Gravity Models of Trade: Unobserved Heterogeneity and Endogeneity

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Introduction and Some Motivations

- Traditional panel data involves two indexes, i and t, but data structure becomes increasingly complex and often goes beyond two dimensions in the index space.
- An obvious example is Gravity model where there are three indexes to represent export countries, import countries and time.
- The typical approach is to treat each (i, j) pair as an individual.
- Depending on the underlying assumptions of the unobserved heterogeneity, this approach is often sufficient.

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- Traditional panel data involves two indexes, i and t, but data structure becomes increasingly complex and often goes beyond two dimensions in the index space.
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- Depending on the underlying assumptions of the unobserved heterogeneity, this approach is often sufficient.
- BUT....

Gravity Model - Standard Approach

Consider the following specification:

$$y_{it} = X_{it}'\beta + \alpha_i + \lambda_t + u_{it}$$

- Dummy variables - the number of dummies grow very fast, especially in gravity model where we treat each pair as individual. The number of individual pairs is $N(N-1)$.
- Can apply transformations to eliminate the presence of α_i and λ_t. Not always possible and often involves taking difference of some sorts (losing information).
- Can treat α_i and λ_t as random variables but if either of them are correlated with X_{it} then least squares type estimator are inconsistent. Classic case of endogeneity.
- Can use Instrumental Variables
- BUT....

The Limitation of Standard Approaches

- External Instrumental Variables are often difficult to find and justified.
- Instrumental variables generated from within existing dataset often required certain rank conditions, see for example, Hausman and Taylor (1981) and Serlenga and Shin (2007).
- These rank conditions are often hard to meet if there are lots of time invariant explanatory variables, which is not unusual for Gravity type models.
- Standard approaches are also unable to distinguish the heterogeneity between export and import countries, since it treat each (i, j) pair as individual. Specifically, there is no existing technique to deal with the following specification:

$$y_{ijt} = X'_{ijt}\beta + \underbrace{\alpha_{ij} + \gamma_{it} + \lambda_{jt} + u_{ijt}}_{\nu_{ijt}}.$$

Second Order Moment

$$y_{ijt} = X_{ijt}'\beta + \underbrace{\alpha_{ij} + \gamma_{it} + \lambda_{jt} + u_{ijt}}_{\nu_{ijt}}.$$

- One way to deal with this is to consider a particular type of variance-covariance structure on ν_{ijt}, then derive a set of moment conditions to be used in GMM in such as way that avoid the problem of endogeneity (correlation between the unobserved components and the regressors).
- This can be done because endogeneity does not always cause problem. OLS explicitly assumes exogeneity because the proof of consistency requires it. However, it does not feature in the proof of consistency in GMM.
- The main argument in the proof requires the true parameter vector β_0 minimises the objective function uniquely, that is β_0 uniquely minimises $\mathbb{E}\left[g'(\beta)\Sigma^{-1}g(\beta)\right]$.
- Therefore, as long as we can show that is the case, then the estimator is still consistent in the presence of endogeneity.
- An example is IV, let $Y = X\beta + u$ and consider the moment condition $Z'u = 0$ for some variables Z, then $Z'\left(Y - X\hat{\beta}\right) = 0$ and $\hat{\beta} = \left(Z'X\right)^{-1}Z'Y$. In this case, endogeneity does not cause a problem!

Some Assumptions

A1. For every $i = 1, \ldots, N$, $\mathbb{E}(\alpha_{i\bullet}\alpha'_{i\bullet}) = \sigma_\alpha \mathbf{I}_{N-1}$ for all $i = 1, \ldots, N$.

A2. Let $\gamma_t = (\gamma_{1t}, \ldots, \gamma_{Nt})'$,

$$\mathbb{E}(\gamma_t \gamma_s') = \begin{cases} \sigma_\gamma^2 \mathbf{I}_N & t = s \\ \mathbf{0}_N & t \neq s. \end{cases}$$

A3. Let $\lambda_t = (\lambda_{1t}, .., \lambda_{Nt})'$,

$$\mathbb{E}(\lambda_t \lambda_s) = \begin{cases} \sigma_\lambda^2 \mathbf{I}_N & t = s \\ \mathbf{0}_N & t \neq s. \end{cases}$$

A4. For every $i = 1, \ldots, N$,

$$\mathbb{E}(u_{i\bullet t} u'_{i\bullet s}) = \mathbb{E}(u_{\bullet it} u'_{\bullet is}) \begin{cases} \sigma_u^2 \mathbf{I}_{N-1} & t = s \\ \mathbf{0}_{N-1} & t \neq s. \end{cases}$$

A5. The four unobservable components, namely, α_{ij}, γ_{it}, λ_{jt} and u_{ijt} are independent from each other for all (i, j) pairs and for all $t = 1, \ldots, T$.

A6. For each (i, j) pair $\{\mathbf{W}_{ij}\}_{t=1}^{T}$ is stationary and ergodic. Moreover $\mathbb{E}\left(||\mathbf{X} \otimes \mathbf{X}||^2\right) < \infty$.

A7. For each (i, j) pair $\mathbb{E}(u_{ijt}|\mathbf{x}_{ijt}) = 0$, $\mathbb{E}(\alpha_{ij}|\mathbf{x}_{ijt}) = 0$, $\mathbb{E}(x_{it}\gamma_{it}) = \gamma < \infty$, $\mathbb{E}(x_{jt}\lambda_{jt}) = \lambda < \infty$ and $\mathbb{E}(\gamma_{it}|x_{jt}) = \mathbb{E}(\lambda_{jt}|x_{it}) = 0$ for $t = 1, \ldots, T$ and $i \neq j$.

First Attempt on the Moment Conditions

C1. For all $i, j = 1, \ldots, N$, $i \neq j$, $\mathbb{E}\left(v_{i\bullet t} v'_{i\bullet t} - v_{j\bullet t} v'_{j\bullet t}\right) = \mathbf{0}_{(N-1)\times(N-1)}$, $t = 1, \ldots, T$.

C2. For all $i, j = 1, \ldots, N$, $i \neq j$, $\mathbb{E}\left(v_{\bullet it} v'_{\bullet it} - v_{\bullet jt} v'_{\bullet jt}\right) = \mathbf{0}_{(N-1)\times(N-1)}$, $t = 1, \ldots, T$.

C3. For all $i, j = 1, \ldots, N$, $i \neq j$, $\mathbb{E}\left(v_{i\bullet t} v'_{i\bullet t-1} - v_{j\bullet t} v'_{j\bullet t-1}\right) = \mathbf{0}_{(N-1)\times(N-1)}$, $t = 2, \ldots, T$.

C4. For all $i, j = 1, \ldots, N$, $i \neq j$, $\mathbb{E}\left(v_{i\bullet t} v'_{i\bullet t} - v_{j\bullet t-1} v'_{j\bullet t-1}\right) = \mathbf{0}_{(N-1)\times(N-1)}$, $t = 2, \ldots, T$.

C5. For all $i, j = 1, \ldots, N$, $\mathbb{E}\left(v_{i\bullet t} v'_{j\bullet t-1}\right) = \mathbf{0}_{(N-1)\times(N-1)}$, for $t = 2, \ldots, T$.

C6. For all $i, j = 1, \ldots, N$, $\mathbb{E}\left(v'_{\bullet it} v_{\bullet jt-1}\right) = \mathbf{0}_{(N-1)\times(N-1)}$, for $t = 2, \ldots, T$.

A maximum of $\frac{5}{2} TN^2(N-1)$ moment conditions.

Some Theoretical Results

Proposition

If $\{\mathbf{Y}_{ij}, \mathbf{X}_{ij}\}$ follows the gravity model as defined previously, then under Assumptions 1 -7, Assumptions 2.1-2.5 in Hansen (1982) and the moment conditions C1-C6, the GMM estimator is consistent, that is $\hat{\beta} \xrightarrow{p} \beta_0$ as $T \to \infty$.

Proposition

Under the Assumptions in the previous Proposition and Assumptions 3.5 and 3.6 in Hansen (1982), $\sqrt{T}(\hat{\beta} - \beta_0) \xrightarrow{d} N(0, V)$ where

$$V = \mathbb{E}\left[\frac{\partial g'(\beta)}{\partial \beta}\left(g(\beta)g'(\beta)\right)^{-1}\frac{\partial g(\beta)}{\partial \beta'}\right]^{-1}\Bigg|_{\beta=\hat{\beta}}. \tag{1}$$

Finally, An Example

- The data, unbalanced panel dataset of 1,056 trading partners and 33,514 observations of the current OECD countries over the years 1960-2005.
- Sourced from the IMF, World Bank, the World Trade Organisation and CIA.
- Dependent variable is the log of real export flows.
- Explanatory variables include: dummies for being in GATT/WTO, GDP, distance between trading partners, land area of countries, dummy for common language, dummy for common land border, dummy for landlocked country, dummy for island nation, dummy for whether the export country had ever colonized the import country, dummy for common colonizer, dummy for monetary union membership and dummy for a bilateral or regional trade agreement.

And the Empirical Results

Table: Estimation Results

	Identity	Optimal
$ONEIN_{ijt}$	0.569	0.632
	(6.979)	(7.336)
$BOTHIN_{ijt}$	0.958	1.038
	(12.220)	(12.711)
$LNRGDP_{it}$	0.038	0.090
	(1.872)	(1.831)
$LNRGDP_{jt}$	0.710	0.740
	(363.035)	(363.122)
$LNRGDPOP_{it}$	0.822	0.863
	(24.839)	(25.403)
$LNRGDPOP_{jt}$	0.210	0.144
	(67.373)	(67.705)
$LNDIST_{ij}$	-0.852	-0.834
	(-173.368)	(-174.025)
$LNLAND_i$	1.073	1.156
	(61.547)	(62.348)
$LNLAND_j$	0.027	-0.005
	(17.416)	(17.557)
$CLANG_{ij}$	0.748	0.771
	(57.952)	(58.176)
$CBORD_{ij}$	-0.387	-0.289
	(-9.832)	(-9.207)
$LLOCK_i$	0.771	0.711
	(9.710)	(9.157)

	Identity	Optimal
$LLOCK_j$	-0.426	-0.520
	(-47.048)	(-47.364)
$ISLAND_i$	-0.541	-0.591
	(-6.570)	(-6.988)
$ISLAND_j$	-0.075	-0.169
	(-13.266)	(-14.176)
$EVCOL_{ij}$	-3.640	-3.556
	(-63.628)	(-64.032)
$COMCOL_{ij}$	1.150	1.165
	(23.303)	(24.139)
$MUNI_{ijt}$	0.906	1.004
	(40.433)	(41.021)
TA_{ijt}	0.076	0.147
	(6.889)	(7.680)
C	-25.138	-25.117
	(-88.646)	(-89.537)
σ^2_γ	36.660	44.820
	(3.797)	(9.517)
σ^2_λ	0.247	0.154
	(3.284)	(3.479)
σ^2_u	6.656	6.732
	(2.970)	(4.099)
σ^2_α	366.924	349.281
	(2.277)	(6.916)
σ^2_v	410.488	400.988
	(3.379)	(20.578)

Empirical Results

- Coefficients on ONEIN and BOTHIN imply GATT/WTO memeberships have positive effects on trade.
- Similarities between partners have positive effects on trade: Common language, Common Colonizer, landlocked but not common border and land area (possible threshold effects for the latter).
- Bilateral and trade agreement have positive effects on trades.

Conclusions

- Extend the existing model on Gravity Model to allow for heterogeneous characteristics between export and import countries.
- Propose a nonlinear GMM estimator to estimate the parameter of the model. Under certain assumptions on the variance-covariance matrix of unobserved components, the proposed estimator is shown to be consistent and asymptotically normal.
- Further consideration includes:
  - Allows a more general variance-covariance structure.
  - Selecting the most relevant set of moment conditions.