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Abstract: The gravity model has long been used for modelling and predicting trade flows. This paper generalises the gravity model allowing for proper representation of local and target country effects and also the business cycle(s). The new approach is based on a panel data framework (instead of a simple cross sectional or times series approach) where the additional information available from using both types of data is utilised to properly model all the specific effects. The model is then estimated for a panel of APEC countries.

Key words: Gravity model, Panel data, Foreign trade, Fixed effects model, Exports flows, APEC countries.

JEL classification: C23, F17

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1. Introduction

Modelling and predicting foreign trade flows has long been an important task in international economics. For (more or less) well defined economic areas, or trading blocs, such as the EU, MERCOSUR or APEC, the central problem is to formalise the bilateral trade flows within the countries of the area and the rest of the world as a function of the characteristics (size of the economy, population, etc.) of the exporting and importing countries and possibly business cycle(s).

From an economic modelling perspective there are several ways to tackle this problem. One of the most fruitful ones has been the use of gravity type models. These have long been recognised for their empirical sucess in explaining and predicting different types of flows. In the case of modelling trade flows they exhibited consistently high statistical explanatory power, but had been criticized during the first applications for their appearent lack of theoretical foundation (*Tinbergen* [1962] and *Pöyhönenn* [1963]). Later *Linnemann* [1966] and *Aitken* [1973] justified their models by a multi–equation export supply and import demand system. The lack of prices in their model, however, at this stage, was hard to justify. *Tursby and Thursby* [1987] derived a model using again demand and supply equations which now included export and import prices. On the other hand *Anderson* [1979], *Bergstrand* [1985] and *Oguledo and MacPhee* [1994] derived gravity type models where the lack of prices was completely justified by the theoretical model. Anderson and Oguledo and MacPhee used a (linear) expenditure system to get their model while Bergstrand utilised a general equilibrium setup for his derivation. An excellent review of these models can be found in *Oguledo and MacPhee* [1994].

In all applications these models were estimated using a cross section of countries (*Aitken* [1973], *Bergstrand* [1985], *Brad* [1994], *Oguledo and MacPhee* [1994] and *Frankel et al.* [1995]) or a country by country time series approach (*Tursby and Thursby* [1987]). Only *Zhang and Getis* [1995] tried a formulation based on both types of data. Unfortunately, the derived model was badly misspecified from an econometric point of view, as all local (exporting) and target (importing) country effects were missing from the specification. One important problem with all the above gravity models is that they lack dynamics and therefore the possible effect(s) of business cycles are completely ignored. An additional statistical problem with the purely cross sectional or time series approach is the lack of degrees of freedom. It is hard to get statistically significant local and target country specific effects, in fact to separate these two effects at all. For example, if X and Z are export volumes for two countries in the sample and an important explanatory variable is the growth rate in X, say a, and in Z, say b, it is hard to separate the effect that a and b have when X exports to Z from what they have when Z exports to X.

In this paper we generalise the gravity model, to our best knowledge for the first time in the literature, allowing for proper representation of local and target country effects and also the business cycle(s). The new approach is based on a panel data framework (instead of simple cross sectional, times series or naive cross sectional/time series approach) where the additional information available from using both types of data is utilised to properly formalise all specific effects. We then estimate the model for a panel of the APEC countries.

2. The model

We use here the basic form of the gravity model, where no prices appear in the equation. The model is also augmented by some financial varibles

$$\begin{aligned}\ln EXP_{ijt} = \alpha_i + \gamma_j + \lambda_t + \beta_1 \ln Y_{it} + \beta_2 \ln Y_{jt} + \beta_3 \ln POP_{it} + \beta_4 \ln POP_{jt} \\ + \beta_5 \ln FCR_{jt} + \beta_6 \ln RER_{ijt} + u_{ijt}\end{aligned} \tag{1}$$

where:

EXP_{ijt} is the volume of trade (exports) from country i to country j at time t;

Y_{it} is the GDP in country i at time t, and the same for Y_{jt} for country j;

POP_{it} is population for country i at time t, same for POP_{jt} for country j;

FCR_{jt} is the foreign currency reserves of country j at time t;

RER_{ijt} is the real exchange rate between countries i and j at time t;

$i = 1, \dots, N$, $j = 1, \dots, i-1, i+1, \dots N+1$, where the $N+1$-th element here is the rest of the world, $t = 1, \dots, T$;

α_i is the local country effect, $i = 1, \dots, N$;

γ_j is the target country effect, $j = 1, \dots, N+1$;

λ_t is the time (business cycle) effect, $t = 1, \dots, T$; and

u_{ijt} is a white noise disturbance term.

From an econometric point of view the α, γ and λ specific effects can be treated as random variables (error components approach) or fixed parameters (fixed effects approach). Given that we are specifically interested in these effects we formalise them as fixed unknown parameters.

The triple indexed model (1) should be viewed as a generalisation of any usual panel data and gravity models (both double indexed). In vector form it can be written as

$$y = D_N\alpha + D_J\gamma + D_T\lambda + Z\beta + u\,, \tag{2}$$

where y is the $(N \times N \times T) \times 1$ vector of observations of the dependent variable EXP

$$y = [y_{121}, y_{122}, \dots, y_{12T}, y_{131}, \dots, y_{13T}, y_{N11}, \dots, y_{N1T}, \dots y_{N(N-1)1}, \\ \dots, y_{N(N-1)T}, y_{N(N+1)1}, \dots, y_{N(N+1)T}]\,,$$

Z is the matrix of observations of the explanatory variables in (1), organised in a similar way to y, D_t and D_N are dummy variable matrices ($D_N = I_N \otimes l_{NT}$, $D_T = l_{N^2} \otimes I_T$, where l is the vector of ones with its size in the index), α is an $(N \times 1)$, λ is a $(T \times 1)$, γ is an $((N+1) \times 1)$, β is a $(K \times 1)$ parameter vector with K the number of explanatory variables and u is the vector of the disturbance terms. The structure of the D_J $(N^2 \times T) \times (N+1)$ matrix is a bit more complex:

$$D_J = \begin{pmatrix} \widetilde{I}^{(1)} \\ \vdots \\ \widetilde{I}^{(N)} \end{pmatrix} \qquad \text{where}$$

$$I^{(1)} = \begin{pmatrix} 0 & I_N \end{pmatrix} \qquad \text{and} \qquad \widetilde{I}^{(1)} = I^{(1)} \otimes l_T$$

$$I^{(2)} = \begin{pmatrix} 1 & & \\ & 0 & I_{N-1} \end{pmatrix} \qquad \text{and} \qquad \widetilde{I}^{(2)} = I^{(2)} \otimes l_T$$

$$\vdots$$

$$I^{(N)} = \begin{pmatrix} I_{N-1} & 0 & \\ & & 1 \end{pmatrix} \qquad \text{and} \qquad \widetilde{I}^{(N)} = I^{(N)} \otimes l_T\,.$$

This model can be regarded as the generic form of all gravity type models. When cross sectional data is used $T = 1$ and implicitly the restriction $\lambda_t = 0\ \forall t$ is imposed on the model. When time series data is used $N = 1$ and the restriction $\alpha_i = 0\ \forall N$ is imposed, while when panel data is used there are no such restrictions. Unfortunately, none of the previous applications of this model bothered to take into account the local, target and time effects, which means that all practitioners were imposing (involuntarily) the unnecessary restrictions $\alpha_i = \gamma_j = \lambda_t = 0$ for all i, j and t. These are unlikely to be correct and can be tested for anyway in (1).

Model (1) was estimated in an augmented form as well, allowing up two lags in the explanatory variables and we also experimented with a specification where the balance of payments was included as an additional explanatory variable. All these specifications, however, after estimation, turned out to be overspecified and therefore not suited for analysis.

From the matrix form (2) of the model, it can clearly be seen that this is a direct generalisation of the fixed effects panel data model (*Balestra* [1995, pp. 34–40]) and therefore can be estimated by OLS if some simple restrictions are imposed on the specific parameters α, γ and λ. We adopt here the most obvious procedure to include an overall constant term in (2) and adding up conditions such as: $\sum \alpha_i = 1$, $\sum \gamma_j = 1$ and $\sum \lambda_t = 1$.

3. The data

The Asia-Pacific Economic Cooperation (APEC) group includes the following 12 countries: Australia, Brunei, Canada, Indonesia, Japan, Korea, Malaysia, New Zealand, Philippines, Singapore, Thailand and the United States. Brunei is not taken into account in this study, because most of the necessary international trade data is not available.

All data but a few come from two types of International Monetary Fund (IMF) publications: the yearbooks and quarterly issue of International Financial Statistics (IFS) for 1995, 1996 and September 1996, respectively and the yearbooks of Direction of Trade Statistics (DOTS) for 1989, 1995 and 1996. As for definitions, country composition and classification in general, these publications are consistent with each other. As far as the few missing observations are concerned, when possible, we estimated the yearly data from quarterly measurements. When this was not feasible we extrapolated the historical time-series using the average annual growth rate of the previous 10 (occasionally only 5) years.

The data comprises annual measures for 1982–1994 of the following variables:

- $EXP_{i,j}$: Export from country i to country j in terms of millions of US dollars, deflated using the GDP deflator. It is measured on the free-on-board (f.o.b.) basis, that is by the value of the goods at the border of the exporting country. The only exception is Singapore: the trade data published exclude trade with Indonesia. To fill in this gap we used the imports of Indonesia from Singapore and adjusted the total export series of Singapore accordingly. We also had to estimate two 1995 figures. Indonesian export to Singapore was obtained by extrapolation, while Korean export to New Zealand was approximated using import from Korea to New Zealand.

- Y_i: Gross Domestic Product of country i at constant prices in national currency. In order to obtain GDP in constant prices we used the published GDP deflator series. The observations were then transformed to US dollars.
- POP_i: Population of country i. They are midyear estimates provided by the UN. The 1995 values for Japan, Korea and Malaysia have not yet been published, we estimated them from the previous ten years' exponential trend.
- FCR_i: Foreign currency reserve (foreign exchange) of country i. It includes the claims of monetary authorities on nonresidents in the form of bank deposits, treasury bills, and government securities at the end of a given year. It is given in terms of millions of US dollars.
- RER_i: The exchange rate defined as the annual average of the national currency unit per US dollar. For most of the countries we use the market rate, if not available, we use the official rate.

Besides the APEC countries the European Union (EU) is also involved in the analysis. Being the most significant economic bloc of the world, it is used as a proxy for the "rest of the world" blocks of the explanatory variables of the model. Although the Maastricht Treaty came into force only three years ago, and the Union has had 15 members for only two years, we consider EU over the whole sample period as the group of Austria, Belgium, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, the Netherlands, Portugal, Spain, Sweden and the United Kingdom. We computed the EU figures for Y, POP and FCR as the sum of the individual countries' observations. GDP was calculated both in 1990 and current US dollars, and their ratio is considered as the GDP deflator for EU. The exchange rate is with respect to the ECU.

4. Empirical results

The first striking results come from comparing the structural parameter estimates presented in Tables 1 and 2. Recalling that all previous studies on the gravity model used a specification similar to the one presented in Table 1 (no specific country or

Table 1:
Estimation results for the fully restricted model
$\alpha_i = \gamma_j = \lambda_t = 0$ for all i, j and t

Variable	Param. Estimate	t statistic
const.	-2.531838	-11.462
ln Y_{it}	0.7545090	32.290
ln Y_{jt}	0.3472864	11.349
ln POP_{it}	-0.3018460	-10.131
ln POP_{jt}	0.7231308E-01	2.342
ln FCR_{jt}	0.4775595	16.558
ln RER_{ijt}	-0.4690180E-01	-5.000
R^2	0.6950	
$\overline{R}^2$	0.6939	
F	594.92	

Table 2:
Estimation results for the unrestricted model

Variable	Param. Estimate	t statistic
const.	-16.63496	-3.279
ln Y_{it}	0.4805742	2.776
ln Y_{jt}	0.6856045	4.511
ln POP_{it}	2.289908	2.410
ln POP_{jt}	2.293028	2.323
ln FCR_{jt}	0.8246629E-01	1.306
ln RER_{ijt}	0.2129929	1.157
α Australia	1.172926	1.925
α Canada	-0.9342641	-3.146
α India	-2.984454	-2.005
α Japan	-2.055049	-1.558
α Korea	0.5906693	0.826
α Malaysia	1.965828	2.831
α New Zeal.	4.509955	2.147
α Philip.	-1.938950	-3.438
α Singapore	7.160723	3.079
α Thailand	-1.232547	-2.685
α USA	-5.254839	-2.524
γ Australia	2.280733	2.834
γ Canada	0.5633781	1.499
γ India	-4.991234	-3.677
γ Japan	-2.504959	-2.069
γ Korea	-0.7924030	-1.051
γ Malaysia	2.687917	2.949
γ New Zeal.	5.033522	2.111
γ Philip.	-1.420083	-3.555
γ Singapore	7.815317	2.939
γ Thailand	-1.107041	-3.951
γ USA	-2.954889	-1.492
γ rest world	-3.610259	-1.569

Table 2 (cont.):
Estimation results for the unrestricted model

Variable	Param. Estimate	t statistic
λ 1982	0.4612319	3.479
λ 1983	0.3891196	3.197
λ 1984	0.3297954	3.020
λ 1985	0.2475528	2.461
λ 1986	0.8687752E-01	1.018
λ 1987	0.9161916E-01	1.264
λ 1988	0.5472182E-01	0.816
λ 1989	0.4598400E-01	0.650
λ 1990	-0.8680540E-02	-0.110
λ 1991	-0.1058566	-1.119
λ 1992	-0.1515080	-1.383
λ 1993	-0.2030484	-1.606
λ 1994	-0.2378086	-1.619
R^2	0.8518	
$\overline{R}^2$	0.8480	
F	225.93	

time effects were taken into account), it is obvious that the estimation results are quite different if these effects are properly specified. In other words, as theoretically expected, the restricted and unrestricted model specifications yield substantially different parameter estimates. From the restricted specification one would incorrectly infer that the population of the exporting country, for example, has a negative effect on the volume of exports, while it is clear from the unrestricted model that this absolutely not the case. Moreover, given the statistical significance of the specific parameters (twenty of these effects out of a total of thirty-six can be considered statistically significant, although obviously this number increases dramatically when moving away from the 5% test size) this implies that the previous models have been erroneously restricted, casting doubts as to the validity of their results.

The effect of the GDP on the volume of export is obvious, simply representing the size of the economy in terms of available goods (Y_{it}) and target markets (Y_{jt}). Indeed, as one might expect, a larger effect is afforded by the target country's GDP as it absorbs exports from the source one. A similar argument holds for the significance of both target and source country population, with the former (helping to) define the production possibilities and the latter the potential market. These effects appeared to be of the same magnitude.

Somewhat surprising was the apparent insignificance of the financial variables, foreign currency reserves and the exchange rate. Presumably the level of foreign currency reserves is simply a reflection of the country's current and past trade flows and consequently has no bearing on the desired level of imports. It is difficult to explain, however, why the exchange rate should apparently be uninfluential in the flow of exports. Moreover, the variable also appears to be perversely signed, as the exchange rate is defined as units of foreign currency per unit of domestic currency. It may be that the specific effects have captured most of the influence of this variable. Or, it may also be, that the exchange rate is very volatile during each year, so an annual average is a poor representation for large parts of the year. That is exporters and importers may be reacting to quite different exchange rates from those in the model. On the other hand, this could be counterbalanced by the fact that exporters and importers have probably made use of currency derivatives to hedge against certain exchange rate movements, and so decreasing sensitivity to exchange rates.

For the interpretation of the specific parameters it is important to keep in mind that these represent the effects influencing the behaviour of the volume of exports beyond those explained by the economic variables considered. Time effects: "large" values indicate a year when exports were high relative to the whole sample period, whilst "small" ones indicate a relatively sparse period for exports. Target effects: these indicate the openness of the economy as a target country. It covers two areas of the economy simultaneously. On the one hand, that there are no major administrative hurdles making foreign trade difficult and, on the other, that there are no financial obstacles to keeping imports down. Local country effects: this shows the extent of the absolute advantage a particular country has in exporting relative to the rest of the trading block. If for a country both Target and Local are large (and positive) the country could be said to have an open economy whilst the opposite is true if both parameters are small and/or negative. Also, a negative (or small) target country effect, may also be indicative of trade restrictions.

We can see from Table 2 that Australia, Malaysia, New Zealand, and Singapore are the only countries with positive local and target country effects which means that they can be considered as having the most open economies in the APEC area. These countries simultaneously appear to have both absolute export advantages and also be strong importers. On the other hand, the US, India and Japan have the least open economies in the area, at least as far as foreign trade is concerned.

Analysing the time effects we can notice that there are three well defined periods in the sample. The 1982-85 "golden era" which was favorable towards foreign trade, 1986–1989 which are still "not bad" years and the nineties which have a dragging effect. Even if we take into account the significance level of these parameters (the time effects for the period 1986–1994 are statistically marginally insignificant), the early and mid eighties appeared much better for exporting than the next decade. This, although seems to contradict the "usual wisdom" that trade has been easier in the nineties, is so much supported by the data, that possibly policy makers may be tempted to re-think some trade policy issues.

4. Conclusion

This paper proposed an extension of the gravity model of export flows to take into account local and target country specific effects, as well as time (business cycle) effects. The model was applied to the APEC trading block and found to have very high explanatory power. Moreover, the statistical significance of most of the specific effects clearly illustrated that all previous studies not including such were misspecified, thereby questioning any analyses based upon them.

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