​=exp(ηi,t​+ψj,t​+γij​+β1,NN​PTA\_NNij,t​+β2,NN​PTA\_NNij,t−5​+β1,NS​PTA\_NSij,t​+β2,NS​PTA\_NSij,t−5​+β1,SS​PTA\_SSij,t​+β2,SS​PTA\_SSij,t−5​+t∑​bt​)+ϵij,t​

In this equation:

* β1,NN\beta\_{1,NN}β1,NN​ and β2,NN\beta\_{2,NN}β2,NN​ are the coefficients for NN PTAs at time ttt and t−5t-5t−5, respectively.
* β1,NS\beta\_{1,NS}β1,NS​ and β2,NS\beta\_{2,NS}β2,NS​ are the coefficients for NS PTAs at time ttt and t−5t-5t−5, respectively.
* β1,SS\beta\_{1,SS}β1,SS​ and β2,SS\beta\_{2,SS}β2,SS​ are the coefficients for SS PTAs at time ttt and t−5t-5t−5, respectively.
* PTA\_NNij,t{PTA\\_NN}\_{ij,t}PTA\_NNij,t​, PTA\_NSij,t{PTA\\_NS}\_{ij,t}PTA\_NSij,t​, and PTA\_SSij,t{PTA\\_SS}\_{ij,t}PTA\_SSij,t​ indicate whether the trade pair ijijij is participating in a NN, NS, or SS PTA at time ttt, respectively.

**Extended Model with PTA Heterogeneity and Types**

Next, you want to extend the model allowing for PTA heterogeneity to also distinguish between different types of PTAs.

**Equation (2) with PTA Types:**

(4)     Xij,t=exp⁡(ηi,t+ψj,t+γij+∑A(β1,A,NNPTA\_NNij,t+β2,A,NNPTA\_NNij,t−5)+∑A(β1,A,NSPTA\_NSij,t+β2,A,NSPTA\_NSij,t−5)+∑A(β1,A,SSPTA\_SSij,t+β2,A,SSPTA\_SSij,t−5)+∑tbt)+ϵij,t(4)\ \ \ \ \ X\_{ij,t}=\exp(\eta\_{i,t}+\psi\_{j,t}+\gamma\_{ij}+\sum\_{A}\left(\beta\_{1,A,NN}{PTA\\_NN}\_{ij,t} + \beta\_{2,A,NN}{PTA\\_NN}\_{ij,t-5}\right) + \sum\_{A}\left(\beta\_{1,A,NS}{PTA\\_NS}\_{ij,t} + \beta\_{2,A,NS}{PTA\\_NS}\_{ij,t-5}\right) + \sum\_{A}\left(\beta\_{1,A,SS}{PTA\\_SS}\_{ij,t} + \beta\_{2,A,SS}{PTA\\_SS}\_{ij,t-5}\right) + \sum\_{t} b\_t)+\epsilon\_{ij,t}(4)     Xij,t​=exp(ηi,t​+ψj,t​+γij​+A∑​(β1,A,NN​PTA\_NNij,t​+β2,A,NN​PTA\_NNij,t−5​)+A∑​(β1,A,NS​PTA\_NSij,t​+β2,A,NS​PTA\_NSij,t−5​)+A∑​(β1,A,SS​PTA\_SSij,t​+β2,A,SS​PTA\_SSij,t−5​)+t∑​bt​)+ϵij,t​

In this model:

* β1,A,NN\beta\_{1,A,NN}β1,A,NN​ and β2,A,NN\beta\_{2,A,NN}β2,A,NN​ are the coefficients for NN PTAs for a specific agreement AAA at time ttt and t−5t-5t−5, respectively.
* β1,A,NS\beta\_{1,A,NS}β1,A,NS​ and β2,A,NS\beta\_{2,A,NS}β2,A,NS​ are the coefficients for NS PTAs for a specific agreement AAA at time ttt and t−5t-5t−5, respectively.
* β1,A,SS\beta\_{1,A,SS}β1,A,SS​ and β2,A,SS\beta\_{2,A,SS}β2,A,SS​ are the coefficients for SS PTAs for a specific agreement AAA at time ttt and t−5t-5t−5, respectively.

**Variables:**

1. **PTA\_NN**: Dummy variable that takes the value of 1 if the trade pair ijijij is part of a North-North PTA at time ttt, and 0 otherwise.
2. **PTA\_NN\_{t-5}**: Dummy variable that takes the value of 1 if the trade pair ijijij was part of a North-North PTA at time t−5t-5t−5, and 0 otherwise.
3. **PTA\_NS**: Dummy variable that takes the value of 1 if the trade pair ijijij is part of a North-South PTA at time ttt, and 0 otherwise.
4. **PTA\_NS\_{t-5}**: Dummy variable that takes the value of 1 if the trade pair ijijij was part of a North-South PTA at time t−5t-5t−5, and 0 otherwise.
5. **PTA\_SS**: Dummy variable that takes the value of 1 if the trade pair ijijij is part of a South-South PTA at time ttt, and 0 otherwise.
6. **PTA\_SS\_{t-5}**: Dummy variable that takes the value of 1 if the trade pair ijijij was part of a South-South PTA at time t−5t-5t−5, and 0 otherwise.

These models allow you to capture the differentiated impacts of PTAs depending on whether they are between two developed countries (NN), between a developed and a developing country (NS), or between two developing countries (SS).

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