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A MONTECARLO EXPERIMENT**

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A NOTE ON DUMMIES FOR POLICIES IN GRAVITY MODELS: A MONTECARLO EXPERIMENT

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ABSTRACT

The use of the gravity model to evaluate the effect of policies in a cross-country framework is largely predominant in the international economics empirical literature. This literature usually implements importer and exporter fixed effects to account for the theoretical Multilateral Trade Resistances, while preferential trade policies are approximated through the use of dummy variables. Results from a Monte Carlo experiment confirms that the identification of trade policy impact using a gravity equation including fixed effects is severely limited. Moreover, the consequences of the error in measurement of the policy variable are magnified by the fixed effects control for unobserved heterogeneity.

Keywords : Gravity model, Policy evaluation, Monte Carlo Analysis

JEL Classification : C130; C140; F100, F430

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1. Introduction

The ‘structural’ gravity model (Anderson and van Wincoop, 2003) includes multilateral resistance terms (MRT) capturing the basic intuition that what really matters for international trade are relative (rather than absolute) bilateral trade costs. It is common practice to approximate MRT using country (exporter and importer) dummies, that also take care of exogeneity and unobserved heterogeneity (omitted variables) problems, replacing the theoretically appropriate variable capturing country size and bilateral and multilateral resistance (Feenstra, 2004; Baldwin and Taglioni, 2006).

A large body of literature has used the gravity model to assess the impact of trade policies using a dyadic dummy as a proxy for preferential trade agreements (PTA) (e.g., taking the value 1 if the two countries share a common PTA). However, since most trade policies are continuous (e.g. tariffs, preference margins), gravity type models using policy dummies are misspecified due to a nonclassical error in variable, leading to improper econometric inference (Måtyàs, 1997).

In this paper, we set up a Monte Carlo simulation analysis that allows to assess the consequences of the “PTA as a dummy” specification on the estimation of the policy impact. We argue that in such a case the identification of trade policy effects using a gravity equation that includes fixed effects to control for MRT is severely limited: the more we control for unobserved heterogeneity, the less we are able to correctly estimate the policy effect of interest. More specifically, we consider the interaction between the “PTA as a dummy” and the strategy of dismantling unobserved heterogeneity by MRT fixed effects. On the one hand, we confirm that the magnitude and significance of the policy dummy become very sensitive to the specification of the gravity equation and the regression tends to overestimate the impact of the policy. On the other hand, we show that the MRT fixed effects strategy to account for unobserved heterogeneity, is often inappropriate, exacerbating the effects of the measurement error in the policy variable.

2. The Monte Carlo Simulation

2.1 The Anderson-van Wincoop Gravity Equation

Following Anderson and van Wincoop (2003) we define bilateral trade, at sectoral level k , between country i and j at time t , as:

$$X_{i,j,t}^k = \frac{E_{j,t}^k Y_{i,t}^k}{Y_t^k} \left(\frac{T_{i,j,t}^k}{P_{j,t}^k \Pi_{i,t}^k} \right)^{1-\sigma_k} \quad (1)$$

where Y_i^k / Y^k is the exporting country i 's share of the world's sales of goods class k ; E_j^k / Y^k is the importing country j 's share of the world spending on k ; $\sigma_k > 1$ is the elasticity of substitution across goods in k ; $P_j^k \Pi_i^k$ are the MRT and $T_{i,j,t}^k$ is the trade cost, depending on commercial policy, and geographical and economic distance (i.e. common border, language, colony).

Regarding the policy component of the trade cost, we define the preference margin ($pref_{ij,t}^k > 1$) as the ratio between the Most Favourite Nation (MFN) applied tariff factor ($1 + M_{j,t}^k$) and the actual duty paid by each exporter ($1 + \tau_{i,j,t}^k$). The trade cost is a negative function of the preference margin: higher preferences decrease trade cost and, thus, reduce the negative trade impact of bilateral tariffs (Cipollina and Salvatici, 2010).

Working at a (highly disaggregated) sectoral level k usually implies the presence of many zero trade flows, creating obvious problems if the gravity equation is expressed in a log-linear

form. Using a Poisson fixed effects estimator to address the issues of heteroskedasticity and zeroes in bilateral trade flows (Santos Silva and Tenreyro, 2006),¹ the econometric specification of the gravity equation (1) is:

$$X_{i,j,t}^k = \exp\{\beta_1 \ln E_{j,t}^k + \beta_2 \ln Y_{i,t}^k - \beta_3 \ln Y_t^k + (1 - \sigma_k)[\beta_4 \text{border}_{i,j} + \beta_5 \text{lang}_{ij} + \beta_6 \text{colony}_{ij} + \beta_7 \text{dist}_{ij} - \ln \text{pref}_{i,j,t} - \ln P_{j,t} - \ln \Pi_{i,t}]\} + \varepsilon_{ij,t}^k \quad (2)$$

where the continuous policy variable can be eventually replaced by the dummy $\text{dummypref}_{i,j,t}^k$ assuming value “1” when time $M_{j,t}^k > \tau_{i,j,t}^k$.

The objectives of the Monte Carlo study are twofold. On the one hand, we investigate the interaction between the policy measurement and the MRT modelled as a set of exporter and importer fixed effects. On the other hand, we quantify the consequences of the errors in measurement of the trade policy due to the replacement of a continuous variable with a dichotomous one. Results show that in such a case fixed effects are not suited to take into account unobserved heterogeneity of the MRT, since they also capture part of the heterogeneity of the policy variable.

2.2 The data-generating process

The setup of the Monte Carlo simulation comprises 26 industrial sectors (ISIC Revision 2 Classification), 12 countries importing from 46 exporters, over the period 2001–2005. The dataset is built on information provided by the TradeProd and the GeoDist Cepii databases (<http://www.cepii.fr/>) on production, expenditure, distances between countries and dummies for contiguity, common language, and former colonial links. We then implement a data-generating-process, replicated 10,000 times. First, from the initial dataset we randomly select a sample of 2 importer countries, 10 products and 10 exporter countries during a period of 5 years, in order to get a dataset containing 1,000 observations, a number of observations easily manageable in regressions with the full set of dummies. Second, we generate the following normally-distributed random variables: $M_{j,t}^k, \tau_{i,j,t}^k, P_{j,t}^k, \Pi_{i,t}^k$. Third, we define residuals along the lines of a remark by Rose (2004), pointing out that residuals cannot be randomly generated since they are expected to show dependency across time (bilateral trade flows in one year has something to do with the same flows in the previous period), and countries (imports from one exporter have something to do with imports from other exporters):

$$\varepsilon_{ij,t}^k = e_j + e_i + e_{ij} + e_t + e_{it} + e_{jt} + e_{ijt} + e^k + e_i^k + e_j^k + e_{ij}^k + e_t^k + e_{i,t}^k + e_{j,t}^k + e_{ij,t}^k \quad (3)$$

where each e is normally-distributed randomly generated.

Finally, we generate the bilateral trade flows at the sectoral level k between country i and j at time t ($X_{i,j,t}^k$)⁰ using the following specification:

$$(X_{i,j,t}^k)^0 = \exp\{\beta_1 \ln E_{j,t}^k + \beta_2 \ln Y_{i,t}^k - \beta_3 \ln Y_t^k + \gamma_1 \text{border}_{i,j} + \gamma_2 \text{lang}_{ij} + \gamma_3 \text{colony}_{ij} + \gamma_4 \text{dist}_{ij} + \sigma_k - \ln \text{pref}_{i,j,t} + \sigma_k - 1(\ln P_{j,t} - \ln \Pi_{i,t})\} + \varepsilon_{ij,t}^k \quad (4)$$

¹ There is quite a lively debate about the ‘zero problem’ in gravity models (De Benedictis and Taglioni, 2011; Head and Mayer, 2013), see also Martin and Pham (2008) and Xiong and Chen (2012) on using different nonlinear estimators in Monte Carlo simulations.

where $X_{ij,t}^k = (X_{ij,t}^k)^0$ if $(X_{ij,t}^k)^0 \geq 0$; $X_{ij,t}^k = 0$ if $(X_{ij,t}^k)^0 < 0$.

Zero trade flows cover around the 40% of the total sample, consistently with the percentage of zero values generally observed in actual sectoral data. All coefficients are set to 1 for simplicity. The elasticity of substitution, σ_k , is fixed to 8, a value within the range of the estimates included in the survey by Anderson and van Wincoop (2004).

We estimate the model in eq. (4) using either the continuous ($pref_{ij,t}^k$) or the dichotomous ($dummpref_{ij,t}^k$) policy variable (Table 1). Moreover, we implement the following fixed effect specification:

$$X_{ij,t}^k = \exp[\gamma_1 border_{ij} + \gamma_2 lang_{ij} + \gamma_3 colony_{ij} + \gamma_4 dist_{ij} + (\sigma_k - 1) \ln pref_{ij,t}^k + \eta_{i,t}^k + \theta_{j,t}^k] + \varepsilon_{ij,t}^k$$

$$\eta_{i,t}^k + \theta_{j,t}^k = \ln \left[\frac{E_{j,t}^k Y_{i,t}^k}{Y_t^k} (P_{j,t}^k \Pi_{i,t}^k)^{\sigma_k - 1} \right] \quad (5).$$

We apply different specifications, presenting partial articulations of the fixed effects structure. In all cases, all time variant variables are removed. Estimates are summarized in Table 2

3. Results

We replicate each regression 10,000 times using a Poisson fixed effects estimator with times dummies, getting the set of $\hat{\beta} = (\hat{\sigma}_k - 1)$ and standard errors, under the hypothesis of full information. All simulations results are combined and summarized in order to get an overall magnitude of the effect. The main outcome is an overall mean effect that it's not a simple average of the estimates in all the replications, giving more weight to simulations with more precise estimates. Our strategy is to collect all estimates and account for heterogeneity using a random effect (MA-RE) model in the spirit of the Meta-analysis literature (Stanley and Jarrell, 2005).²

Descriptive statistics of the estimated $\hat{\beta}$ are reported in Table 1. As expected, the estimated coefficients coincide with the ones assumed in the data-generating process. So, coherently to our setting, in column 1 the estimated coefficient of the variable $\ln(pref_{ij,t}^k)$ implies an elasticity of substitution of around 8 ($\sigma = 6.93 + 1$). The estimated elasticities range from 4.03 to 8.27.

Table 1
Meta-Analysis Random Effect (MA-RE): Benchmark Results.

	$\ln(pref_{ij,t}^k)$	$dummpref_{ij,t}^k$
Mean	6.93***	2.35***
Min	3.03***	-3.44**
Max	7.27***	9.14***

Notes: Dependent variable: $X_{ij,t}^k$. Poisson Fixed-effect Model with time dummies. Simulations with 10,000 replications. *** significant at 1%; ** 5%; * 10%

² The MA-random effect (MA-RE) computes the single “true” effect as the weighted average of the Monte Carlo results with weights incorporating an estimate of the between-regression heterogeneity (Higgins and Thompson, 2002). Given the high heterogeneity of our results, such a choice was preferred to the MA-fixed effect model, where the weights are inversely proportional to the square of the standard errors of various estimates.

In order to shed some lights on the capability of the dummy variable to proxy the effect of policy,³ we re-run eq. 5 including $dummypref_{ij,t}^k$ instead of $\ln(pref_{ij,t}^k)$. In column 2 of Table 1 we show the descriptive statistics of the estimated impact of the preference dummy. The results obtained in our simulations are far from the true value and vary widely, from -3.44 to 9.14.

In Table 2, Model 1 shows that the omission of MRT leads to inconsistent estimates. The estimated coefficients are higher on average, but the most striking result is the much wider range (from -0.13 to 36.11) of significant estimates implying a large under/overestimation of the trade policy impact. In Model 2 and 3, we introduce exporter, importer and product fixed effects: results show that there is not much room for improvement if we don't take into account the time-varying dimension. As a matter of fact, the best results are obtained by Model 4 and 5: the average impact is closer to our benchmark, and the range of variation is greatly reduced introducing fixed effects interactions.

Table 2:
Meta-Analysis Random Effect (MA-RE): MRT Treatment

	Model 1	Model 2	Model 3	Model 4	Model 5
MA-RE with $\ln(pref_{ij,t}^k)$					
Mean	7.74 ^{***}	7.64 ^{***}	7.72 ^{***}	6.91 ^{***}	6.62 ^{***}
Min	-0.13 ^{**}	-0.00	-0.91 ^{***}	1.58 ^{**}	4.14 ^{***}
Max	36.11 ^{***}	29.93 ^{***}	33.98 ^{***}	15.24 ^{***}	8.73 ^{***}
with $dummypref_{ij,t}^k$					
Mean	3.58 ^{***}	2.03 ^{***}	2.61 ^{***}	1.96 ^{***}	1.46 ^{***}
Min	-3.03 ^{***}	-3.13 ^{***}	-2.77 ^{***}	-3.83 ^{***}	-4.77 ^{**}
Max	565.24	6.37 ^{***}	8.13 ^{***}	6.90 ^{***}	254.71
Time dummies	Yes	Yes	Yes		
Time-invariant FE					
Importer		Yes			
Exporter		Yes			
Product		Yes		Yes	
Importer*product			Yes		
Exporter*product			Yes		
Time-varying FE					
Importer*time				Yes	
Exporter*time				Yes	
Importer*product*time					Yes
Exporter*product*time					Yes

Notes: Dependent variable: $X_{i,j,t}^k$. Poisson Fixed-effect Model with time dummies. Simulations with 10,000 replications. *** significant at 1%; ** 5%; * 10%

³ To proxy for PTA, many contributions to the gravity literature use a “PTA as a dummy” specification. The use of this empirical strategy is in general not adequate because: (i) the PTA dummy also captures other factors that are specific to the country-pair and contemporaneous to the trade policy of interest; (ii) it does not discriminate among different policy instruments; (iii) it does not discriminate according to the level of trade barriers or the different PTA a country is part of (Cardamone, 2011). The quantitative survey by Cipollina and Pietrovito, (2011) shows that the results of the empirical analyses using a “PTA as a dummy” specification tend to overestimate the effect of the trade policy, relatively to the results obtained by the studies using some explicit measures of preference margins. The two different specifications are however not really comparable: the estimated coefficient of the “PTA as a dummy” refers to a level effect, while the one of the preference margin is an elasticity.

When we consider a “PTA as a dummy” specification of eq. 5, including $dummypref_{ij,t}^k$ instead of $\ln(pref_{ij,t}^k)$, it is confirmed that the omission of MRTs leads to an overestimation of the policy impact (Model 1). On the other hand, time invariant fixed effects (Model 2 and 3) appear to be quite effective in approximating the true value of the elasticity of substitution and in reducing the estimates variability. However, the most interesting result is that introducing time varying fixed effects (i.e. the common proxy for MRT) does not improve the accuracy of the estimate: the average impact is largely underestimated and introducing the full structure of time varying fixed effects (Model 5) greatly inflates the estimates range due to the presence of high collinearity.

4. Conclusions

This paper contributes to the literature pointing out that identification of trade policy effects with a gravity equation that includes dummies to control for the multilateral trade resistance terms is severely limited (Stack, 2009; Hornok, 2011). Our results confirm that omitting a crucial variable such as the multilateral resistance leads to an overestimation of the policy impact. Moreover, the more we control for country-product-time unobserved heterogeneity, the more the estimated parameter gets closer to the true (assumed) value.

This result however is not guaranteed if we associate a measurement problem to a omitted variables problem. As a matter of fact, if the continuous trade policy is proxied through dummies, a full-blown fixed effects specification severely limits the assessment of trade policy effects. In particular, this is the case when the time-varying dummies tend to be collinear with the policy variable of interest.

In conclusion, ignoring unobserved heterogeneity translates into biased estimates and an incorrect inference regarding the policy effect on trade. Potential bias can be alleviated when a full interaction effects design is used. However, if we proxy a policy variable with a dummy instead of a continuous one, the need to properly control for heterogeneity through a full interaction effect design could prevent us from evaluating trade policy effects greatly inflating the estimates range due to the presence of high collinearity.

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